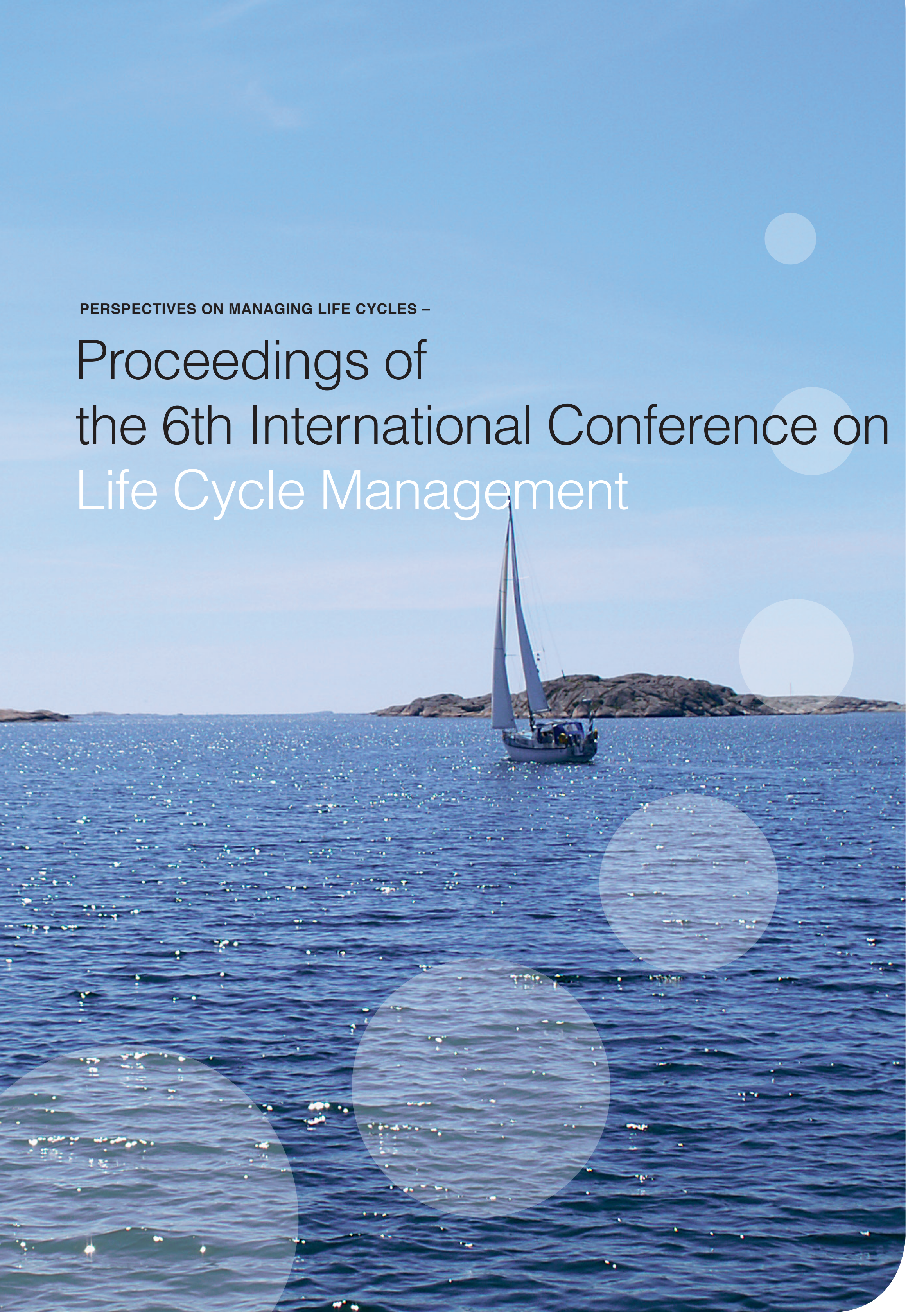


PERSPECTIVES ON MANAGING LIFE CYCLES –

Proceedings of the 6th International Conference on Life Cycle Management

LCM 2013

25–28 August 2013
Gothenburg, Sweden

CHALMERS UNIVERSITY OF TECHNOLOGY
THE SWEDISH LIFE CYCLE CENTER
ISBN NO: 978-91-980973-5-1
AUGUST 2013

PERSPECTIVES ON MANAGING LIFE CYCLES

The life cycle approach holds great opportunity for environmental, and more broadly, sustainability, work. Through its systemic cradle-to-grave approach it reduces risks of sub-optimization and problem shifting from one part of the life cycle to another or from one type of impact to another. It brings new insights about how action in one part of the life cycle may give effects far upstream or downstream the product chain, perhaps in vastly distant geographical locations. In this respect it is an empowering concept, which brings new opportunities for influence, beyond organizational and national borders. Many different types of actors, consumers as well as producers and policy makers, hold the potential to render product chains more sustainable. And yet, none of them fully control the chain.

It is no easy task to make use of these new insights and opportunities of influence in practical work. The management of life cycles implies a new logic for governance, focusing the purposive flow of material instead of the nation or the company. Furthermore, it is not enough to understand the physical material flow and the physical relationships in the life cycle. It must also be understood how the actors managing the physical flow between them organize the flow.

To achieve life cycle action many different perspectives, scientific as well as practical, need to be placed on the material flows which constitute the production and consumption of the world. The 6th International Conference on Life Cycle Management (LCM 2013) invited social scientists and engineers/natural scientists to try and bridge the gap between them and use their different perspectives to create a richer understanding of how product life cycles may be managed sustainably. Likewise, practitioners from policy, industry and NGOs were invited to give their perspectives and experiences from managing product life cycles.

Contributions were invited under three sub-themes, in themselves constituting different perspectives on the management of life cycles for sustainable value chains:

Local versus global perspectives in life cycle work - Product life cycles stretches all over the globe. And yet, action may often only be taken more locally, within a production site, a company, a nation or a settlement. The relationships between local and global perspectives constitute one of the sub-themes of the conference.

Roles and responsibilities in product life cycles and value chains - The role play between producers, consumers and policy makers is a key to sustainable governance of life cycles. Of particular interest is finding ways to share the responsibility in a meaningful way.

Conceptions of sustainable product life cycles and value chains - In our world with a growing population with increasing material expectations, sustainable production and consumption patterns are crucial. There are many theoretical and practical approaches to this issue. The third sub-theme addresses how sustainable product life cycles may be conceived of, and how the different perspectives may complement or conflict to each other.

Guided by these three sub-themes over 90 suggestions for sessions were made and more than 500 abstracts were submitted to the conference. Based on these contributions the scientific program for LCM 2013 was moulded to cover some 30 different topics. It was a tough task to select contributions from the wide array of high quality abstracts submitted. In this work, we have had invaluable help from our international Scientific and business committee, consisting of more than 70 people from universities, governmental organizations, institutes, non-governmental organizations and business.

For the final program, around 200 oral and 150 poster presentations were selected. All contributions were offered to prepare a short paper, resulting in more than 230 papers which you now can enjoy in these conference proceedings. They cover many different aspects of life cycle management, ranging from the role of LCM in policy making to the challenges and opportunities LCM presents to industrial companies, in strategy and in several specific fields of application, including communication and labeling, production, and innovation and product development. Also management of natural resources and waste management emerged as important topics and specific industries (e.g. food and retail) are high-lighted in some sessions.

LCM 2013 builds on a series of conferences which has grown to be one of the world's leading events on sustainability. The first LCM conference was held in Copenhagen in 2001 and had *LCM as a bridge to sustainable products* as its theme. The second conference in the series was held in Barcelona in 2005 and focused *Innovation by life cycle management*. The third conference in Zürich in 2007 high-lighted *From analysis to implementation* and the forth in Cape Town in 2009 had *The global challenge of managing life cycles* as its theme. The motto of the 2011 LCM conference in Berlin was *Towards life cycle sustainability management*.

In you (virtual) hand you now hold the proceedings from the 6th international conference on life cycle management, arranged in Gothenburg 2013. Enjoy!

Anne-Marie Tillman
Chair of Scientific and
business committee, LCM 2013

Emma Rex
LCM 2013 conference chair

TABLE OF CONTENT

MONDAY, AUGUST 26, 2013

01.30 pm – 03.00 pm

Business strategy and LCM

Does research matter? - The role of LCA and LCM tools in public policy-making

LCA critical review

MONDAY, AUGUST 26, 2013

3:30 pm - 5:00 pm

The role of communication in LCM

Application of life cycle approach in environmental policy

Chemical assessment

Preparing for right prices

LCA highlights: PechaKucha

TUESDAY, AUGUST 27, 2013
08.30 am – 10.00 am

Exploring challenges and opportunities of LCM and LCA - Industry cases

Current developments in life cycle based labeling

Metrics behind the management of supply chains

TUESDAY, AUGUST 27, 2013

10.30 am – 12.00 pm

Roles and responsibilities in building and construction

Current developments in life cycle based declarations

Management of green product portfolios: Panel

Databases and capacity building

TUESDAY, AUGUST 27, 2013

01.30 pm – 03.00 pm

Sustainable product chains - The role and responsibilities of retailers

Innovation and product development

Governance of critical raw materials

TUESDAY, AUGUST 27, 2013

03.30 pm – 05.00 pm

Sustainability data exchange

Innovation and product development: Interactive

Management of natural resources - Abiotic

WEDNESDAY, AUGUST 28, 2013

08.30 am – 10.00 am

Broadening the scope of LCA – LCSA

End of life management

LCM and decision making - What we have learnt

Management of natural resources - Biotic

WEDNESDAY, AUGUST 28, 2013

10.30 am – 12.00 pm

Broadening the scope of life cycle approaches

Sustainable production 1

Exploring challenges and opportunities of LCM and LCA for the industry: Panel

Food waste in a value chain perspective 1

WEDNESDAY, AUGUST 28, 2013

01.30 pm – 02.30 pm

Management of seafood and fisheries

Sustainable production 2

Food waste in a value chain perspective 2

BUSINESS STRATEGY AND LCM

Monday, Aug 26: 1:30 pm - 3:00 pm

Session chairs: Sarah Jane McLaren, Massey University, New Zealand
Lennart Swanström, ABB AB Corporate Research, Sweden

A LIFE CYCLE APPROACH THAT UNLEASHES BUSINESS OPPORTUNITIES: JOHNSON & JOHNSON'S EARTHWARDS® PROCESS

Jim Fava, PE INTERNATIONAL Inc. and Al Iannuzzi, Johnson & Johnson*

** 626 Meadow Drive, West Chester, PA, USA 19380*
j.fava@pe-international.com

Keywords: sustainability; consumer goods; life cycle thinking; hot spots; marketing.

ABSTRACT

Johnson & Johnson's Earthwards® process supports its corporate objectives of using life cycle thinking towards reducing the environmental footprint of its products and delivering greater value to customers. The use of life cycle thinking helps uncover innovative ideas and develop differentiated products. The process also helps support the company's objectives of being a successful and responsible corporate citizen.

With its emphasis on applied life cycle thinking and continuous improvement, the Earthwards® process provides support for product developers to include sustainability into their standard development processes. As a result, product developers increase their skills, knowledge and confidence on life cycle thinking and the company produces more marketable products, helping drive business success, reduce impact and address the needs of its customers.

INTRODUCTION

Johnson & Johnson is one of the world's leading consumer goods and healthcare companies. The company consists of 250 subsidiaries, employs over 114,000 employees worldwide, and sells some of the world's most recognizable brands. Products fall into three broad categories – consumer products, medical devices & diagnostics and pharmaceuticals. Further, since the company's foundation in 1886, managing for the long term – including environmental stewardship – has been a core value at Johnson & Johnson (R.W. Johnson, 1947).

Today, this commitment is articulated through Johnson & Johnson's Healthy Future 2015 Goals. One of these goals is to increase the sustainable design of Johnson & Johnson's products, including having all new products and packaging evaluated for sustainability improvements.

Achieving this corporate, global aim required the development of a process to consistently identify ways of reducing a product's environmental footprint and present opportunities to make credible environmental claims.

This paper describes the Earthwards® process – Johnson & Johnson's life cycle thinking based process that enables product designers to better understand the areas of greatest impact and guide how they should focus their efforts.

METHODS

In 2009, Johnson & Johnson worked with PE INTERNATIONAL's Five Winds Strategic Consulting, to develop the Earthwards® process. The elements of the Earthwards® process included a product evaluation scorecard and process, the design and development of a governance system, and third party assurance.

Product Evaluation Scorecard and Process

The Earthwards® process consists of four steps. The first two, or their equivalent, are required for all products and the final two available for products with significant sustainability improvements which are pursuing Earthwards® recognition.

First, in the prerequisite stage, product teams ask themselves a series of questions aimed at ensuring a minimum standard of performance and raising their awareness of key sustainability issues and opportunities.

Second, the product undergoes a life cycle screening that examines its environmental and social impacts across key areas of concern. This steers the product team to focus on minimizing the impacts that occur during the most important life cycle stages.

Using life cycle thinking as a basis, PE INTERNATIONAL worked with Johnson & Johnson to identify seven key areas of concern which were relevant across the full spectrum of products. These seven categories are shown in Figure 1.

Figure 1. Seven areas of concern of Johnson & Johnson's EARTHWARDS® environmental scorecard process.

Third, the product teams identify potential improvements. A product which shows more than a 10 percent improvement in three or more categories can qualify as an Earthwards® recognized product.

Finally, for those pursuing recognition, a product team submits the evaluation results and supporting documentation to a review board composed of experts from inside and outside Johnson & Johnson. This review process ensures the accuracy of the improvements identified in the previous steps.

Governance System

The governance system comprises a review board consisting of Johnson & Johnson product developers and brand marketers, as well as external subject matter experts from organizations such as Practice Greenhealth and World Wildlife Fund. The Board conducts a review of each application for Earthwards® recognition, thereby ensuring strict quality standards and brand reputation.

Third Party Assurance

UL Environment provides ongoing annual assurance review of the Earthwards® process and verifies that process guidelines and minimum requirements are met.

RESULTS

The Earthwards® process has been applied to the full scope of products from Johnson & Johnson's Consumer Products, Pharmaceuticals, and Medical Devices and Diagnostics sectors.

As of March 2013, all new products and packaging have gone through the initial three critical stages of the Earthwards® process. Amongst these, 36 exceptional products have received Earthwards® recognition, proving that the company is well on its way towards achieving its Healthy Future goal of 60 Earthwards® products by 2015.

As importantly, the Earthwards® process is teaching the company how to better focus its efforts and infuse innovative thinking into its product development process. As lessons are learned, they are communicated broadly internally to inform Johnson & Johnson's full suite of products.

DISCUSSION

While key outcomes of the Earthwards® process, increased life cycle thinking and awareness across the organization are difficult to capture and quantify. The more tangible measure of its influence and impact is in the increased communications about environmental benefits. A sample of these, from Johnson & Johnson's Earthwards® website, includes:

- SUNDOWN® Sunblock Lotion which through a streamlined transportation process cut fuel use by 95%
- NATUSAN® First Touch Diaper Ointment which increased its use of environmentally preferred ingredients by 40% over the previous formula
- NUCYNTA® Tapentadol which improved its manufacturing process to achieve a 78% reduction in water use compared to the previous production methods
- SURGICEL® Brand Absorbable Hermostats which reduced their packaging material by 50% [through design improvements] and increased sustainable packaging materials by 100% versus the previous version.
- NEUTROGENA® Naturals Purifying Facial Cleanser which achieved a 70% reduction of greenhouse gas emissions by optimizing its distribution network.

For Johnson & Johnson, the objective of the Earthwards® process was to have a systematic approach for reducing the environmental footprint of its products and delivering greater value to customers. These two objectives go hand in hand. Without the communication of the value to customers, the innovation and the environmental improvements alone do not create business value.

Johnson & Johnson has found that product teams that complete the Earthwards® process develop the capacity to translate technical data gathered to communicate compelling environmental benefits to its stakeholders. Johnson & Johnson uses an outcome-based metric that measures the percentage of Earthwards® generated claims that are actually being used to communicate with customers. The higher this percentage, the more the company knows the Earthwards® process helps to drive meaningful communication about sustainability, thus demonstrating its business value. An example of this is Earthwards® influence in the company being ranked number two in Interbrand's Best Global Green Brands 2012.

As for any business, the market is the ultimate judge. Many of the Earthwards® recognized products sit at the top of their product categories, proving that Johnson & Johnson's approach is helping drive business success.

CONCLUSIONS

The Earthwards® process provides the needed structure and support for product developers to invest time into building their capacity on life cycle thinking. As a result, product developers increase their skills, knowledge and confidence, and the company produces more marketable 'greener' products, helping drive business success, reduce their impact and address the needs of its customers.

REFERENCES

Johnson & Johnson. (2009). 2009 Sustainability Report. Accessed at: http://www.investor.jnj.com/2009 sustainabilityreport/index.html

Johnson & Johnson. (2011). 2011 Sustainability Report. Accessed at: www.jnj.com/2011responsibilityreport

Johnson, Robert Wood. (1947). Or Forfeit Freedom. Doubleday & Company, Garden City, New York, pp. 37-38.

Interbrand. (2012). Best Global Green Brands 2012. Accessed at http://www.interbrand.com/en/best-global-brands/Best-Global-Green-Brands/2012-Report.aspx

Johnson & Johnson. (2013). Eathwards® Recognized Products. Accessed at http://www.jnj.com/responsibility/ESG/Environment/Product_Stewardship/Earthwards+Recognized+Products/

ECO-CONCEPT PROGRAM: HOW TO TRANSFORM SMES' STRATEGY INTO A LIFE CYCLE MANAGED STRATEGY

Philippe SCHIESSER (Ecoeff), Sylvain GRELET (Ecoeff), Joel PORCHER (CCI départementale de Seine-Saint-Denis), Thierry RAMON (CCI départementale de Seine-Saint-Denis)*

**2 à 20 Avenue du President S. Allende, Mozinor, 93106 MONTREUIL CEDEX, philippe.schiesser@ecoeff.com*

Keywords: ecodesign; Management; strategy; LCA; eco-innovation.

ABSTRACT

Because the information on Life Cycle Strategy (LCS) for Small and Medium Enterprise (SME) is an important topic in environmental protection in Europe, Ecoeff and the Seine-Saint-Denis CCI[1] created the Eco-concept program. That program enables SMEs managers to get information on several themes, such as ecodesign, LCA tools, strategy, communication and eco-innovation. Moreover, the program shows these managers how to implement LCS management into their business. Results show that a lot can be done and that the program is an opportunity for managers to rethink their business.

INTRODUCTION

Depletion of resources and pressure on ecosystems are key stakes. Moreover, that pressure on environment and resources is increasing. As the World summit on sustainable development (WSSD) pointed it in Johannesburg (2002), it is vital to change the way that societies produce and consume. To achieve that, the WSSDs "Plan of Implementation" seeks to increase the eco-efficiency of goods and services and calls for a better accountability of environmental damages with appropriate tools. According to the last European SME Performance Review (2012), SMEs are the backbone of the European Economy with some 20.7 million firms accounting for more than 98 per cent of all enterprises. To build a more sustainable society, it is crucial that life cycle management becomes a key element in SMEs strategies. That is why the Eco-concept program was created. It postulates that local action and close support on thematic subjects provides a better eco-efficiency. It is a one year partnership between Ecoeff and the Seine-Saint-Denis Chamber of commerce and industry (CCI) which enables selected SMEs to optimize their products and services and transform their strategies into a life cycle management oriented strategy. The program is financed by the Département of Seine-Saint-Denis, the ADEME (Environment and energy management agency), the DIRECCTE (Regional office for business, competition, consumption, work and employment), and Europe with the European Regional Development Fund (ERDF). To reach a final state where the activity of these SMEs is more sustainable, the eco-concept program promotes environmental friendly management tools via several training courses for SMEs' managers. There were no conditions regarding the main activity of these SMEs to attend that program. On the contrary, the more the panel was heterogeneous, the better it was, as the goal was to impact all sectors of entrepreneurship. That program followed a 3 step path with 3 different objectives. The first step was a phase of evaluation (i). It was followed by a phase of information (ii) and concluded by a phase of realization (iii). That paper ends with a small discussion on the results of the program (iv).

SELECTION AND PREDIAGNOSIS

Seine-Saint-Denis is a geographic area where there are more than 54000 SMEs. Therefore, a selection was necessary to achieve the goal of the Eco-concept program. The first idea of the Seine-Saint-Denis CCI was to focus its selection on SMEs who are related to industry or who produces services for industry. Indeed, these were the biggest sectors where environmental cost could have been cut. However, during the selection process some SMEs without link with industry sector showed their interest for Eco-concept. Because organizers whished better diffusion of environmental management tools, that heterogeneity was finally a blessing for the program. A 24 SMEs group has been selected to optimize their products and services in different activities sectors such as mechanical industry, food, textile, transport, communication, electrical car rental and sale, surface treatment, etc. Each general manager was able to evaluate its SME regarding ecodesign. That pre-diagnosis was realized with the methodology of the national eco-design center of Saint-Etienne, France. It enabled managers to pinpoint various opportunities of eco-management in their business. It was a preliminary, although necessary, step for Ecoeff.

THEMATIC MEETINGS

First, managers followed formal meetings on themes linked to eco-management. The Eco-concept program tried to develop a large panel of subjects, providing solutions and tools for every managers. All these meetings were designed to give SMEs managers an overall perspective on life cycle sustainability management. Ecoeff worked on a 2 axis approach:

- What are the specific tools of Life Cycle Assessment (LCA)?
- How to use management tools to perform Life Cycle Management (LCM) solutions?

Among these, several themes were developed, such as ecodesign, LCA tools, strategy, communication and eco-innovation.

Tools of LCA

SMEs are not well aware of what can be done to create sustainable products or create them in a sustainable way. Therefore, it was important to begin thematic meetings with ecodesign and LCA tools to teach SMEs what are the possibilities to get on the way of LCS management. The first meeting was intended to present standards of ecodesign, how to evaluate its SME environmental impact and what the tools to achieve successfully a LCA are. First, Ecoeff presented what was the French law and what were the ISO standards (AFNOR, 2009), underlining the importance of standardization in life cycle management. Although that normalization is a cornerstone for LCS management, it was also important for Ecoeff to present the key steps and tools of ecodesign (Schiesser, 2011 and 2012). Finally, to ensure a more vivid meeting, Ecoeff used simplified software (ADEME, 2011) to realize a simple LCA on a case study.

Using management tools to perform LCS management (LCSM)
Environmental protection and LCM is often seen as brake on growth rather than opportunities for SMEs. To inverse that point of view, Ecoeff succeeded to adapt strategy and business model tools to implement life cycle sustainability management. The aim of Ecoeff was to rely on its LCM expertise to pinpoint LCSM opportunities for SMEs, using the Blue Ocean Strategy (BOS) (Mauborgne and Kim, 2004) or the Business Model Generation (BMG) (Osterwalder et al., 2010) canvas. Each company used the BOS tools to discover new market and positioning itself versus competitors. The BMG tools were used by to find new partnerships and eco-innovation opportunities.

Ecoeff also worked with SMEs on environmental communication. Good communication adds value to a LCSM process, it was therefore necessary to underline traps of environmental communication. In fact, it is an element which can turn a LCSA action into a business opportunity, which is really important for SMEs. Using its experience and advice from the ADEME (2012), Ecoeff presented what the rules of success were. The aim was to avoid greenwashing and prove that a good message can enhance LCS management.

Finally, Ecoeff also worked on eco-innovation to help these SMEs. Concerning that meeting, Ecoeff used basic creativity exercises (de Bono, 2008) and presented existing business models based on eco-innovation. The aim was to help SMEs to have new opportunities with new ideas such as biomimicry, upcycling or principles of the blue economy (Pauli, 2010).

INDIVIDUAL SUPPORT

For the last part of the Eco-concept program, the Seine-Saint-Denis CCI planned an individual one-day support, provided by Ecoeff, for each SME manager. The goal was to help and guide SMEs who try to improve their products and services. That support was based on environmental impact reduction, improvement of brand image, cost optimization, increase market share and answer to customers' exigencies. The deliverables were: a simplified life cycle assessment, sustainable procurement or communication. The simplified life cycle assessment was realized in a short time support by realizing data collection and modeling on simplified software for LCA during the first half-day on site. The second half-day on site, results were presented to the general manager for further action. At the end of the Eco-concept program, each of the 24 SMEs was able to focus on their action on life cycle sustainability management, they were also able to foresee what can be done in their business and finally they were helped to launch their first life cycle assessment. Moreover, companies were able to use simplified LCA tools during their product and service development.

DISCUSSION AND CONCLUSION

Sustainable procurement and communication deliverable were written after the first half-day on site. It permitted to visit the company, to collect data on each phase of product life cycle, from raw materials (information on suppliers), transport and logistics schemes (mean of transport, distances, etc.), production process (kind of material and energy used) to end of life. First work for a textile company highlighted environmental benefits of reusable product versus disposable version for main utilization cases and designate hotspot redesign. Second work for a mechanical industry allowed the firm to develop a specific data for steel tube cold stretching, a kind of non-existing data in actual databases. Another action for a SME in car industry underlines a default in corporate communication. In fact there was good behavior in LCS management but it was not explained to clients and SME members. Profits of the action were actually underestimated. Finally, because the group of SMEs was heterogeneous, the training session organized by Ecoeff enables some SMEs to create partnerships based on recycling or upcycling.

Even if the eco-concept program is a good way to teach LCSM to SMEs, it is albeit interesting but insufficient. In fact, every visit on site for each SME was limited because of time. One day is not sufficient enough to conduct a true LCA or to implement LCSM tools. Therefore the action of Ecoeff was not complete enough and needed more steps to really fulfill LCSM principles in SMEs strategy. Moreover, there was not a long-time support to evaluate the environmental profits of a change in SMEs strategy. Finally, the partnership between the Seine-Saint-Denis CCI and Ecoeff remains an interested process and method for SMEs managers. Indeed, the same kind of partnership will be conducted with other CCI for the same goal.

REFERENCES

ADEME – Université de Cergy Pontoise (2011), Bilan produit

ADEME (2012), Guide anti-greenwashing, *ADEME Edition*

AFNOR (2009), Ecoconception : recueil de normes, *AFNOR Edition*

de Bono, E. (2008), Comment avoir des idées créatives, *Leducs, Paris.*

European Commission (sept. 2012), EU SMEs in 2012: at the crossroads, *Annual report on small and medium-sized enterprises in the EU 011/12, Rotterdam*.

Mauborgne R., Kim W. C. (Oct. 2004) Blue Ocean Strategy. *Harvard Business Review (Boston: Harvard Business School Press)*

Osterwalder, A., Pigneur, Y., Smith, A., and 470 practitioners from 45 countries, (2010) Business Model Generation, *Self published*

Pauli, G. (2010). The Blue Economy, *Paradigm Publication*.

Schiesser, Philippe (2011). Eco-conception, indicateurs – méthodes – réglementation, *Paris, Dunod.*

Schiesser, Philippe (2012). Pratique de l’eco-conception, *Paris, Dunod.*

UN General Assembly (2002) World Summit on Sustainable Development: Plan of Implementation. *United Nations Division for Sustainable Development, New York*.

INTEGRATING LIFE CYCLE MANAGEMENT INTO DANONE'S WATER SUSTAINABILITY STRATEGY

Jean-christophe Bligny, Environment Scientific Affairs Director, Environmental Methodologies & Water Leader, Danone Group, Mob. +33 609 369 953, jean-christophe.bligny@danone.com*
Jean-Jacques Beley, Water Science & Technology Expert, Water Resources and Processing Dpt, Danone Research
Jean-Baptiste Bayart, Project Manager, Quantis International – France
Samuel Vionnet, Water Sustainability Expert, Quantis International – Switzerland

Keywords: water footprint, sustainability strategy, corporate footprint

ABSTRACT

Water management is a high priority for companies worldwide but poses some difficulty regarding its integration into existing sustainability strategies.

Life Cycle Management concept is well adapted to water and is based on measurements, e.g. water footprint. Danone benchmarked water footprint methodologies and found that there is a growing consensus that a global water footprint should include both water resources consumption and pollution aspects. Methodologies addressing water resources consumption are found to be more robust than the ones addressing pollution aspects.

Based on this finding, Danone Waters' business unit is now deploying a water consumption indicator weighted by a regionalized water stress index and is pursuing research and development on methodologies addressing degradative water use.

INTRODUCTION

Corporate sustainability strategy has already integrated climate change and non-renewable energy (use) impacts related to companies' direct operations, and more recently is including impacts along the value chain. Danone reduced its carbon footprint by 35% between 2008 and 2012 (Danone 2012), not only of its direct operations but of packaging, transport, storage and end-of-life as well. This achievement first required the measurement of Danone's carbon footprint, followed by the development of a mitigation plan to manage it over time. The engagement of stakeholders was necessary when greenhouse gases emissions were not directly under the responsibility of Danone.

Recently, water issues have increased significantly (United Nations World Water Assessment Programme 2012) and will certainly follow the same type of management by companies within their sustainability strategy, along with climate change and non-renewable energy use. However, water remains a challenge to integrate into a sustainability strategy. Companies usually measure and report direct water use, which is often a standard industrial key performance indicator. They also set water use mitigation targets and communicate these values extensively. But developing an integrated water sustainability strategy along an entire value chain, following Life Cycle Management principles is as a challenge for many reasons, among them the lack of standardization in water footprint assessment and the lack of external pressure from stakeholders, although the latter is rapidly evolving.

Danone Waters' business unit, has been integrating water resources management at the site level for many years in order to preserve its resources. Overall Danone has decreased its operational water use by 43% since 2000 and continues to make improvements (reduction of 3.1% in 2012 compared to 2011). But at a higher level, water sustainability strategy implies a more comprehensive approach including product footprints, supply chain management and Life Cycle Management. It requires going beyond simple figures of operational water use, including the entire value chain and accounting potential impacts by considering local specificities (regionalization).

This article describes the approach chosen by Danone to achieve integrated Life Cycle Management of its water footprint, within its corporate sustainability strategy.

METHODS

The links between Life Cycle Management and sustainability strategy are presented in Table 1. The life cycle stages are defined for each Danone product and sustainability pillars are derived from Epstein et al. 2008, although they are often broadly defined in every sustainability strategy. This matrix approach exposes the complexity of a sustainability strategy, particularly regarding water. Every strategy relies on a measure of the company's and products' footprint, presented in the first column of the Table 1.

	Governance/Sustainability strategy			
	Measure	Manage	Engage with stakeholders	Disclose
Raw materials/ Agriculture	**Upstream carbon and water footprint**	e.g. Sourcing strategy / Agriculture impact management	e.g. Suppliers, farmers and local communities	e.g. Achievement in sustainable sourcing
Industrial production	**Danone direct operations (Scope 1 carbon footprint and water use figures)**	e.g. Mitigation strategy in place. Energy and water efficiency plan.	e.g. Local communities, employees, NGOs	e.g. Achievement on industrial efficiency
Transport **Sales** **Consumption** **End of life**	**Downstream carbon and water footprint**	e.g. Marketing, product footprint, waste management and packaging	e.g. Consumers, local communities and countries	e.g. Product efficiency and Environment Product Declaration (EPD), labelling

Table 1. Link between sustainability strategy steps and Life Cycle Management

A sustainability strategy is first based on a measurement (e.g. water footprint) to be able to analyze, take sound decisions based on facts, prioritize mitigation actions, and communicate and engage with stakeholders, among other actions. Danone Waters has recognized this as being a critical part of the company strategy. Usually companies tend to focus on direct operations or on sectors of direct interest and business objectives. This often discourages a life cycle perspective and can possibly lead to wasted resources on less important issues. As already stated, companies have a good understanding of their direct water use, but water use might be greater within the supply chain or even downstream during product use or end of life. For the food and beverage sector, agriculture plays an importantrole in terms of water footprint and should be addresed within the life cycle perspective.

Various water footprint measurement methodologies have been recently developed in the frame of life cycle assessment. Different methodologies suggest different results for the same system assessed which is an issue for many companies who want to be able to benchmark their progress, to measure environmental benefits, to get recognition for their efforts and to ensure their credibility. In this respect, the ISO 14’046 working group is a valuable initiative, however this standard will not be available before 2014. As actions must be taken now regarding water, Danone Waters cannot wait for a consensus to be found before measuring its footprint. Danone Waters has taken the lead on this water footprint measurement task by selecting the most relevant indicators and methodologies to measure its water use related impact (i.e. water footprint).

RESULTS AND DISCUSSION

Danone benchmarked water footprint methodologies in order to select the most suitable one to measure its corporate and product water footprints. There is a growing consensus that this water footprint should include both water resources consumption and pollution aspects. This benchmark showed that water consumption methodologies provide more robust indicators than water degradation methodologies. The latter is difficult to apprehend and provides a high variability in the results, leading to difficulties for decision making. A lack of data is also recognized as being an important issue for supply chain measurement and downstream operations, although this is currently being addressed by some initiatives such as the Water Footprint Network, Quantis Water Database and ecoinvent v3.

Based on this finding, Danone Waters is now deploying a water consumption indicator weighted by a regionalized water stress index, also known as a water scarcity footprint. This indicator is based on the methodology presented by Pfister et al. 2009 at the midpoint level. The focus is not only on volumes of water, but on the local context. A region prone to higher scarcity will have a higher impact than a region with a lower one. This measure is closer to an environmental impact than the standard volumetric indicators (e.g. key performance indicator) and will lead to better global water management and decision taking within Danone Waters.

Danone Waters pursues research and development on methodologies addressing degradative water use and is engaging with stakeholders to promote the awareness and potential solutions addressing it. It includes engaging with scientific communities at conferences, engaging at the national level in France in the ISO 14’046 water footprint standard project, and communicating the process and its outcomes to stakeholders, among others.

As an outcome of this process to integrate water within its sustainability strategy, Danone Waters is building a tool called “DROP” (Danone water Resource Optimisation Programme).

This tool will allow the measurement in 2013 of the Danone Water Division water footprint, and commit to a water footprint reduction by 2020. The tool will integrate the water scarcity footprint in its first version, and in a further versiona water degradation indicator will be included.

This tool will allow the yearly update of water footprint measurements and allow managers to establish scenarios to support decision making to decrease Danone Waters' water footprint. As described above, this initiative is an important step towards a water strategy at the corporate level. Indeed, this first phase of deployment within the Danone Waters division is supposed to build the experience and methodological consistency to pave the way for other Danone businesses as complex agricultural supply chain and impacts should be assessed with an accurate, robust and recognized methodology.

CONCLUSIONS

Decreased impact and pressure on water resources globally require companies to integrate water within their sustainability strategy and to account for a Life Cycle Management perspective. Danone Waters shows the path of how to achieve this, by starting with the measurement of its division water footprint. This is the first step towards better management, engagement with stakeholders and communication across the entire business of Danone.

REFERENCES

Danone (2012) Danone 2012 sustainability report – strategy and performance, http://www.danone.com/images/pdf/sustainable_report_2012.pdf

Epstein M J, Elkington J, Leonard H B. (2008) Making sustainability work: best practices in managing and measuring corporate social, environmental and economic impacts. *Berret-Koehler Publishers*

Pfister S, Koehler A, Hellweg S. (2009) Assessing the environmental impacts of freshwater consumption in LCA. *Environ Sci Technol* 43(11):*4098–4104*

United Nations World Water Assessment Programme. (2012) The United Nations World Water Development Report 4 (WWDR4). 4th Edition, vol 1, 2 and 3, Paris, *UNESCO*

INTEGRATION OF STRATEGIC PLANNING AND LIFE CYCLE MANAGEMENT: A DISCUSSION BASED ON A LITERATURE REVIEW

*Fabio Puglieri, Engineering School of Sao Carlos, University of Sao Paulo (USP), Brazil.**

Diego Iritani, Engineering School of Sao Carlos, University of Sao Paulo (USP), Brazil.

Aldo Ometto, Engineering School of Sao Carlos, University of Sao Paulo (USP), Brazil.

**Department of Production Engineering, Av. Trabalhador sao-carlense, 400, 13566-590, Sao Carlos/SP, Brazil. Email address: puglieri@usp.br*

Keywords: strategic planning; life cycle management; integration; business; systematic literature review

ABSTRACT

This paper aims to explore how Strategic Planning (SP) and Life Cycle Management (LCM) could be worked together, since both have similar concepts but they are not seen in an integrated way. A systematic literature review was carried out to identify researches that bring the integration of LCM and SP, and then SP activities and LCM practices were included in a relationship matrix to analyze where integration opportunities can be found. The results show that academic literature which brings business SP and LCM concepts together is still far away from maturity and new approaches need to be developed.

INTRODUCTION

Strategic Planning (SP) is known by several definitions. According to Fischmann and Almeida (1991), SP should be understood as a managerial technique to identify opportunities and threats, strength and weak points, defining the direction that an organization should follow. For Nolan, Goodstein and Goodstein (2008), SP is a critical management process for organizations, and it should guide its members towards a situation of desired future situation. Thus, in few words, SP is a management technique to create a long-term vision whereby an organization should follow aiming the creation of value and competitive advantage.

Similar to SP definitions, Life Cycle Management (LCM) also encompasses many concepts. One of the most accepted LCM definition comes from the United Nations Environment Program (UNEP). According to UNEP (2007, 2009), LCM is a business approach to improve the companies' sustainable performance aiming the long-term value creation in the whole life cycle, i.e., suggesting a holistic vision of the organization.

Although both concepts have similar goals, few researches have showed how SP and LCM can be applied together. For Valentine (2010), the fusion of the environmental knowledge into a framework for a functional SP needs more development, and according with Lubin and Esty

(2010) companies do not have a roadmap to guide their environmental strategies. In other words, literature lacks to present a comprehensive framework which proposes the integration between SP and environmental issues, including the LCM.

In this sense, considering the previous discussion above, this paper aims to present how LCM concepts and practices could be integrated with SP to provide better environmental business strategies to guide firms' activities. The next topic presents the methodological procedures assumed to elaborate this paper.

MATERIALS AND/OR METHODS

A systematic literature review was conducted according to the roadmap proposed by Conforto, Amaral, and Silva, (2011). This roadmap has as main characteristics: the research strings tests and refinements; the iterative processing of the results, with more detailed selection filters at each iteration; and the references by references search. The roadmap is composed by 3 stages (Inputs, Processing and Outputs) which includes objective definition, database selection, strings, and the inclusion of criteria definition, execution phase and results analysis. In this study, the string "("life cycle management" OR "lifecycle management") AND ("strategy" OR "strategic planning")" was applied in five databases (ISI Web of Science, Scopus, Compendex, IEEE Explore and Science Direct). By the use of this string, an amount of 1015 articles were found (counting all databases). Then, the duplicated articles were removed and the inclusion criterion, defined by "to present the integration of LCM practices in strategic planning process", was applied. Finally, 6 articles that attend the inclusion criterion were fully analyzed and the integration of LCM practices into SP steps was extracted.

In order to identify potential interactions between SP and LCM, a relationship matrix was proposed. This relationship matrix consists in crossing the SP steps with the main LCM practices. The SP steps and LCM practices were found through a previous comprehensive literature review of SP and LCM. As result, seven major steps were identified for SP: strategy diagnosis, mission and vision statement, internal and external analysis (also known as SWOT analysis), strategy definition, strategy analysis, objective and goals, and strategy implementation. For LCM, environmental practices and approaches as Life Cycle Assessment (LCA) and The Natural Step Framework (TNS) were also identified.

RESULTS

SP comprises seven steps in general. First, top-management team has to identify which strategies are being adopted by the company, known by Strategic Diagnosis, followed by the Mission and Vision Statement. The third step consists in an Internal and External Analysis, mainly through the application of a SWOT analysis, which intends to identify strengths and weakness inside the firm, and the opportunities and threats in the whole environment, including the political and economic changes. Potential strategies are proposed (Strategy Statement), assessed (Strategy Analysis), and then measurable goals are defined (Goals Statement). Finally, the Implementation consists in the strategic plan deployment into tactical and operational plans.

The LCM practices which presented integration with SP steps were LCA and TNS framework. LCA is a quantitative technique which aims to assess environmental impacts through the whole product life cycle while TNS framework is built on the backcasting principle which intends to incorporate sustainability into strategic decision-making process. The Table 1 shows the main contributions identified in SLR related to SP steps. The Table 2 shows the relationship matrix.

Authors	**LCM contributions for SP**	**SP Step**
Lozano (2012)	Discusses the integration of LCM through the analysis of the sustainable life cycle from the backcasting concept (TNS).	• Internal and External Analysis
Ny et al. (2006)	This paper presents a sustainable LCA with the backcasting concept for firm's external analysis.	• Internal and External Analysis
Saur (2003)	Author suggests that top-managers need to incorporate LCM concepts in firm's mission and policies.	• Mission and Vision Statement
Sánchez, Wenzel e Jorgensen (2004)	Present an overview of LCM strategy adoption in organizations. This paper allows to evaluate the occurrence level of LCM practices in companies and the product chain.	• Strategic Diagnosis • Internal and external analysis
Rebitzer e Buxmann (2005)	Present streamlined LCA to support goals definition based on environmental impacts results.	• Goals definition
Seidel et al. (2011)	Propose a framework based on SWOT Analysis and streamlined LCA to analyze environmental impacts in the product life cycle. The framework also includes stakeholders analysis to identify possible partners. The authors highlight the communication of LCM strategy and projects across the company to establish a LCM culture.	• Mission and Vision Statement • Goals definition

Table 1. LCM contributions for SP steps

LCM practices \ SP steps	1	2	3	4	5	6	7
Traditional Life Cycle Assessment			X				
Streamlined Life Cycle Assessment			X		X	X	
The Natural Step Framework			X	X	X		

Legend
1 Strategic Diagnosis
2 Mission and vision statement
3 Internal and external analysis
4 Strategy definition
5 Strategy analysis
6 Goals definition
7 Implementation

Table 2. Relationship matrix based on results showed in Table 1

DISCUSSION AND CONCLUSIONS

Although SP and LCM are presented as two important management approaches to incorporate sustainability into business activities, and synergies are found between them, academic literature presents poor examples of how SP and LCM can be integrated together.

It is possible to conclude that new researches must be developed to incorporate life cycle concepts and practices in the strategic planning processes, allowing decision-makers to consider sustainability issues in the business strategic plan, and the firms’ value chains.

REFERENCES

Conforto, E. C.; Amaral, D. C.; Silva, S. L. DA. Roteiro para revisão bibliográfica sistemática : aplicação no desenvolvimento de produtos e gerenciamento de projetos. 8o Congresso Brasileiro de Gestão de Desenvolvimento de Produto, 2011.

Fischmann, A. A.; Almeida, M. I. R. (1991). Planejamento Estratégico na Prática. Segunda edição. São Paulo: Editora Atlas.

Lozano, R. (2012). Towards better embedding sustainability into companies’ systems: an analysis of voluntary corporate initiatives. Journal of Cleaner Production, v. 25, p. 14-26.

Lubin, D; Esty, D. (2010). The sustainability imperative. Harvard Business Review.

Ny, H.; MacDonald, J. P.; Broman, G.; Yamamoto, R.; Robèrt, K-H. (2006). Sustainability Constraints as System Boundaries: An approach to making Life-Cycle management strategic. Journal of Industrial Ecology, v. 10, i. 1, p. 61-77.

Rebitzer, G.; Buxmann, K. (2005). The role and implementation of LCA within life cycle management at Alcan. Journal of Cleaner Production, v.13, p.1327-1335.

Sánchez, I.; Wenzel, H.; Jørgensen, M. (2004) Models for defining LCM, monitoring LCM practice and assessing its feasibility. Greener Management International, v.45.

Saur, K. (2003) Life cycle management as a business strategy for sustainability. Environmental Progress, v.22, i.4, p.237-240.

Seidel, M.; Seidel, R.; Shahbazpour, M. (2011). An integrated LCM framework for manufacturing SMEs. In: LCM 2011 – Towards Life Cycle Sustainability Management, Berlin, 2011.

UNEP (2007). Life Cycle Management: A business guide to sustainability.

UNEP (2009). Life Cycle Management: how business uses it to decrease footprint, create opportunities and make value chains more sustainable.

Valentine, S. V. (2010). The green onion: A corporative environmental strategy framework. Corporate Social Responsability and Environmental Management, v.17, p.284-298.

NOKIA'S PRODUCT LIFE CYCLE ASSESSMENT OVER THE YEARS, INCLUDING CHALLENGES AND KEY FINDINGS

Ilona Santavaara (Nokia), Noora Paronen (Nokia). *Visiokatu 4, 33720 Tampere, Finland, ilona.santavaara@nokia.com*

Keywords: LCA, mobile phone, smart phone, climate change, integrated circuit

ABSTRACT

Nokia has been continuously improving product life cycle assessments and keeping up to date with latest developments in methods and datasets to better evaluate their products. Because of the complexity of the products and long and complex supply chain, conducting product life cycle assessments is a very complicated task to begin with. There are factors that make the task even more challenging. Some of the biggest challenges faced along the way as well as key findings from Nokia's LCA studies are presented and demonstrated in this paper.

INTRODUCTION

Nokia has a long experience in conducting Life Cycle Assessments (LCAs) and has carried out environmental impact assessments since the middle of the 1990's. We have continuously improved our assessments, including methods and inventory data, to adapt them to better evaluate our products. Lately Nokia has piloted new methodologies as they have been developed and have become available. Recently Nokia has participated in the Directorate General for the Environment's (DG ENV) road testing of Product Environmental Footprint guide and also in the pilot test by Directorate General for Communications Networks, Content and Technology (DG Connect) to test the various methodologies to assess the energy consumption and greenhouse gas emissions of ICT.

LCA is an important tool as it gives a quantitative basis for measuring sustainability. At Nokia, LCA is used for example to calculate the environmental impact of products and activities and assessing and monitoring the environmental performance over time. The main goal of the method is to reduce the environmental impact by guiding the decision-making process. The results of the LCAs are used internally to help identify the key stages in the product life cycle, for example where the largest sources of emissions and energy use over the phone life cycle take place, and to take action to minimize these impacts.

Although externally Nokia only communicates climate change impact and energy use inventory data, other relevant impact categories are taken into account internally in decision-making to avoid burden shifting to other categories. Selecting the relevant impact categories for specific products needs to be done with enough knowledge and information to back the selection up. Calculating even just the greenhouse gas (GHG) emissions for our products requires extensive work and research due to the complexity of our products and long and complex supply chains. Some of the biggest challenges and key findings from our LCA studies are presented and demonstrated in the following pages.

VARIATION IN RESULTS BASED ON ASSUMPTIONS AND CHOICES

We are constantly comparing and evaluating different databases, datasets, tools and methods to improve the accuracy of our calculations. Because of this, during the last few years the LCA figures for Nokia products have changed quite often. Based on all the work we have done with LCAs, we have found that no results are absolute and conducting LCAs is a continuous learning process due to the extent of available information and ongoing development in the LCA area.

One of the biggest challenges we have noticed while conducting our studies and participating in pilots is how many different factors affect the results. The impacts of assumptions, different LCA software tools, Life Cycle Impact Assessment (LCIA) methods, Life Cycle Inventory (LCI) databases and scenarios when assessing impacts on the product level all cause variations in the results. We use ISO 14040 and ISO 14044 standards that set the base and are complemented by the ICT specific ETSI TS 103 199 and ITU-T L.1410 that give ICT sector guidance (ETSI, 2011). Nonetheless, standards are just intended to set a framework for LCAs, allowing for many different kinds of studies, inherently allowing a lot of freedom. This allows large variations in results between studies performed by different practitioners and organizations independent of the used standard. Methods and impact categories are not completely unambiguous either, allowing different LCA software manufacturer to make some of their own choices when implementing these to their tools.

Results of climate change impact category for four different Nokia phones in 2010, 2011 and 2012 are presented in Figure 1. Phones themselves have not changed -- change in the figures comes from updates or changes in tools, data, assumptions or any of the other factors mentioned in the previous paragraph.

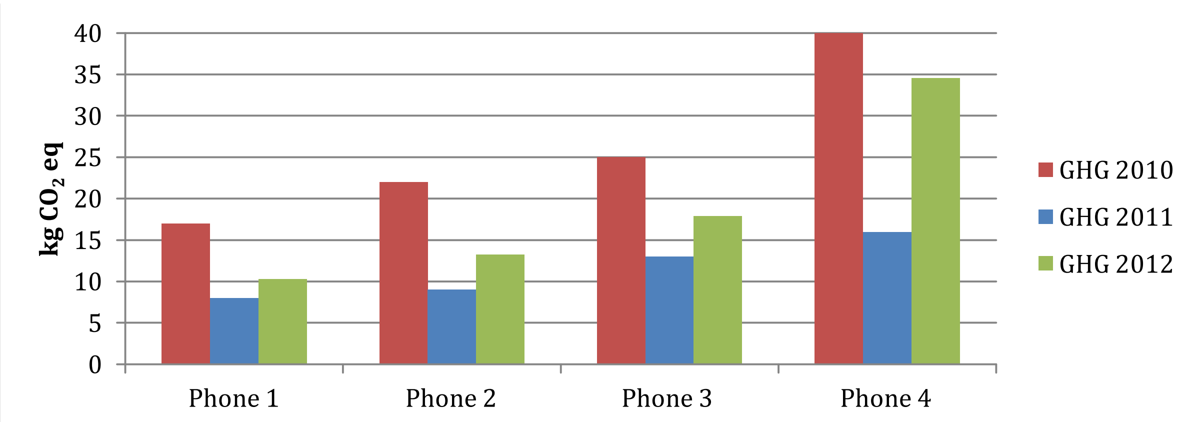


Figure 1. GHG emissions of four phones based on calculations made in 2010, 2011 and 2012.

A more specific example of change in figures can be given about ICs. Ecoinvent’s IC data was compared with PE International’s IC data by selecting the closest IC datasets in terms of silicon die area and other IC key parameters for the ICs in the N97 smart phone. From Ecoinvent v 2.2 datasets “IC, logic type, at plant/GLO” and “IC, memory type, at plant/GLO” were used, while from PE International data for ICs from electronics extension database was used. Comparison was made on how large portion of GHG emissions from raw materials acquisition and component manufacturing is covered by ICs for N97 smart phone. ICs only covered 7% when using Ecoinvent's data, while with PE International's data the share became 28%. The reason is that datasets for the ICs in the Ecoinvent database, from year 2007, underestimate the size of the silicon die. In terms of ICs the differences between these two ICT specific datasets are unquestionable and so the LCA practitioner needs to have the competence to judge which dataset suits the studied functional unit the best.

Measurement and availability of representative data in general is an issue for the ICT sector because of the complexity and fast evolution of the sector and its supply chains, and this too may have a significant impact on the results of LCAs. Because of all of these observations, it is clear that there is inconsistency between impact figures across the industry, and these figures cannot be used for comparison between mobile devices from different manufacturers as also presented in the TENNG study. (TENNG, 2012)

DIFFERENCE BETWEEN MOBILE PHONES VS SMART PHONES

One important thing to tackle is also the comparability between different types of products (i.e. smart phones vs. mobile phones). Comparison to some extent is possible if the same person is making the assumptions and interpreting the standard and data to assess different types of products, but still there are challenges in this kind of comparison. The climate change impact of a basic mobile phone is quite small compared to the climate change of a smart phone. For example, for basic mobile phone Nokia 105 climate change equals 7 kg CO_2e, while for smart phone Lumia 720 climate change equals 21 kg CO_2e. However, these two products and what consumers can do with them differ significantly. Convergence of products should be somehow recognized especially with smart phones, but currently no methodologies define how to do this.

When using impact results to help identify the largest sources of emissions and take action to minimize these impacts, it is important to notice that the distribution of emissions between different life cycle stages is quite different in mobile phones versus smart phones, as can be seen in Figure 2 and Figure 3.

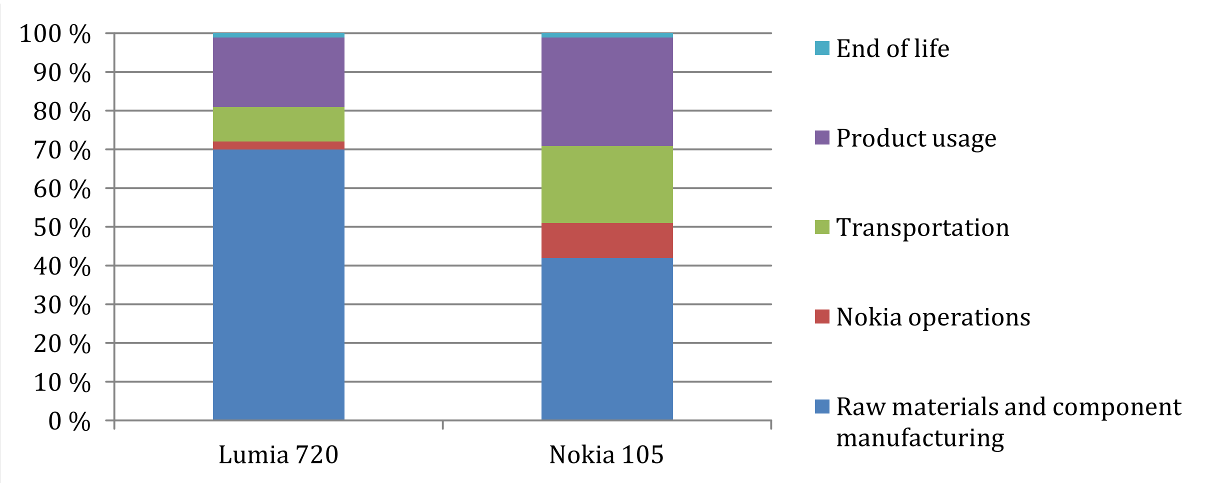


Figure 2. How GHG emissions are divided between different life cycle stages in two different types of products.

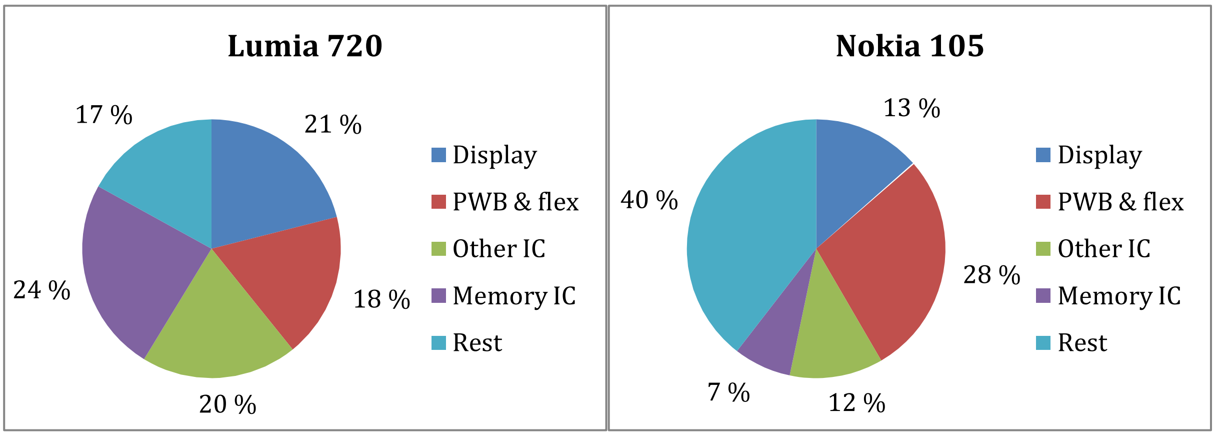


Figure 3. How GHG emissions of raw materials and component manufacturing are further divided between different components in two different types of products.

Furthermore, for example product use stage and the challenges of modeling it for LCA purposes are very different for these two phones. Determining typical consumer behavior for a device gets more and more difficult when the device is multifunctional as people tend to use their devices in very different ways. However, as use stage has a significant impact on overall results, it is not feasible to leave it out of the scope.

Another aspect that is not yet well supported by methodologies is the enabling effect of mobile phones. By identifying largest sources of emissions over the lifecycle companies are taking action in minimizing the environmental impact of products. However, this is just one side of the story as according to a GeSI report ICT sector has also the potential to reduce the impact of other industries, reduction potential being seven times the total direct emissions from the entire ICT sector in 2020 (BCG, 2012).

CONCLUSIONS

To be able to conduct an LCA for an ICT product, a lot of competence and knowledge about the sector specifics is needed together with in depth knowledge about LCA. Due to the characteristics of LCA, assessments of different producers are not comparable, as is presented in this paper. The life cycle based methodologies are well suited for high level policy purposes, such as identifying the key stages in a product's life cycle but are not suited for measures that impact fair competition between companies or market access due to required accuracy and associated uncertainty.

REFERENCES

ETSI. 2011. ETSI TS 103 199 Technical Specification. http://www.etsi.org/deliver/etsi_ts/103100_103199/103199/01.01.01_60/ts_103199v010101p.pdf

The Boston Consulting Group (BCG). 2012. GeSI SMARTer 2020: The Role of ICT in Driving a Sustainable Future. http://gesi.org/SMARTer2020

TENNG (TeliaSonera, Ericsson, Nokia, NSN & GSMA consortium in DG Connect pilot project), 2012. Study on the Usability of Different Standards and Methodologies for Assessing Environmental Performance of ICT Organisations, Products, Networks and Services. http://www.nokia.com/global/about-nokia/people-and-planet/strategy/casestudies/case-studies/

OPEN BUSINESS MODELS AND CO-CREATION IN REAL ESTATE AND CONSTRUCTION SECTOR

M.sc. Karoliina Rajakallio, M.soc sc. Lauri Pulkka, Prof. Seppo Junnila*

**Aalto University School of Engineering, Real Estate Business*
P.O Box 15800, 00076 AALTO, Finland
karoliina.rajakallio@aalto.fi

Keywords: real estate, innovation, intermediation, co-development

ABSTRACT

One reason for low levels of innovativeness and productivity in the Real Estate and Construction sector is its fragmented value chains. We argue that REC companies could gain from theories of open innovation and open business models. In the context of innovation and business models, the aim of the study is to examine how intermediation activities can support innovation process in the REC sector through three cases. During the intermediation process links between the co-development objectives and the business strategy of companies strengthened in all cases.

INTRODUCTION

The real estate and construction (REC) sector has a significant environmental and economic impact on the society. At the same time the sector is associated with low levels of innovativeness and productivity.

One reason for this is the fragmented value chains in the industry (Miozzo and Dewick, 2004). The fragmentation is visible both horizontally and vertically at a project level, multiplied along the temporal axis and posing several challenges from the life-cycle perspective. Due to this fragmentation, almost all innovations in REC sector have to be negotiated with one or more actors within the project coalition (Winch, 1998).

Thus we argue, as they work in highly networked business environment, that REC companies could potentially gain from theories of open innovation and open business models. In the context of innovation and business strategies in the REC sector, particularly the analysis of co-development relationships is interesting. (Chesbrough and Schwartz, 2007)

In the rise of open innovation, open business model and co-development paradigm, the role of intermediates, third party organizations acting as an agent or broker in any aspect of the innovation process, has grown more prominent (Chesbrough 2006, Howells 2006). The different roles that these actors play within the innovation process are various, e.g. third parties, intermediary firms (Stankiewicz, 1995), bridgers (Bessant and Rush, 1995), brokers (Hargadon and Sutton, 1997), and superstructure organizations (Lynn et al., 1996).

The aim of the study is to examine the process, potential and strategies of five REC companies to establish end-user driven and open co-development partnerships. In particular, this paper analyses the effect of third party intermediation focusing on the following questions:

- How the objectives, actions and priorities changed during the intermediation process?
- What was the role of intermediates in the innovation process?

RESEARCH APPROACH AND METHODOLOGY

The study is conducted using an action research approach. It shares similarities with participant observation in the sense that the researcher takes part in the activities of the studied organization. However, the action in action research comes from the strong problem-solving focus and the researcher's central role in the problem-solving process (Susman and Evered, 1978).

Our empirical data consists of three cases. The cases are joint innovation projects with two to three companies, referred as "groups of innovating organizations" (GIOs). All of them partake in the Real Estate and Construction Innovation (RECI) research program, planned to run from 2013–2017. The data was collected in 2012 and 2013 in researcher-led workshops that were held for the GIOs in the planning phase of the research program. For each GIO 3-6 workshops were held in which the agenda was to write a GIO-specific research plan for the program. The GIOs are described in more detail in table 1 below.

Table 1. Description of cases (GIOs)

Participants	*Previous co-development between companies*	*Initial motivations for the innovation project*[1]
GIO 1		
Company A. Large globally operating corporation, with of office, R&D and production facility portfolio.		
Company B. Global facility and construction management services provider		
The companies had a long co-operation history. The competitive advantage of B was declining, since its proactive innovation capacity was seen lesser than its competitors. Company B wanted to enhance its innovation capacity. Company A aims at developing its sourcing practices so, that it would get innovations and proactive inputs for facilities management development from its suppliers.		
GIO 2		
Company C. Medium-sized consulting and engineering company, strong focus on proprietary IT-tools and energy reporting systems development		
Company D. Medium-sized IT solutions provider, specialized in space optimizing and corporate real estate management software		
Company E. Large globally operating corporation with office and production facility portfolio		
Companies C and D had an existing client relationship with company E's real estate department. Company C wanted to integrate software with D's offering, which they see complementary. In addition, they wanted to develop a deeper client relationship with its client (E). Company E wanted to enhance their energy, supplier and space management efficiency and reporting practices		
GIO 3		
Company C. Same company as in GIO 2 but only little overlap in individual project participants, focus more on consultancy		
Company F. Small company focusing on public sector consultancy and resource planning services		

[1] As expressed by the company representatives in the beginning of the co-development process

Over one year of co-development of real estate portfolio optimization tools, with company C focusing more on development and F on data collection. Both companies wanted to further develop their service offering to public sector customers.

RESULTS

The main result is that during the intermediation process links between the co-development objectives and the business strategy of participating companies strengthened in all cases. The transparency of partners' business models and strategic targets made the discussion over targets, actions and required investments more to-the-point. It helped positioning each company's efforts in projects to the actions that will bring most value to them, contributing to the overall common objectives of the co-development project target.

The increased understanding and transparency of companies' joint, as well as company-specific objectives contributed to trust-building among partners and balanced the observed asymmetry of negotiation power between some co-development partners. In some cases new customer–supplier settings were identified. Co-development started to be seen as a strategy to leverage the competitive positioning by improved customer relationship to expand the services to new markets.

DISCUSSION AND CONCLUSIONS

The paper examines the potential and strategies of four real estate and construction sector companies to establish end-user driven and open business models through formal and informal partnerships. We wanted to analyze, how the objectives, actions and priorities changed during the intermediation process, how the business model was taken into consideration and what roles did the intermediates get in the innovation process.

The most visible roles of intermediates were: linking of innovations to the business strategies of participant companies, making them visible to all parties and balancing the positioning of asymmetric parties. This was seen to improve the motivation of companies, indicated by increased contribution to the process. The results of the study confirmed the assumption found in existing literature that co-development partnerships are an increasingly effective means of innovating the business model to improve innovation effectiveness, and that participants should however carefully assess others' business models and needs. (Chesbrough and Schwartz 2007)

The outspoken role of university intermediates in the meetings was facilitator and coder of the discussion (Blayse et al 2006, Winch, 1998). In addition to these roles, it was identified that intermediates also helped to bring dynamism to the meetings and the sequence of workshops. During the process they contributed to identifying common targets and to construct the "big picture" of business strategy and long term targets (Winch 1998, Chesbrough and Schwartz 2007). The common long term business goals then acted as a compass and a time-scale for shorter scale operational activities. Intermediates had the possibility to increase the transparency of co-development motivations as by having the freedom to ask "dumb questions" which otherwise would not have been raised. They also ensured that all parties of co-development projects were heard and their business strategy and development potential were taken into consideration, despite of initial disproportion of the participants.

The quality and focus of innovation projects were significantly improved through the introduction of a neutral party. This appears to be analogical to the REC sector challenge of life-cycle management, where this has been approached utilizing independent life-cycle consultants to watch over the long term targets and optimal solutions over drivers for short term optimization of investment costs.

It seems that the same short term-long term optimization dilemma is identifiable also in REC sector related co-development projects. Especially in project based, client driven projects these implications were observed. It is also clear that the linkage between project goals and business process should be enforced more clearly from the beginning of a co-development project.

This study is an introduction for a four-year research project on REC sector innovations (RECI). It will continue to explore how the innovation capacity of REC sector can be enhanced to unlock the sectors potential.

REFERENCES

BESSANT, J.; RUSH. 1995. H. *Building bridges for innovation: the role of consultants in technology transfer.* Research Policy, v. 24, p. 97–114.

CHESBROUGH, H. W. 2006. *Open Business Models: How to Thrive in the New Innovation Landscape*. Harvard Business Press Books.

CHESBROUGH, H.; SCHWARTZ, 2007. K. *Innovating Business Models with Co-development Partnerships. Research-Technology Management,* v. 50, n. 1, p. 55-59(5, January-Februrary.

EVERED, R.; SUSMAN, I. 1978. *An Assessment of the Scientific Merits of Action Research*. Administrative Science Quarterly, v. 23, n. 4, p. 582-603.

HAGARDON, A.; SUTTON, R. I. 1997.*Technology brokering and innovation in a product development firm.* Administrative Science Quarterly, v. 42, p. 718–749.

HOWELLS, J. 2006. *Intermediation and the role of intermediaries in innovation*. Research Policy, v. 35, p. 715–728.

LYNN, L. H.; REDDY, N. M.; ARAM, J. D. 1996. *Linking technology and institutions: the innovation community framework*. Research Policy, v. 25, p. 91–106.

MILES , M. B.; HUBERMAN, A. M. 1994. *Qualitative data analysis: An expanded sourcebook.* Beverly Hills: Sage Publications.

MIOZZO, M.; DEWICK, P. 2004. *Networks and innovation in European construction benefits from inter-organisational cooperation in a fragmented industry*. International Journal of Technology Management, v. 27, n. 1, p. 68-92.

STANKIEWICZ, R. 1995. *The role of the science and technology infrastructure in the development and diffusion of industrial automation in Sweden.* In: CARLSSON, B. Technological Systems and Economic Performance: The Case of Factory Automation. Dordrecht: Kluwer. p. 165–210.

WINCH. 1998. *Zephyrs of creative destruction:understanding the management of innovation in construction*. Building Research & Information, v. 26, n. 5, p. 268-279.

ORGANIZING SUSTAINABLE PRODUCT CHAINS OF A MULTINATIONAL CORPORATION: LIFE CYCLE MANAGEMENT IN PRACTICE

Hanna Nilsson, Chalmers University of Technology, Henrikke Baumann, Chalmers University of Technology*

** Chalmers University of Technology, Environmental Systems Analysis, SE-412 96 Gothenburg*

Keywords: life cycle management (LCM); product chain; knowledge capabilities

ABSTRACT

LCM literature is mainly of a normative character and LCM is typically defined by holistic environmental focus, internal integration, collaboration with external actors and carried out with an abundant LCM-based toolbox. To contrast, a study of LCM in practice shows here how LCM is enacted by linking environmental initiatives attached to different steps of a generic product chain. It also shows how practitioners struggle with processes of internal integration and external collaboration.

INTRODUCTION

The life cycle management (LCM) literature provides a wide range of definitions and an abundant toolbox. It consists mainly of normative prescriptions of what LCM is, of tools, and of key issues such as the importance of internal company integration of LCM and external integration of LCM in the product chain. But empirical studies of LCM are still relatively uncommon (Seuring, 2004) and not much literature is found about these actual practical difficulties of LCM, nor on how practitioners work with these issues. The aim of this paper is therefore to describe how LCM is enacted in actual practice in one large multinational corporation with explicit LCM intentions.

Life cycle management

Hunkeler et al. (2003) describe LCM as “an integrated framework of concepts and techniques to address environmental, economic, technological and social aspects of products, services and organizations” (p. 69) and Baumann and Tillman (2004) defines it as “the managerial practices and organizational arrangements that apply life cycle thinking. This means that environmental concerns and work are coordinated in the whole life cycle instead of being independent concerns in each company” (p. 62). This variety of definitions is something Poikkimäkki (2006) highlighted when she pointed out that theoretical LCM descriptions “can cover any environmental considerations in a company or among several companies along a product life cycle, from an entirely new management paradigm to a certain perspective and to the use of specific tools" (p. 49). In this broad spectrum the common denominator is environmental consideration that stretches the traditional focus on individual actors to a holistic product chain perspective. Interaction and collaboration between actors is also considered important factors (see for example Remmen et al., 2007; Power (Ed.), 2009).

MATERIAL AND METHODS

The studied organization, here referred to as the Company, is considered a frontrunner with regards to sustainability related goals and activities. It is a multinational company that provides products in several product categories and has production at about 150 sites around the world. The Company has stated ambitions to integrate LCM into internal core business processes as well as stated ambitions to decrease environmental impact within its own company boundaries as well as upstream and downstream its product chains. Due to these preconditions the Company is a well suited corporation for a study of how LCM is enacted in practice.

I have conducted what Czarniawska (1997) would call a window study, which is when "a researcher open an arbitrary time window and describes all that can be seen through it" (p. 65). As such it is also what Mol (2003) would call a praxiology – a study of practice. A qualitative study has been undertaken over a period of one year. Thirteen semi structured interviews of about one and a half hours each were conducted with a selection of practitioners in the organization. The main part of the informants had a strategic position within the company whilst some worked part time with sustainability related issues. The snowballing technique was applied as a way of generating relevant interviewees. Continuous observations have taken place at the Company"s Strategic Sustainability department, as well as document studies.

RESULTS

The study shows that the Company has several on-going environmental initiatives with different focus, such as: *environment health and safety* (EHS) (internal management systems, policies, regulations), *design for environment* (DfE) (internal green design parameters and product development), *life cycle thinking* (LCT) (internal integration of environmental concern into business processes), an *emission strategy* (main focus on in-house activities and upstream actors, emission reduction), *accountable chain management* (supplier focus, codes of conduct, environmental/energy management systems), an *sustainability portfolio* (customer oriented, portfolio of „greener" products and services), and *end-of-use management* (remanufacturing, reuse, refurbishment).

Having these environmental initiatives does not automatically mean that there is an underlying life cycle perspective involved. To really understand the Company"s LCM activity one has to dig deeper into the content of the initiatives to understand their relevance for LCM.

By doing so reveals that the environmental initiatives focus on different aspects and that the Company has linked them so that they cover a generic Company value chain (figure 1).[1]

Figure 1 A generic value chain for environmental initiatives according to the Company (Annual report, 2012)

This shows that the Company has linked its environmental initiatives to a generic product chain with the aim of creating sustainable product chains and working with LCM.

Studying these initiatives also mean studying the practitioners. They come from different functions, departments and divisions within the organization and many are involved in more than one environmental initiative and several parallel networks that concerns environment or sustainability exist within the organization. Integration in the line organization is considered a key issue at the Company mentioned by almost all interviewees related to these initiatives. But even if considered key it is also frequently mentioned as a difficulty. Even though environmental concern is considered to have top management support the everyday activities are still considered to lack a self-going concern for environmental issues in the day-to-day business activity. Neither is environmental concern the only top priority of the organization but instead one of several important aspects.

Another difficulty mentioned is that of gaining external attention for products in the sustainability portfolio. This is exemplified by the fact that the Company now work intensely to promote their greener products but the success of the products depend on the customers‟ recognition and purchase of the products.

CONCLUSIONS

This study shows how LCM at the Company constitutes of a number of environmental initiatives that are related to each other and that are linked to a generic product chain. This relation between the initiatives and the linkage to a generic product chain is what qualifies it as LCM and not only individual corporate environmental initiatives. As such it shows how the Company has enacted its LCM intentions into LCM activity.

What also needs to be considered here is the fact that this is a generic chain. Since the Company has numerous suppliers and production sites this means a large number of product chains that needs to be managed. In actual practice there are also often even more physical

[1] The term ‘value chain’ is used in the annual report (2012) but in this paper the term ‘product chain’ (Boons, 2002) is used since I believe that it better represents the physical phases involved in generating and managing a product during its lifetime.

phases involved then can be derived from a generic product chain. Therefore the next step in the development of LCM and sustainable product chains would therefore be to study a selection of these products and product chains to see if and how they actually are connected to the Company‟s overall life cycle management.

LCM literature often point out the importance of external integration of LCM and collaboration with external actors in the chain. The Company has with time gained a more and more holistic view of environmental aspects, even though the Company to date has mainly focused its efforts on collaboration internally. Some external parties have though recently been included as a way of adding to sustainability and the Company‟s LCM work. The Company is therefore still in the starting blocks of this next step of LCM of collaboration with external actors in the product chain. A difficult step – as the example with sales of green products show, LCM is not in the hands of one company but rather the interaction of actors in the product chain. Such interaction requires further studies.

LCM literature also identifies internal integration as key but lacks descriptions of practitioners. Studying them shows a dynamic organization with several networks. It also shows that integration indeed is a key issue but something that practitioners struggle to manage, especially with regards to everyday business activities. Generally this study shows how LCM activity in practice is much more than can be depicted from the mainly normative literature on LCM and that it is a continually evolving process as people in the organization gain knowledge and capabilities to manage LCM organization.

REFERENCES

Baumann, H. & Tillman, A-M. (2004). *The hitch hiker's guide to LCA: an orientation in life cycle assessment methodology and application*. Lund: Studentlitteratur.

Boons, F. (2002). Greening products: a framework for product chain management. *Journal of Cleaner Production, 10*(5), pp. 495–505.

Czarniawska, B. (1997). *Narrating the organization: dramas of institutional identity*. Chicago and London: University of Chicago Press.

Hunkeler, D.; Saur, K.; Rebitzer, G.; Finkbeiner, M.; Schmidth, W-P.; Jensen, A.A.; Stranddorf, H. & Christiansen, K. (2003). *Life-cycle management.* SETAC Press.

Mol, A. (2003). *The body multiple: ontology in medical practice.* Durham, NC: Duke University Press.

Poikkimäki, S. (2006). *Look closer to see further – exploring environmental life cycle management, LCM.* PhD dissertation. University of Jyväskylä.

Remmen, A.; Jensen, A. & Frydendal, J. (2007). *Life cycle management: a business guide to sustainability.* Nairobi, Kenya: UNEP/SETAC.

Seuring, S. (2004). Industrial ecology, life cycles, supply chains: differences and interrelations. *Business Strategy and the Environment*, *13*(5), pp. 306–319.

Power, W. (Ed.) (2009). *Life cycle management: how business uses it to decrease footprint, create opportunities and make value chains more sustainable.* United Nations Environment Programme & Society of Environmental Toxicology and Chemistry Europe.

SOCIAL PRACTICES – A NEW FOCUS AREA IN LCM

Kirsten Schmidt, Aalborg University. E-mail: kirstens@plan.aau.dk.
Aalborg University Copenhagen, A.C. Meyers Vaenge 15, 2450 Copenhagen SV, Denmark.

Keywords: LCM; social practices; organizational structures; learning; engagement

ABSTRACT

The present understanding of LCM as a product management system supported by a number of tools and methods does not pay attention to the importance of social practices that the employees develop in relation to the systematic approach. A new conceptual model of LCM including the social practices is presented and discussed from theoretical and empirical perspectives. Theoretically, the analyses cover the formalized structures related to the division of labor and the coordination of the tasks on the one hand, and the social practices as meanings, values and priorities on the other hand. A larger Danish company serves as case for the empirical analyses of the formalized structures and their interaction with the social practices developed by the employees over time.

INTRODUCTION

Since the 1990'ies, life cycle thinking has been a part of the understanding of how organizations should deal with their environmental and sustainable responsibilities by including the whole value chain. Life cycle thinking can be implemented in different ways, including for example Life Cycle Assessments as a part of designing more sustainable products and product systems. Life cycle thinking can also be implemented as a management concept - Life Cycle Management, LCM – with the aim of securing continuous improvements in relation to products and services (Remmen et al, 2007).

The latest definition of LCM presented in the UNEP/SETAC Guideline for Life Cycle Management emphasizes LCM as a product management system aiming at continuously minimizing the environmental and socioeconomic burdens of an organization's product portfolio during the entire life cycle and product chain (Remmen et al, 2007).

LCM is thus understood as a holistic and systematic concept supported by the development of guidelines, tools and methods for implementation on both the strategic and operational levels of an organization (UNEP-SETAC, 2013). Nevertheless, the development of social practices in organizations are generally, but not specifically addressed as a part of the LCM concept.

This paper discusses how a systematic, structured approach interacts with the development of social practices in an organization's internal and external relations. The analyses are constructed in the form of a conceptual model of LCM which is developed from a theoretical as well as an empirical approach. The model serves as inspiration for organizational learning as a way of stimulating sustainability in organizations and in their value chains.

METHODS AND APPROACHES

From a theoretical approach, the analyses are conducted from two different perspectives - the formalized structures of the organization and the social practices. Moreover, the interaction of the two perspectives is included in the conceptual model.

The formalized structures are analyzed from Mintzberg (1983) with special attention to aspects in relation to the division of labor and the coordination between the divided tasks.

The social practices are analyzed from Wenger (1998) and include aspects like working practices; identity; development of meaning; and relations-building among the employees.

Case study – the empirical approach

A larger Danish producer of medical devices serves as the empirical case in the analyses. The company has more than 20 years of experience in working with aspects of sustainability and can thus provide both formalized structures and social practices for the investigation of LCM. The analyses included policies, reports, internal documents and more than 15 interviews with employees in different functions and departments.

The analyses are included in a PhD thesis focusing on the interaction between formalized structures and the development of social practices related to sustainability initiatives in organizations (Schmidt, 2011).

RESULTS – LCM INCLUDING SOCIAL PRACTICES

The developed conceptual LCM model, Figure 1, illustrates the sustainability effort as an entirety comprising the formalized structures and the social practices internally and in the interactions with the organizations' environment. Formalized structures, including the use of specific tools and methods, consolidate a systematic and on-going effort while the social practices play a role e.g. in creating meaning of and prioritizing sustainability initiatives in the daily work.

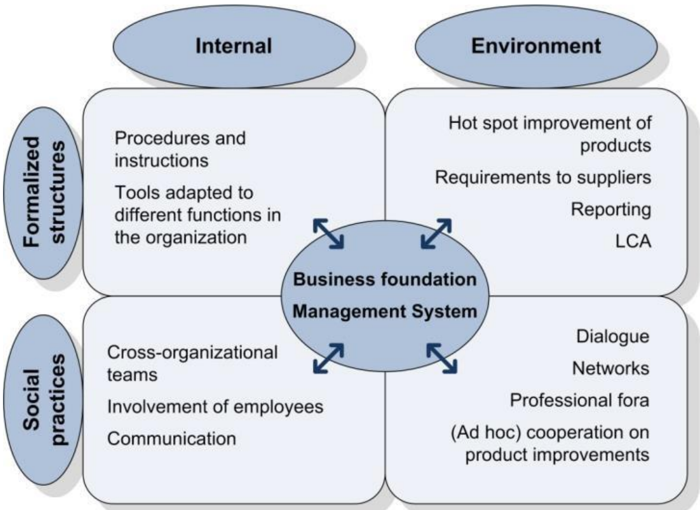


Figure 1. Conceptual model of LCM including formalized structures and social practices (Schmidt, 2011, with inspiration from Remmen, 2001)

In a life cycle perspective, the employees' active sharing of knowledge and experiences is a potential source of learning and innovation as they develop their social practices through an interaction with external as well as internal persons and structures.

The conceptual LCM model also underlines the importance of understanding the interaction between the strategic and the operational levels of the organization both in relation to the formalized structures and the social practices. By focusing on the interaction between the structures and the social practices, the management of the organization is challenged not only to put structures like management systems in place but also to reflect on, how the employees develop their understanding and practices in relation to these structures.

The model proposes an understanding of the "structures and social practices interaction" as a balance of handling on the one hand the structural organizational aspects related to defining and dividing sustainability related responsibilities and tasks and coordinating these responsibilities – and on the other hand including the meanings, perceptions and identities of the employees as well as the relations developed over time.

DISCUSSION – THEORETICAL AND EMPIRICAL UNDERSTANDINGS

With his attempt to formalize structures, Mintzberg focus on the division of the tasks and the coordination of these tasks across the company (Mintzberg, 1983). Wenger, on the other hand, brings into focus the relations among people and actefacts and how knowledge and skills are developed over time (Wenger, 1998). Thus, the sustainability effort could be seen as a unity of structures and social practices, since the employees develop their commitment and daily work from both perspectives.

From an empirical approach, the analyses in the case company show that the formalized procedures and tools clearly influence the issues that the employees deal with. But the system alone does not define the social practices – e.g. the meanings, identities and priorities – established around the procedures. Other aspects of daily business, personal beliefs and professional language in a specific department highly influence the attitudes and engagement related to the sustainability effort. The content and focus of the formalized structures and the social practices are illustrated in Figure 2.

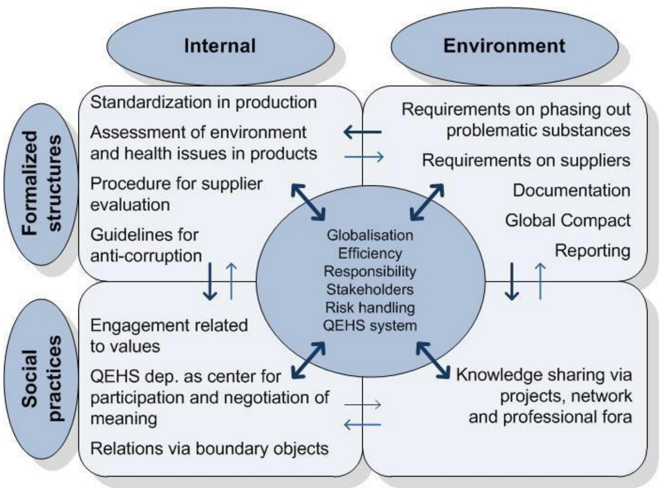


Figure 2. Conceptual model of LCM in a case company (Schmidt, 2011)

In the case company who puts emphasis on the formalized structures, the analyses showed a need for taking the social practices around the structures into account. If the management would like the employees to become actively engaged in taking the sustainability effort further, space for negotiation of meaning across different functions is needed. With a view to the continuous development of the effort, such negotiation of meaning should balance the fulfillment of existing procedures and development of new initiatives. *Balancing* in this context is not necessarily a question of equilibrium in for example priorities or in the use of resources. Rather, it is a question of concurrency in creating spaces for mutual engagement while fulfilling specified procedures. In a company where the sustainability effort is based on the initiatives of the individual employees, it could in reverse be relevant to consider the need for more formalization and coordination to balance the effort.

CONCLUSIONS

The results show the need for understanding sustainability in organizations as a nexus of management concepts, formalized structures and social practices. Formalized structures consolidate a systematic effort while an on-going negotiation of meaning plays a role in developing the sustainability effort. In a highly formalized company, there could be a development potential in creating spaces for participation to allow for learning and sharing of knowledge within the company and with external parties. Among other things, such spaces can foster sustainable business innovations and build an understanding of how the individual employee can see his own as well as concerted options in this regard.

As a first step to include social practices in the development of LCM, the present definition (Remmen et al., 2007) could be extended by adding the following text *(in italics)*:

Life Cycle Management (LCM) is a product management system aiming to minimize environmental and socioeconomic burdens associated with an organization's product or product portfolio during its entire life cycle and value chain. *As a management concept, LCM includes both formalized structures and social practices within the organization and in its external relations.* LCM is making life cycle thinking and product sustainability operational for business through the continuous improvements of product systems, and LCM supports the business assimilation of policies such as integrated product policies.

REFERENCES

Mintzberg H (1983). Structure in Fives. Designing Effective Organizations. *Prentice Hall Inc.*

Remmen A (2001). Livscyklusbaseret miljøledelse – balancen mellem en teknisk og social tilgang (Life cycle based environmental management – balancing a technical and a social approach). In: Loke no.3, September 2001, pp.6-7.

Remmen A, Jensen AA, Frydendal J (2007). Life Cycle Management. A Business Guide to Sustainability. *United Nations Environment Programme*.

Schmidt K (2011). Bæredygtighed i organisationer – samspillet mellem strukturer og social praksis (Sustainability in Organizations – interaction of structures and social practices*). PhD thesis, Aalborg University.*

UNEP-SETAC (2013). http://www.lifecycleinitiative.org/

Wenger E (1998). Communities of Practice: Learning, Meaning, Identity. *Cambridge University Press.*

THE BUSINESS MODEL, THE SILENT RULER OF DESIGN LOGIC

Thomas Nyström Chalmers University of Technology, Mats Williander Viktoria Swedish ICT*

**Chalmers University of Technology Design & Human Factors SE-41296 Göteborg, Sweden +46 730795821 thomas.nystrom@chalmers.se*

Keywords: Circular business models; Planned obsolescence; Product recovery; Product Service Systems; Remanufacturing.

ABSTRACT

In a traditional linear business model (LBM), focus is on maximization of a product's value at point of sale (POS) and devaluation to obsolescence, creating a path dependency towards faster replacement cycles to retain sales volumes. Resulting in increasing volumes of waste and pollution from products being disposed of, with low incentives or possibilities for recovery by e.g. reuse and remanufacturing. Based on a case study of a bicycle manufacturing SME, using an interventionist research setting, we have found that a business model change affects the existing design logic quite effectively. It seems that the business model is conditioning the decision logic of senior management and has to be addressed first in firms that want to make significant eco-sustainability improvements.

INTRODUCTION

More and more firms consider it crucial to become eco-sustainable for their business (Kiron, 2012). This is highly challenging as most companies strive to maximize profits that for manufacturing firms running linear business models (LBM) arises from margins between price and cost, times volume sold. This encourages cost minimization and volume maximization and to willingly making own products obsolete to maintain sales on saturated markets. However, Product-Service Systems (PSS) combined with closed material loops through e.g. reuse, and remanufacturing is considered to profitably reduce resource consumption up to 80% (Pearce, 2009; Nasr, 2011; Nasr & Thurston, 2006), but requires a business and design logic with focus on product's lifecycle profit maximizing instead of POS. Given the daily efforts in industry to reduce cost and improve competitiveness and profits, why is not these profitable sustainability improvements rapidly introduced? We set out to test the idea that a firm's business model "rules" its management's decision logic. A more eco-sustainable business model must then precede more sustainable design logic to obviate any conflict between sustainability and profit. When it does, the business model will support the more sustainable design logic regardless of senior management's sustainability engagement.

MATERIALS

Already in1932 Bernard London argued for the importance to plan for short product lives to get the industry back on feet from the recession (London, 1932). This was successfully implemented in industry by yearly facelifts and with a design logic "instilling in the buyer the desire to own something a little newer, a little better, a little sooner than is necessary" (Adamson, 2005:129). And since then well implemented in today's product-design; often pristine, fragile and inviolable (Cooper, 2010), resulting in functional and aesthetical obsolescence or breakdowns with few possibilities for profitable product recovery, sometimes even prevented by the OEM (Pearce, 2009). LBMs together with planned obsolescence have created a path dependency towards faster replacement cycles, once in harmony between industry and society but now leading towards unsustainability with eco efficiency efforts being more than offset by increased product volumes and faster product life- cycles (Stahel, 2007).

A business model (BM) describe how a firm create, deliver and capture value (Osterwalder, 2004). All firms have a BM but the vast majority does not articulate it and lack a process for rejuvenating it (Chesbrough, 2007). Over time, as the BM shows it´s strengths, it also becomes an inhibitor for new BM´s (Johnson, 2010). The most common BM among manufacturing firms is the linear BM were the legal right over a product is transferred at POS to the buyer, who also will inherit all future risks; esthetical, functional, operational, and financial with low economical incentive's and several barriers for product recovery (King and Burgess, 2005). Guiltinan, (2009) notes that, design and engineering has made progress in building a sustainable culture. But at the executive management level however, eco sustainability initiatives purposely does not include extending product durability for profitability and employment reasons (Sonntag, 2000 in Guiltinan, 2009).

We draw from Guiltinan's (2009) model of decisions and influences in our assumption of a master and servant role between a firm's business model and the design and engineering practices.

METHOD

A research project was set up with an Original Equipment Manufacturer (OEM) who was open to introduce a PSS for a new product segment and who didn't have any articulated eco-sustainability vision, strategy or ambition. The study was designed as a longitudinal single case intervention research study (Lukka, 2006), with an insider/outsider approach (Bartunek and Louis, 1996). The authors helped the OEM implementing a CBM during a twelve months period, working closely with the owners along the principles of customer development (Blank and Dorf, 2012), and with a user centred approach. Another researcher followed as an observer, collecting data about the developments and perceived challenges. Data was collected with the aim of observing and understanding how the managers of the firm reasoned about bicycle design and why, and how that reasoning changed when the CBM evolved and was implemented. An initial interview was held with the two owners/managers representing their uninfluenced design logic. Then followed the collaborative project phase with concept generation of a CBM, design of the PSS with service-touch points, and design of the service carrier optimized for product recovery over three use cycles, one year each. A final interview was held at the end of the project to collect data on if, how and why the managers design logic had changed. Recordings of all meetings and interviews were used to validate the field notes. For testing our assumption of the master /slave relationship, the main data to analyse was from the initial and last interview in the project.

RESULTS

Unicykel AB (UC), a small Swedish bicycle B2C manufacturer, design and produce bicycles under the brand Nishiki. UCs core values is to provide premium, stylish and sporty bicycles, pricing from € 500 to € 5000. In 2011 the two owners/managers wanted to develop an electric assisted bicycle, a fast growing market in the world that also had started to grow in Sweden. But UC had hesitated due to high cost for a product with their premium requirements (approx. 2500€). The authors of this article approached the two owners of UC and proposed a concept for a CBM with a PSS were UC should keep ownership over the bicycle and provide mobility through a subscription. UC was initially very hesitant to the proposal due to achieved financial risks and possible negative effects in their value chain. But after some considerations they saw a potential that a CBM could be a way for UC to bridge the gap for customers with high up front cost and perceived high risk of buying a technically advanced, relatively unproven technology. Remanufacturing was then used as a key enabler to decrease costs without lowering quality. But this was something completely new for UC and their value chain, and challenging for the owners as well as for their subcontractors.

After the collaboration period were the CBM and PSS was developed in parallel with continuous iterations with potential customers, a complete concept for a CBM with PSS was launched in a first prototype series with a set of six pilot customers volunteered to a full-priced service subscription. The test pilots were carefully chosen from a customer segment of people commuting by car or public transport and for which a manual bicycle was considered undesirable. After some months of testing the owner-designer had now embraced the logic of a CBM and started the design of a production version for the electric bike that would be used for high-volume subscriptions.

DISCUSSION

In the previous business decision logic focus was on achieving premium quality balancing between component price/functionality at a customer target price at POS successfully implemented in a design logic with e.g. own frame design, with much care of colour and surface finish, hand built rims and use of disc brakes on all models. The altered business logic achieved by introducing the CBM resulted in a change of focus from item price towards choices of components, functions with a potential to minimize wear and life cycle cost for the OEM. Examples were to choose drum/roller brakes with minimal service need, a protective textile cover for the frame to prevent scratches and minimized need for repainting in the reuse and remanufacturing stage. The tires were chosen with the best available flat tire protection technology as flat tires dramatically could drive service cost, which is included in the subscription.

There are clear signs that the design logic at UC changed with the introduction of the circular business model towards focus on prolonged product life and maximum lifetime profit. Subsystem costs became of less importance if prolonging the lifetime of the bike and/or could be reused many times e.g. electrical motor, frame etc. Such a view rarely gets support in a linear BM as it contradicts mainstream economic thinking (Stahel, 2007). An enabler for altering the design logic was when the design manager could simulate the product’s lifetime profit in a conceptual phase of the PSS design. But CBM´s with PSS´s doesn’t automatically lead to eco sustainability improvements (Tukker, 2004) and we see a need for further research about methods an practical applicable tools for simulation and optimization of possible eco-sustainability effects in PSS design for circular business models.

CONCLUSIONS

Designers and engineers have the potential to create products with a higher overall eco sustainability performance, but if not aligned with how the firm's senior management think about profit and growth, they will not get through in the decision process. Therefore, we see it necessary to address the business model first in firms that want to make significant eco-sustainability improvements, so that profitability and sustainability can go hand in hand.

REFERENCES

Adamson, G. (2005). Industrial Strength Design: How Brooks Stevens Shaped Your World. *Cambridge, MA: The MIT Press*

Bartunek, J. M., & Louis, M. R. (1996). Insider/outsider team research. *CA: Sage Publications Thousand Oaks.*

Blank, S., & Dorf, B. (2012). The startup owner's manual - the step-by-step guide for building a great company. *Pescadero, California: K&S Ranch Incorporated.*

Chesbrough, H. (2007). Business model innovation: it's not just about technology anymore. *Strategy & Leadership, Vol. 35 Issue 6, pp.12 - 17*

Cooper, R. (2010). Ethics and Altruism: What Constitutes Socially Responsible Design?, *Design Management ReviewVolume 16, Issue 3*

Guiltinan, J. (2008). Creative Destruction and Destructive Creations: Environmental Ethics and Planned Obsolescense. *Journal of Business Ethics 89:19–28*

Johnson, M.W. (2010). Seizing the White Space: Business Model Innovation for Growth and Renewal. *Boston: Harvard Business School Publishing.*

King, A. M., Burgess, S. C. (2005). The development of a remanufacturing platform design- a strategic response to the Directive on Waste Electrical and Electronic Equipment. *Proceedings of the Institution of Mechanical Engineers; ; Vol 219 Issue 8, pp. 623-631*

Kiron, D., Kruschwitz, N., Haanaes, K., & Von, S. V. (2012). Sustainability nears a tipping point. *MIT Sloan Management Review,Vol 53 Issue* 2, *pp. 69-74.*

London, B. (1932). Ending the Depression Through Planned Obsolescence. *University of Wisconsin.* Retrieved from http://babel.hathitrust.org/cgi/pt?id=wu.89097035273;view=1up;seq=5

Lukka, K. (2006). Interventionist research. *Financial management pp. 36-36.*

Nasr, N., & Thurston, M. (2006). Remanufacturing: A key enabler to sustainable product systems. *Rochester Institute of Technology*

Nasr, N. (2011). Real-world remanufacturing. *Industrial Engineer, Vol. 43 Issue* 6, *pp. 24-24*

Osterwalder, A. (2004). The business model ontology: A proposition in a design science approach. *Lausanne: Université de Lausanne*

Pearce, J. A. (2009). The profit-making allure of product reconstruction. *MIT Sloan Management Review, Vol 50 Issue 3, pp. 59-65.*

Stahel, W.R. (2007) Resource-miser business models, *International Journal of Environmental Technology and Management, Vol. 7, Nos. 5/6, pp.483–495.*

Tukker , A 2004 Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet *Business Strategy and the Environment. Vol. 13 Issue 4, pp. 246–260*

TOWARDS A FRAMEWORK OF LIFE CYCLE MANAGEMENT

Ioannis Mastoris (im359@cam.ac.uk), Dai Morgan, Steve Evans*

The ESPRC Centre for Industrial Sustainability, Institute for Manufacturing, Department of Engineering, University of Cambridge, 17 Charles Babbage Road, Cambridge, CB3 0FS

Keywords: LCM; information diversity; information flows; information cycle

ABSTRACT

This research builds on the technical competence of lifecycle tools and focuses on how the obtained lifecycle knowledge is used by industry corporations to support sustainability informed decision making. A review of the literature and preliminary practice review on lifecycle tools' effectiveness in supporting decision making capability as well as working with industrial partners on product lifecycle sustainability has produced the knowledge that has generated three frameworks, info-diversity, info-complexity and info-cycle frameworks. These frameworks are currently developing further as additional information will be obtained from future work with industrial partners. This paper highlights the progress so far and outlines future goals that could lead to the development of a lifecycle management (LCM) framework.

INTRODUCTION

Companies make decisions that affect people and the environment, directly through their own operations or indirectly through their value chain. These impacts challenge the business sector to address the issue of sustainability. This challenge requires firms with well-planned strategies at the organization (i.e. business units) level that are aligned with the performance at the operational (i.e. value chain) level. Although more and more companies claim activity towards sustainability at the strategic and operational levels, it appears that the frameworks used to support these activities do not adequately account for environmental and social issues. There is a need for sustainability evaluation to be included as a part of everyday business processes (Labuschagne & Brent, 2005); this evaluation process should map the value chain and address problems that relate to the three pillars of sustainability.

Life Cycle Thinking (LCT) is a way to consider the upstream and downstream issues and ensure that solutions are applied at the actual part of the value chain leading to implementable sustainable solutions (Thabrew & Ries, 2009). Lifecycle tools (i.e. ELCA, LCC, and SLCA) individually accomplish the criterion of mapping the value chain according to their focus, but there is need to combine the three lifecycle perspectives to help understand the problems that are related to the three dimensions. This analysis will be very useful for sustainability-informed decision making.

Life Cycle Management (LCM) is a system that manages sustainability related information to support decision making towards more sustainable products from a lifecycle perspective. At the moment, the technical competency of individual lifecycle tools is high and these tools provide valuable information. Based on observation and discussion within companies, it would be very useful to identify how the obtained information is going to be used to support decision making towards more sustainable products. Using the three lifecycle tools will yield disconnected stories of the lifecycle of the same object. This information will then have to be managed from the business unit that is related to support sustainability in the organization who then distributes this information to the units responsible for decision making. The information is divided and distributed according to the role of the recipient and the lifecycle stage that they represent. This results in multiple sustainability related information flows within an organization.

This research aims to help the coordinator of sustainability within an organization by developing a strategic LCM framework that assists in reaching more sustainable products from a lifecycle perspective. A set of exploratory frameworks have been developed through an extensive review of the literature and exploratory studies. These frameworks are going to be tested in different organizations. The aim is to: a) map sustainability related information flows in different companies, b) identify if the current information flows help towards more sustainable decision making and c) find ways to improve information flows by developing a LCM framework.

METHOD

Conducting LCT studies on products and explore the applicability of the frameworks through action research is the chosen method. The studies focus on involvement with real company projects that seek solving problems related to lifecycle sustainability. Action research is used because there is the intention to solve a complex problem by obtaining a holistic view (Waterman et al., 2001). Furthermore, the research is conducted in real social contexts where participants are actively involved and help to refine the frameworks through their feedback (Kemmis & McTaggart, 2000).

RESULTS

So far, the results have yielded three frameworks; these frameworks are under development and change form as more experience from the ongoing studies is gained. The first is the info-diversity framework which is described in Figure 1. Info-diversity attempts to map the sustainability related information through the lifecycle of a product and describe the diversity of information that can be obtained. The second, the info-complexity framework, maps the sustainability related information flows in an organization, as seen in Figure 2. Finally, the info-cycle framework, also described in Figure 2, attempts to map the sustainability related information cycle from lifecycle tools raw information to the actions it may affect in an organization.

DISCUSSION

The info-diversity framework was inspired by Rebitzer & Hunkeler's (2003) framework on LCC and Jensen & Remmen's (2004) framework on product chain collaboration. By focusing on how the obtained information can support decision making, the product-process-location approach is proposed. Product and process approach is inspired by Labuschagne & Brent

(2005) who pointed out the difference between product and asset lifecycles. The product's life cycle starts at resource extraction (or when the material renews its life through end-of-life management) and includes the resource or resources' transition to useful raw material, product, waste and end-of-life option. The process lifecycle contains the processes that transform the materials to products, the use phase processes and end-of-life processes. In addition, it includes the processes' inputs and outputs. The location approach was derived from Potting & Hauschild (1997) who mentioned that the unique situation at each location leads to different impacts for the same exposure. Each location's environmental, economic and social situation have different reactions to each activity.

Thus far, the study that used the product-process-location approach has proved helpful in decision making. However, working on the location aspect proved problematic as the access to location data was extremely difficult to obtain and the methodology as to how this data was acquired raised issues of uncertainty on the information's validity.

The case company as described in Figure 2, is the value chain actor that is responsible for the design and marketing of the product under study. The case company is comprised of the executive board that makes strategic decisions and the business units that implement them through their own processes and interactions with the value chain actors. The case company has a business unit responsible for promoting sustainability within the organization. This unit is accountable for the flow of sustainability related information directly within the organization and indirectly with the value chain actors. Additionally, they inform the other units of issues relating to sustainability and offer advice on how the units can make more sustainability-informed decisions affecting the lifecycle performance of the product.

The flow of sustainability information in the organization triggered the framework of info-cycle. The results of the lifecycle tools analysis generate information that gives knowledge to the sustainability related unit about the product's lifecycle issues. The sustainability unit informs the executive board about the hotspots and possible solutions. The board authorizes the direction and criteria towards sustainability inspired mainly by stakeholders' theory and CSR. The sustainability unit then interacts with the other units informing them about changes that may be implemented; these changes will assist in creating greater sustainability informed decisions yielding actions that will improve the overall performance of the product.

CONCLUSIONS

The current frameworks are based on a literature review, a study using location approach and a study focusing on the lifecycle of a product. This research will be expanded with the addition of further projects offering more insight and refinements to these framework as to create a LCM framework. The preliminary discussions with individuals from the industry regarding the abovementioned frameworks has been met with positive interaction and comments. We are looking forward to discussing and using our frameworks on future projects with more industrial partners.

REFERENCES

Jensen, A.A., Remmen, A. (Eds.) 2004. A Background Report for a UNEP Guide to Life Cycle Management– a bridge to sustainable products. Final draft, 30 December 2004.

Kemmis, S., & McTaggart, R. (2000). Participatory action research. In Denzin N. & Lincoln Y. (Eds.),Handbook of qualitative research (2nd ed., pp. 567–605).Thousand Oaks, CA: Sage.

Labuschagne C. and Brent A., 2005. Sustainable project life cycle management: the need to integrate life cycles in the manufacturing sector. International Journal of Project Management, 23, 159-168.

Potting J., Hauschild M., 1997. Spatial Differentiation in Life-Cycle Assessment via the Site-Dependent Characterisation of Environmental Impact from Emissions. Int.J.LCA (4).

Rebitzer G. and Hunkeler D., 2003. Life Cycle Costing in LCM: Ambitions, Opportunities, and Limitations. Discussing a Framework. Int J LCA 8 (5) 253 – 256.

Thabrew Lanka and Ries Robert, 2009. Application of Life Cycle Thinking in Multidisciplinary Multistakeholder Contexts for Cross-Sectoral Planning and Implementation of Sustainable Development Projects. Integrated Environmental Assessment and Management, Volume 5, Number 3—pp. 445–460.

Waterman H., Tillen D., Dickson R. and de Koning K., 2001. Action research: a systematic review and guidance for assessment. Health technology assessment, 5 (23).

FIGURES

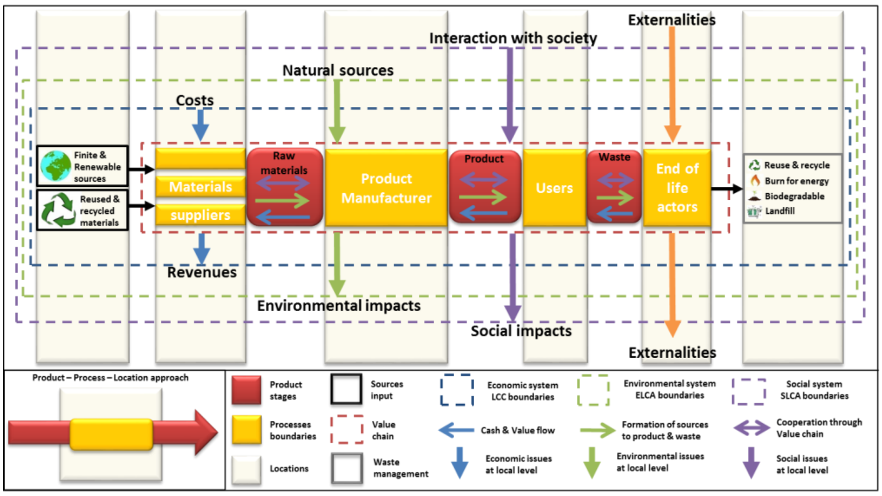


Figure 1.Info-diversity framework.

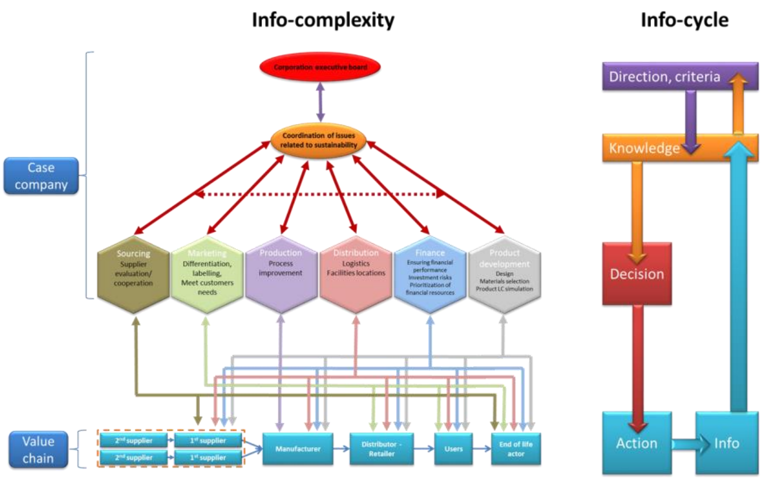


Figure 2. Info-complexity and Info-cycle.

USE OF THE LIFE CYCLE APPROACH ON COMPANY, CATEGORY AND PRODUCT LEVEL TO SUPPORT THE GREENHOUSE GAS STRATEGY IN A MULTINATIONAL COMPANY

Nicole Unger, Henry King. *Unilever SEAC – Safety and environmental assurance centre, Colworth Park, Sharnbrook, MK44 1QL UK, Nicole.unger@unilever.*

Keywords: Carbon footprint; GHG management; company footprint.

ABSTRACT

Unilever routinely uses life cycle assessment to understand the environmental impacts of its products and to support decision making.

Five years ago Unilever started an initiative to assess its global environmental footprint including GHG emissions as well as water use, consumer waste and sustainable sourcing. The results of this global footprinting exercise helped inform the Unilever Sustainable Living Plan launched in 2010. Focussing on GHG, this paper describes how the information has been used internally and externally at various levels of aggregation.

INTRODUCTION

Product life cycle assessments (detailed and streamlined) have been performed in Unilever for over 20 year. Such assessments were generally performed on a case by case basis and often on a specific product in a market. As such these studies provided an incomplete picture of the global business and were of limited value in understanding strategic decision-making at the various organisational levels (e.g. company or category).

In 2008 Unilever started an ambitious initiative to assess its global footprint including GHG (greenhouse gas) emissions, water use, consumer waste and sustainable sourcing. The results of these global footprints were communicated at the launch of the Unilever Sustainable Living Plan in 2010. This was the first time, the full life cycle GHG impact of the company's portfolio was assessed consistently across all product categories and it formed the basis for Unilever's ambitious target to double the size of the business by 2020 whilst reducing its environmental footprint and increasing its positive social impact. The GHG footprint approach has been described previously (Unger et al., 2011) and this paper focuses on:

- How the footprint information can be aggregated and expressed at different levels to inform decision making across the company
- Improvements in the footprint approach and on-going challenges

METHOD

The footprinting methodology was designed specifically for the external reporting of Unilever's footprint and for internal management needs. It was not designed for the measurement and external communication of product level data to current reporting standards/requirements but it does not preclude such use of the data with the appropriate caveats.

The Unilever footprint is measured at an individual representative product or stock keeping unit (sku) level across the life cycle and it is aggregated at a sku, product cluster (e.g. format, pack size and type), category, country and company level. It is expressed in two formats namely: per consumer use and as absolute totals.

The Unilever footprinting methodology comprises three main phases namely:

- a business data extraction phase covering sales, product specifications and consumer habits information,
- a footprint measurement phase that combines the business data with environmental information and
- an interpretation/reporting phase.

There are on-going to systematise and improve the quality and efficiency of the annual measurement. Delivering the corporate footprint does not only provide the footprint data for reporting but crucially also supports innovation tools, provides guidance for the innovation process and allows to systematically predict future product impacts (Franceschini et al., 2011).

RESULTS

The Unilever Footprint has now been performed three times and it is planned to repeat it annually. This has only been made possible by significant improvement in the footprinting processes and the development of bespoke data validation and reporting tools that hold and manage data from the different business IT systems. The first footprint took approximately 18 months to complete and this has now been reduced to 8 months (see Table 1). In addition there have been significant improvements in data quality, increased granularity and number of representative skus enabling greater specificity and brand level assessments and reporting. Moreover, the footprinting activity initiated a number of research projects to address science gaps, such as approaches to filling data gaps (Roches et al. 2010), degradation of chemicals in the environment (Muñoz, Rigarlsford, Milà i Canals & King, 2013) and land use change (Flynn et al. 2012).

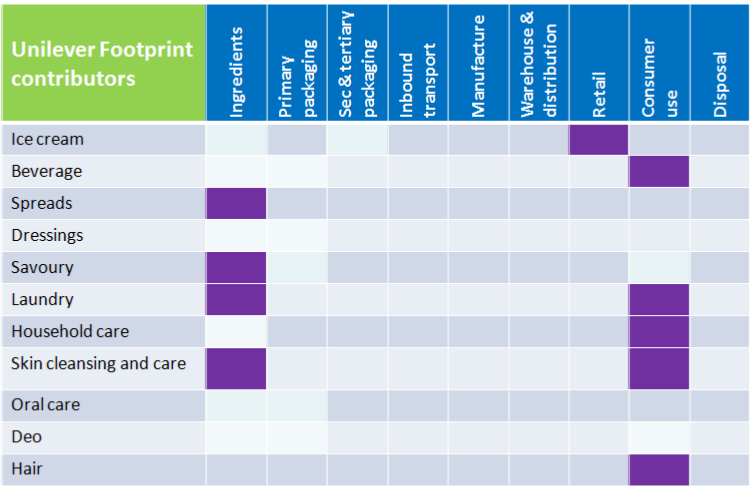
Table 1. Progress in footprinting efficiencies

The footprint in numbers	2008	2010	2011/12
% clustered sales in 14 countries	84 %	93 %	96 %
Number of clustered SKUs	20,300	25,600	41,800
Number of representative SKUs per cluster	1,638	1,860	2,507
Duration (months)	18	12	8

Internal uses of the information:

Product, category and company footprint details provide valuable insights. For example each category can be analysed in detail to understand how much each product format contributes to the category footprint, understand the countries with the most consumer uses and the drivers for the impact. In addition, looking across the results of all categories and contributing life cycle aspects helps identifying the key contributors. The top ten contributors (Table 2) cover about 80 % of the total footprint with the 'Skin cleansing and care' category use phase being by far the highest contributor of just under 50 %. The second highest contributor is about 8 %, the lowest of the top ten contributors is about 2 %.

Table 2. Top ten contributors to Unilever's GHG footprint



External uses of the information

The footprint is essential part Unilever's external target of halving the average per consumer use impact. Between 2010 and 2013 the GHG footprint per consumer use could be reduced by about 6 %, however hot waste use associated with soap, shower gels and shampoos remains a key challenge. In addition the behaviour of individual consumers need to be changed. Unilever published the behaviour change model 'Five levers for change' (Unilever website) which comprises a set of key principles, which, if applied consistently to behaviour change interventions, increases the likelihood of having an effective and lasting impact.

A summary of the applicability of Unilever footprint method and data for various levels of public disclosure is shown in Table 3.

Table 3. Assessment of public disclosure of data versus Unilever methodology and data

Level of data aggregation	Comments	Suitability of Unilever methodology and data for disclosure
Unilever	• Basis of USLP target • Highest level of aggregation • Minimises inaccurancies related to measurement assumptions and approaches • Required to support company reporting and commentary	Yes
Category	• Highlights potential differences between formats • Supporting strategies	Yes
Product	• Low data specificity (e.g. not supplier, geography specific) • Not suitable for on-pack labelling	No

DISCUSSION AND CONCLUSION

The contribution analysis (Table 2) highlights that it is not (only) the inherent design of the product, e.g. a soap that drives the impact but also the number of sold consumer uses, local infrastructure (e.g. grid electricity) and the typical consumer behaviour. Therefore, mitigation measures cannot be limited to innovation alone but also needs to include communication, behaviour change and advocacy. It also aides thinking about new business models and enables ways of delivering a service which might be outside the current business practice. Data and the underpinning life cycle models enable future scenarios to be conducted on aspects that can be influenced/driven by the company. Based in the footprinting data it is possible to estimate how a new product launch or change to an existing product might affect the footprint.

Conducting such footprints also brings challenges, in particular improving data quality and representativeness as well as incorporating new methodological developments in a efficient manner. Although resource intensive, a company footprint as subsequently updates to the footprint are an essential tool in corporate GHG management. It is going beyond the traditional life cycle approach in the sense that it includes sales information. However, such a company footprints does not address all questions and detailed life cycle assessments are still essential for further developing the LCA capability and answering specific questions.

REFERENCES

Franceschini, H., Calvert, S., & King, H. (2011). Integrating environmental decision making into the product innovation process. *Proceedings of LCM 2011Berlin*. http://www.lcm2011.org/papers.html.

Flynn, H. C., Milà i Canals, L., Keller, E., King, H., Sim, S., Hastings, A., Wang, S., & Smith, P. (2012). Quantifying global greenhouse gas emissions from land-use change for crop production. *Global Change Biology*, *18*, 1622-1635. doi: 10.1111/j.1365-2486.2011.02618.x

Muñoz, I., Rigarlsford, G., Milà i Canals, L., & King, H. (2013). Accounting for greenhouse gas emissions from the degradation of chemicals in the environment. *International Journal of Life Cycle Assessment*, 18, 252-262. doi 10.1007/s11367-012-0453-4

Roches, A., Nemecek, T., Gaillard, G., Plassmann, K., Sim, S., King, H., & Milà i Canals, L. (2010). MEXALCA: a modular method for the extrapolation of crop LCA. *International Journal of Life Cycle Assessment, 15*, 842-854. doi 10.1007/s11367-010-0209-y

Unger, N., King, H., & Calvert, S. (2011). How to Measure and Manage the Life Cycle Greenhouse Gas Impact of a Global Multinational Company. In: Finkbeiner M. (Ed.). *Towards Life Cycle Sustainability Management* (207-215). Dordrecht, Heidelberg, London, New York: Springer Science and Media B.V.

Unilever website: http://www.unilever.com/ (accessed April 2013)

DOES RESEARCH MATTER? - THE ROLE OF LCA AND LCM TOOLS IN PUBLIC POLICY-MAKING

Monday, Aug 26:	1:30 pm - 3:00 pm
Session chairs:	Björn A. Sandén, Chalmers University of Technology, Sweden Pavel Misiga, European Commission, Belgium

HOW AND WHY ACTORS USE LCA IN THE CONTEXT OF WASTE POLICY? JUSTIFYING THE USE OF LCA THROUGH PLURAL SYSTEMS OF LEGITIMACY

David Lazarevic. Division of Industrial Ecology, KTH – Royal Institute of Technology Teknikringen 34, 100 44 Stockholm, Sweden. dalaz@kth.se. *Keywords:*

life cycle assessment; waste policy; legitimacy; justification.

ABSTRACT

For several decades, LCA has been used to support decision-making. However, little effort has been placed on understanding how actors apply LCA, the arguments mobilised when justifying its application and the controversies surrounding its application. The aim of this work is to understand the legitimacy of LCA in the context of European waste management regimes. LCA is used as a test of the environmental efficiency of waste treatment options, and as a tool for private sector actors to gain a greater market share. Criticisms of the use of LCA highlight the limitations of LCA to act as a test of environmental efficiency and the friction which arises when LCA is used to subjugate the civic nature of waste management decisions.

INTRODUCTION

Life cycle assessment (LCA) is used as a tool used support waste management decision-making in a "scientifically robust manner" (European Commission, 2011:1). Boons and Howard-Grenville (2009) suggests most scientists involved in industrial ecology, of which LCA is a tool, hold the view point that acquiring information will lead to its application. However, the authors remark that, in the face of social science based research, this is an untenable position as actions taken by individuals and organisations can only be understood by taking the social context in which they transpire into account.

In waste management, the decision to recycle, incinerate or landfill a waste stream is often studied by LCA. Such a decision is often accompanied by controversy and dispute among the industrial sector, residents and governmental authorities. Hence, in terms of understanding the role of LCA in waste management decisions, we should look at the use of such a concept in the context of a social framework of action. Taking this as a point of departure, this paper suggests that LCA should be seen in the context of the *complex society* in which we find waste management decision situations transpiring. A society is complex when its actors possess the competencies to identify the nature of a situation and navigate situations which arise from different systems of legitimacy (Boltanski & Thévenot, 2006).

This paper aims to understand the justifications actors give in the defence of their use of LCA, and the legitimacy of LCA in the context of European waste management regimes. More specifically, the objectives of this paper are to: a) identify the chain argumentation actors utilise in the justification of their use of LCA; and b) discuss the possible limitations of LCA in the context of coordination in waste management regimes.

APPROACH AND METHODS

The economics of conventions

This paper utilises the economics of conventions, and the model of the economies of worth focuses on the construction of agreement in situations of public dispute. This model shows that to avoid perpetual disagreement "persons can appeal to a principle of coherence, in their behaviour and in the arguments they use to justify that behaviour" (Boltanski & Thévenot, 2006:79). Boltanski and Thévenot (2006), identify six systems of legitimacy allowing an ordinary sense of what is just within the construction of a political philosophy: the *inspired*, the *domestic*, the *fame*, the *civic*, the *market* and the *industrial*.

Godard and Laurans (2004:9) suggest that "the usual way to arbitrate disagreements is to make use of such agreed tests which, in following conventional but precise rules distinctive to each justification order, imply observable results that 'anyone accepts', at least temporarily, as incontestable facts." The authors characterise the requirements of 'pure tests' corresponding to each systems of legitimacy. For instance, in the industrial, agreed tests include "sophisticated scientific and objective methodologies and measures of phenomena", which use indicators such as the rate of the use of natural resources and technical rates of efficiency (Godard & Laurans, 2004:28). For the civic, tests relate to the democratic quality of institutional bodies and the degree to which stakeholders are represented.

It is important to assess the legitimacy of LCA on two fronts. Firstly, whether LCA is an effective and 'pure' test to measure and compare the environmental efficiency of waste treatment options. Secondly, if actors bring in any other systems of legitimacy into their criticisms of the application of LCA to waste management decision situations.

Methods

Semi-structured interviews were undertaken with national level actors (major governmental institutions [ministries and agencies], industry associations and private sector actors) and local level waste management actors (waste management authorities) in England (seven national and six local) and France (nine national and nine local). Semi-structured interviews allow for a dialogue with actors, required to understand the justifications they give for their support of, or against, the use of LCA.

JUSTIFYING THE USE OF LCA

In England and France, it was not surprising to find justifications embedded in the *industrial* system of legitimacy. The justification of actions resulting from LCA studies highlights the role of LCA as a *test* used to measure the worth of arguments in relation to the higher common principle of *efficiency*. Additionally, aspects such as a *standardised methodology* that facilitates *transparency* in the *measurement* of environmental efficiency highlights actors' aspirations to replicate the scientific method in the name of producing robust evidence for decision support. Furthermore, LCA was justified as a tool that can provide evidence that projects the possibility of future interactions among waste management processes.

In England and France, justifications for the use of LCA based in the *market* system of legitimacy were also evident. Industrial actors aspired to achieve a higher state of financial worth, by using LCA to differentiate the environmental credentials for their bids in order to achieve a greater market share.

CRITICISM: CHALLENGING THE LEGITIMACY OF LCA

Boltanski and Thévenot (1999) highlight two forms of criticisms in disputes. Actors' criticisms and arguments can be related to the same system of legitimacy (internal) or can be based in two or more systems of legitimacy (external).

Internal Criticism

The internal critiques of the LCA were identified as limitations in the application of LCA to waste management and the subjectivity of LCA.

In England, previous criticisms on the application of LCA to waste management can be found (see Eunomia Research (2004)). However, neither national nor local level actors questioned the application of LCA to waste management. Indeed, actors acknowledged that completing an LCA was part of the 'natural' process that should be carried out. However, in France, actors suggested that it was the role of the producers to undertake LCA (in the context of eco-design), waste management decision had already been made, recycling was being implemented and there was no need for LCA in waste management decisions. In England, whilst the majority of actors recognized the subjectivity of LCA, all actors noted their experience showed the benefits of conducting an LCA outweigh its limitations.

In France, some actors at the national and local level expressed a degree of distrust of LCA as a test of environmental efficiency. Actors' previous experience with LCA had led them to be weary of LCA results. LCA was perceived as subjective and more of a communication tool to forward actors' vested interests.

External Criticism

External criticism of LCA was evoked through the introduction of principles and objects relevant in the civic system of legitimacy. In England when the use of LCA to support the Best Practicable Environmental Option (BPEO) became mandatory in waste management decision-making. It was noted that the BPEO was a technocratic process used to steamroller a sceptical public into options which they dislike or distrust (House of Commons, 2001). In this case, the underlying principle of efficiency was not challenged. However aspects such as consultative decision making and the public interest were introduced to criticise the role of LCA in the BPEO and waste management decision-making. The presence of these aspects confront the legitimacy of LCA as a test in waste management decision-making, as LCA was perceived to be a tool that was used to bypass the civic nature and legitimacy of waste management decisions. The BPEO (and LCA) was subsequently removed as a statutory requirement in waste management planning.

In France, external criticism stemmed from the two different states of legitimate political relations within the civic system of legitimacy: the individual and *their own* particular affiliations and interests, and the individual and *the common* interest. The impression that the black box nature of LCA could allow for the manipulation of data led to some actors to stress that LCAs have been used to implement the issuer's aim. Actors' criticism stems from LCA being used to pursue the 'individual will' and not the common interest.

DISCUSSION AND CONCLUSIONS

If LCA is to be a more socially coherent tool, one should recognise that *industrial* reasoning is not the sole legitimation of action. If LCA is envisaged in the context of participative democracy and decision making, actors involved in the LCA process may recognise that the knowledge produced has limitations. Furthermore, such an acceptance may reify the notion that we can act on incomplete knowledge. Such an approach is intended to broaden and deepen debates and thereby strengthening discussions.

Thus, a pertinent question may be; how could LCA be used in order to improve the efficiency of waste management systems, but also influence actors' behaviours in a more equilibrated way? One of the directions LCA could evolve is to take into consideration the complexity of society, one that represents what is possible within society with the aspirations of actors constrained by several tests; to address external criticisms by modifying the test of LCA or to include tests and parameters emanating from the civic system of legitimacy.

LCA is touted by the European Commission as a science based approach to support environmentally sustainable based policy-making in waste management. Whilst this is a legitimate line of argumentation (based in the industrial system of legitimacy) it does not consider the other possible forms of justification upon waste management regimes are based. LCA was criticised when it was used as part of a technocratic process that allowed scientific models to detract from the civic dimension of waste management decisions. Against this backdrop, we should think of new opportunities for LCT to evolve as a more socially coherent concept.

REFERENCES

Boltanski, L., & Thévenot, L. (1999). The sociology of critical capacity. *European Journal of Social Theory* 2(3), 359-377.

Boltanski, L., & Thévenot, L. (2006). *On justification: Economies of Worth*. Princeton: Princeton University Press.

Boons, F and Howard-Grenville, J. (2009). Introducing the social embeddedness of industrial ecology. In: Boons, F and Howard-Grenville, J (Eds) *The Social Embeddedness of Industrial Ecology*. Cheltenham: Edward Elgar.

Eunomia Research. (2004). *Municipal Waste Management Strategies and the Land Use Planning System for Waste in England*. A report to DEFRA and ODPM.

European Commission. (2011). *Supporting Environmentally Sound Decisions for Waste Management - A technical guide to Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA) for waste experts and LCA practitioners*. Luxembourg: Joint Research Centre, European Commission.

Godard, O., & Laurans, Y. (2004). *Evaluating environmental issue-Valuation as co-ordination in a pluralistic world*. Paris: Ecole Polytechnique, Centre National de la Recherche Scientifique.

House of Commons. (2001). *Environment, Transport and Regional Affairs - Fifth Report - Delivering Sustainable Waste Management*. London: HMSO.

HOW TO MAKE POLICY-RELEVANT LIFE CYCLE ASSESSMENTS OF FUTURE PRODUCTS?

LESSONS LEARNED FROM NANOMATERIALS

Rickard Arvidsson, Duncan Kushnir, Björn A. Sandén, Sverker Molander*

**Rännvägen 6, 412 61, Gothenburg, Sweden, rickard.arvidsson@chalmers.se*

Keywords: nanoparticles; environmental assessments; immature products; technical change; LCA.

ABSTRACT

There is a demand from policy-makers for knowledge about environmental impacts of nanomaterials, and life cycle assessment (LCA) is one method that can be used to obtain such knowledge. Here, we have reviewed 16 LCA and LCA-like studies of nanomaterials, and investigated how these studies handled the fact that for many nanomaterials, complete life cycles do not yet exist to be assessed. We have discovered five different strategies, denoted *likely scenarios*, *extreme scenarios*, *exclusion*, *established system* and *sensitivity analysis*. Their relevance and areas of application are discussed, and it is among other things concluded that extreme scenarios and analogies to established systems can be relevant strategies to assess the environmental impact of very immature products.

INTRODUCTION

Policy-makers increasingly want to know the environmental impacts of products in a very early stage of development in order to avoid severe future negative impacts from the products. Along this line, a number of authors have highlighted the importance of assessing the environmental impacts of new nanomaterials, preferable along the whole product chains or life cycles. These calls generally reflect the idea that environmental assessments should be used to guide technology-relevant policy-making in an iterative fashion, as shown in Figure 1. This view on environmental assessment guiding technological development has been advocated by a number of authors, see e.g. Fogelberg and Sandén (2008). For this purpose, a number of methods that can be used to assess the environmental impacts of products exist, including life cycle assessment (LCA). However, assessing the life cycle environmental impacts, e.g. in terms of emissions and energy use, related to nanomaterials and products that contain them constitutes a great challenge, which makes it difficult to meet such needs from policy-makers.

The challenge is much due to the many uncertainties that surround new nanomaterials at an early point of technological development, which makes environmental assessment methods such as LCA difficult to apply. These uncertainties arise since parts of the product life cycle are not yet established, i.e. do not exist at all or in a premature state. When that is the case, we refer to the whole life cycle, whole product chain or single life cycle process as being *immature*. This term is inspired by the technical change literature, where technologies are often graded with regards to their maturity (Grübler 1998). This immature nature of many nanomaterial life cycles differentiates them from the life cycles of more mature products (such as cement and cucumbers). Assessing the environmental impacts of immature nanomaterial life cycles requires the assessor to make assumptions about the future, or rather some aspects of a number of possible futures. In this paper, we describe how the immature nature of nanomaterials has been handled so far in the LCA literature and similar environmental assessments. Strategies used to consider the future are outlined and their pros and cons are discussed in relation to policy-making. We also exemplify how environmental assessments such as LCA can be used in questionable ways when applied to immature life cycles with the purpose of obtaining policy-relevant results.

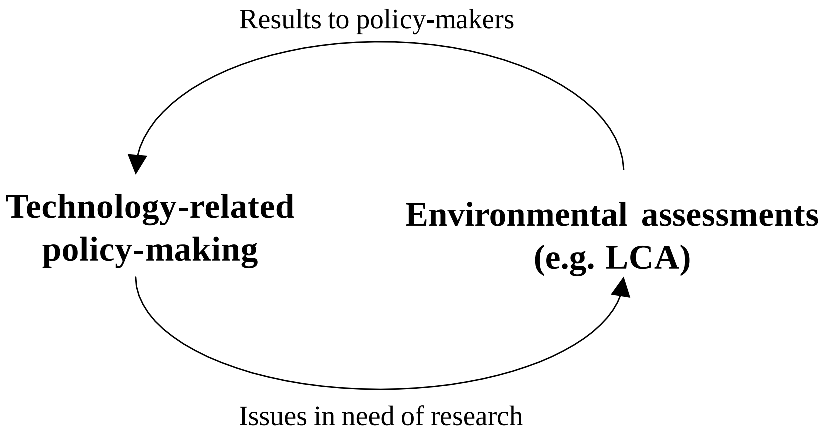


Figure 1. The relationship between technology-related policy-making and environmental assessments such as LCA.

MATERIALS AND METHODS

We have reviewed all existing LCA studies of immature nanomaterial products, which can be found in the reviews by Gavankar et al. (2012) and Hischier and Walser (2012), along with two LCA-like studies where life cycle emissions of immature nanomaterial products where assessed (Arvidsson et al. 2011, 2012). In total, this adds to 16 studies. The texts were coded based on categories representing different strategies used to describe and assess the immature processes in the product chains. The following strategy categories were developed iteratively during the coding:

- **Likely scenarios:** The immature processes are assigned parameter values that are considered likely based on technical arguments. It could be data from pilot projects or trend analysis results.
- **Extreme scenarios:** The immature processes are assigned very high or very low parameter values in order to illustrate extreme aspects or its potential. Worst case scenarios, e.g. assuming very high emissions or only electricity from coal power, belongs to this category.

- **Exclusion:** Immature processes are excluded due to lack of information, which effectively equals an extreme scenario where the environmental impact of the process is set to zero. An example is to exclude the waste handling since no immature product under study has ever been discarded.
- **Mature system:** As a specific variant of the likely scenario strategy, the immature system is here approximated to a mature, believed-to-be similar system. An example is to assume that production of silver nanomaterials will have the same environmental impact as that of ordinary silver.
- **Sensitivity analysis:** Certain parameters of the immature processes are varied within a reasonable range, for example ±X%.

RESULTS

As can be seen from Figure 2, likely scenarios is the most used strategy in the reviewed studies, followed by extreme scenarios, sensitivity analysis, exclusion and mature systems. Often, one study uses several different strategies, with an average of about 2.6 strategies per study. The choice of strategy is sometimes motivated, but most often not.

Another result from our review is that few studies differentiate between foreground and background systems. There are examples where immature nanomaterials are deemed to have high environmental impact, but where this environmental impact did not come from the production of the nanomaterial itself but from emissions from electricity production. Emissions from electricity production may vary considerably over time and says more about the energy system of the region that it does about the immature nanomaterial under study. We therefore consider such assessments to be of questionable use for policy-makers, and underline the importance of differentiating between foreground and background systems when assessing environmental impacts of immature products.

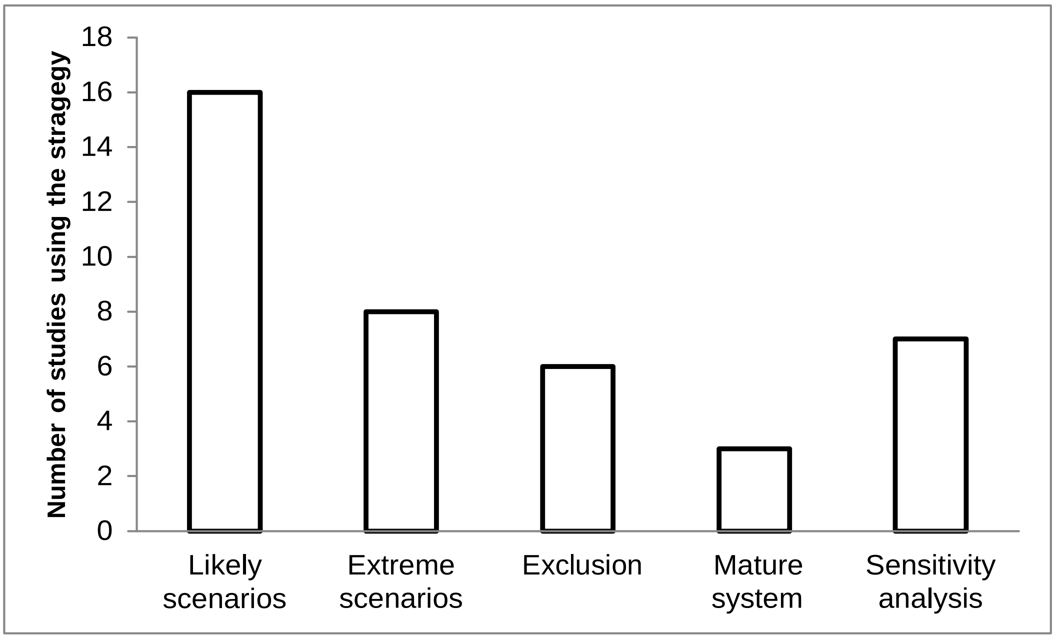


Figure 2. Results from the review of strategies used to consider immature product chains in LCA studies of nanomaterials. See the text for explainations of the strategies.

DISCUSSION

Which of the strategies in Figure 2 is then the most relevant for policy-making? As usual, this depends. Yet probably some strategies are more relevant for almost mature product chains, whereas others are more relevant when considering product chains that are very immature. Likely scenarios and sensitivity analyses are probably more relevant in a shorter time perspective, whereas extreme scenarios are more relevant in a longer time perspective to illustrate the long-term potential impacts of currently very immature products. Using likely scenarios and sensitivity analyses for very immature products, which are almost completely unknown, may create the false impression to policy-makers that the product is well-known. We therefore consider it important to clarify the aim of the study and relate the strategy used to the aim. If the aim is to inform long-term technology-related policy-making, likely scenarios may not be the most relevant strategy.

Although some of us have used the exclusion strategy (Arvidsson et al. 2011, 2012), we consider is unfortunate as it leaves the policy-maker with no information at all. In some cases, extreme scenarios combined with the mature system method may be used instead to provide at least some guidance (e.g. the immature process X is not likely to have a higher environmental impact than the mature process Y). For LCA studies with a very long-term ambition, studying immature product chains or processes, the use and/or combination of extreme scenarios and the mature system method is in general probably the most relevant method with regard to environmental technology-relevant policy-making.

CONCLUSIONS

We have outlined a typology of different strategies for describing and assessing the environmental impact of immature products: *likely scenarios*, *extreme scenarios*, *exclusion*, *established system* and *sensitivity analysis*. We have concluded that some of them are more useful for mature products, and others for very immature products. In particularly extreme scenarios are suggested as relevant for very immature products as it illustrates their potential and avoids assumptions that may appear likely now but may not be so in the future.

REFERENCES

Arvidsson, R., S. Molander and B. A. Sandén (2011). Impacts of a Silver-Coated Future: Particle Flow Analysis of Silver Nanoparticles. *Journal of Industrial Ecology 15(6): 844-854.*

Arvidsson, R., S. Molander and B. A. Sandén (2012). Particle flow analysis - Exploring potential use phase emissions of TiO2 nanoparticles from sunscreen, paint and cement *Journal of Industrial Ecology 16(3): 343-351.*

Fogelberg, H. and B. A. Sandén (2008). Understanding reflexive systems of innovation: An analysis of Swedish nanotechnology discourse and organization. *Technology Analysis & Strategic Management 20(1): 65 - 81.*

Gavankar, S., S. Suh and A. Keller (2012). Life cycle assessment at nanoscale: review and recommendations. *The International Journal of Life Cycle Assessment 17(3): 295-303.*

Grübler, A. (1998). *Technology and Global Change. Cambridge: Cambridge University Press.*

Hischier, R. and T. Walser (2012). Life cycle assessment of engineered nanomaterials: State of the art and strategies to overcome existing gaps. *Science of The Total Environment 425(0): 271-282.*

LCA CRITICAL REVIEW

Monday, Aug 26: 1:30 pm - 3:00 pm

Session chairs: Mary Ann Curran, BAMAC Ltd., United States of America
Steven B Young, University of Waterloo, Canada

CRITICAL REVIEW OF LCA – ESSENTIAL FOR QUALITY AND UNDERSTANDING

Matthias Schulz and Dr Ivo Mersiowsky, DEKRA Consulting GmbH, Handwerkstr. 15, 70565 Stuttgart, Germany*
Email corresponding author: matthias.schulz@dekra.com

Keywords: critical review, life cycle assessment, critical review guideline, peer review process, ISO 14044

ABSTRACT

The critical review provides quality assurance to life cycle assessments (LCAs) by providing an unbiased view on the subject, identifying potentials for improvement and hence contributing towards more scientifically robust and defensible results.

The DEKRA critical review process is designed to achieve these goals by working in close collaboration with LCA practitioners. In accordance with the specific standards used to carry out LCAs, DEKRA developed practical guidelines which provide the respective methodological framework for critical reviews. Experience has shown that this critical review process enhances the quality and credibility of the LCA and additionally contributes towards knowledge building on the side of the LCA practitioner and commissioner of the study while not exceeding target costs.

CRITICAL REVIEWS OF LIFE CYCLE ASSESSMENTS

Ever since the life cycle assessment (LCA) methodology was described in a guiding document, this has been accompanied by a recommendation to undertake a critical review. In 1993 the Society of Environmental Toxicology and Chemistry (SETAC) guidelines proposed a 'peer review' to LCA studies in their "A Code of Practice" (SETAC, 1993). Next, the ISO Standards, which can still be considered the most important guiding document for LCA today, implemented the recommendation to carry out 'critical reviews' and even made it mandatory *"…on LCA studies where the results are intended to be used to support a comparative assertion intended to be disclosed to the public. (ISO 14044, 2006, p.31)"* The growing importance of critical reviews of LCAs is underlined by the fact that the European International Reference Life Cycle Data System (ILCD) describes the requirements and formal procedures of critical reviews as well as reviewer qualifications in detail (EC 2010a, b). Most recently, the Product Environmental Footprint (PEF) methodology made a critical review by *"at least one independent and qualified external reviewer (or review team)"* mandatory if an LCA study is to be called *"in line with the PEF guide (EC 2013, p.69)."* A more detailed overview of the historical development as well as the standard-specific requirements of critical reviews of LCAs can be found elsewhere (e.g. Klöpffer, 2012).

Both the PEF guide (2013) and the ISO Standard 14044 (2006) lay out the following basic requirements as to what the critical review shall ensure (ISO 14044, 2006)[1]:

- The methods used to carry out the LCA are consistent with this International Standard;
- The methods used to carry out the LCA are scientifically and technically valid;
- The data used are appropriate and reasonable in relation to the goal of the study,
- The interpretations reflect the limitations identified and the goal of the study; and
- The study report is transparent and consistent.

In the following, the "DEKRA way" of critical review is described, whereby particular attention is drawn to the preferred review process and the development of a review guideline.

THE "DEKRA WAY" OF CRITICAL REVIEW

In general, the benefits of critical reviews of LCA studies are to enhance the scientific rigour and the technical quality of LCA studies and hence foster the reliability and credibility of LCA results and conclusions. More specifically, critical reviews help detect and avoid errors, provide the opportunity of "a fresh and unbiased pair of expert eyes" offering a different perspective (especially to goal and scope definition) and contribute to an increased comprehensibility and transparency of the LCA study. The authors see another key advantage of the critical review process that goes beyond the before mentioned quality assurance aspects: it contributes to life cycle thinking and knowledge building within organisations. In order to achieve this objective, the critical review process needs to follow a clearly outlined structure and foster interaction among the LCA practitioner, the commissioner of the study and the independent reviewer.

The critical review process can basically be carried out in two ways: 1) The reviewer can provide a critical review after the LCA and the auditable report are completed ("a posteriori"), or 2) the reviewer accompanies the LCA study from the onset of the project ("concurrent review"). The first approach entails the risk that errors or new aspects appear at the very end of the study when most of the work is already done, modelling and reporting are completed and often enough budgets have been exhausted. For these reasons, we favour the concurrent review approach (e.g. Klöpffer, 2012; ILCD, 2010a). Accordingly, the reviewer is typically involved during three phases of an LCA project as illustrated in Figure 1. The review concludes with the compilation of a detailed review report including a verification statement which provides a summary of the subject matter, can be attached to the LCA report and may be used for external communication purposes (e.g. presentations, marketing material, webpage, etc.).

Figure 1. Concurrent review process

[1]Slight differences to the PEF guide include a coherence to specific data quality requirements and the requirement that the study report shall be 'accurate' (EC, 2013).

The main advantage of the concurrent review approach is that potential problems can be identified and corrected at an early stage and before resources are expended on work which later turns out to be inadequate. Furthermore, a concurrent review approach should not be more expensive than an ‘a posteriori’ critical review process. Experience has shown that the increased rates of interaction with the LCA practitioner and/or commissioner are balanced out by the increased complexity to figure out how a complicated result has been influenced by debatable assumptions, or to reconstruct a missing calculation, which is often the situation in ‘a posteriori’ review processes. Finally, the more frequent exchanges provide greater opportunity to discuss, exchange ideas and consequently learn about methodological issues and the subject matter. This in turn fosters a greater understanding of LCA, contributes to knowledge and capacity building within organisations and can lead to knock-on effects of increased quality if, for example, future LCAs are produced.

Besides the basic requirements for critical reviews of LCAs as mentioned above, ISO 14044 (2006) outlines further general requirements that need to be addressed in the LCA report (Chapter 5.1 and 5.2).

Despite the fact that these requirements are listed and hence provide a general idea of which points should be evaluated in a critical review, they need to be interpreted further in order to develop more concrete critical review criteria which can be used to assess LCA studies. A review guideline was developed to provide a practical approach of carrying out critical reviews. It consists of concrete questions or checks, which consider the relevant Standards and ensure that the LCA study is fully compliant. The review guideline structures the review process and has the additional benefit of supporting more inexperienced colleagues in the field, but also LCA practitioners and commissioners of LCA studies in acquiring a better understanding and more detailed insights of the LCA method. In the following, an example is given in which excerpts of the review guideline are presented for a particular methodological LCA issue, i.e. allocation.

The reporting requirements according to ISO 14044 (2006) regarding allocation are that the allocation decision has to be described (Chapter 5.1.2) and that the allocation procedure has to be documented and justified as well as that its uniform application is ensured (Chapter 5.2). The review guideline includes the following checks regarding allocation:

- Have checks been carried out whether allocation could be avoided (e.g. more detailed data collection, system expansion)?
- If allocation is unavoidable, has the allocation principle used been explained and justified and are allocation factors and relevant references given (e.g. references for a similar allocation approach applied for a similar product; prices used in case of economic allocation)?
- Has allocation been carried out correctly: Checking questions include:
    - Do all inputs and outputs of a unit process need to be allocated or can some be attributed to only one product directly?
    - Is the sum of allocated inputs and outputs equal to the sum of unallocated inputs and outputs?
- In cases where several allocation procedures seem applicable, has a sensitivity analysis been conducted?

- Do all co-products actually have a market value or have waste outputs been accounted for as co-products?
- Has the same allocation procedure been applied to similar products leaving and entering the manufacturing site (also check background processes)?
- Were secondary input materials considered correctly (also check background process)?
- Were relevant allocation principles applied to reuse, recovery and recycling processes (e.g. check relevant product category rules; check application of conservative approach; check system boundaries; etc.)?

These checking questions and criteria can either be ticked off, or specific comments or questions can be entered in an MS Excel file. In addition, the particular checks and questions are complemented with illustrative examples of LCA studies drawn from the authors' past LCA experience. Where suitable, these examples can be used in review meeting discussions to illustrate the respective methodological LCA issue. Again, these practical examples are aimed at reinforcing the learning impact among LCA practitioners and commissioners of the study.

CONCLUSIONS

Along with the growing importance of LCA and the stricter requirements to undertake critical reviews, organisations are well-advised to build up internal knowledge in this discipline. Besides the benefits of quality assurance and increased credibility of LCA results delivered by critical reviews, the "DEKRA way" of providing critical reviews offers the additional advantage of contributing towards internal knowledge building. This is achieved by a well-structured review process that includes in-depth interaction with the LCA practitioner and the commissioning organisation and a clear guideline with concrete review criteria, questions and checks enriched with relevant examples that increase learning about the LCA methodology.

REFERENCES

European Commission (EC) (2010a). ILCD Handbook: Review schemes for Life Cycle Assessment (LCA). Joint Research Centre, Institute for Environment and Sustainability. http://www.jrc.europa.eu

European Commission (EC) (2010b). ILCD Handbook: Reviewer qualification for Life Cycle Inventory data sets. Joint Research Centre, Institute for Environment and Sustainability. http://www.jrc.europa.eu

European Commission (EC) (2013). Product Environmental Footprint (PEF) Guide to the Commission Recommendation on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations. Consolidated Version. http://ec.europa.eu/environment/eussd/smgp/product_footprint.htm

International Standard Organisation (ISO) (2006). Environmental management - Life cycle assessment: Requirements and Guidelines. ISO14044, Geneva.

Klöpffer, W. (2012). The critical review of life cycle assessment studies according to ISO 14040 and 14044. International Journal of Life Cycle Assessment, DOI 10.1007/s11367-012-0426-7

Society of Environmental Toxicology and Chemistry (SETAC) (1993). Guidelines for Life-Cycle Assessment: A "Code of Practice". From the SETAC Workshop held at Sesimbra, Portugal, 31 March – 3 April 1993. Edition 1, Brussels and Pensacola, FL.

INTERNATIONAL SURVEY ON CRITICAL REVIEW AND VERIFICATION PRACTICES IN LCA WITH A FOCUS IN THE CONSTRUCTION SECTOR

Sébastien Lasvaux[1], Yann Leroy[2], Capucine Briquet[2], Jacques Chevalier[1]*

[1]*Université Paris-Est, Centre Scientifique et Technique du Bâtiment (CSTB)*

[2]*Ecole Centrale Paris – Laboratoire Genie Industriel – Grande Voie des Vignes, F95295 Châtenay-Malabry Cedex – France – Yann.leroy@ecp.fr*

Keywords: LCA, survey, verification, review practices.

ABSTRACT

Use of consistent and representative data is required to obtain reliable LCA studies. To do so, the LCA review is a key part. Yet, at the international level, few guidelines are provided to conduct a critical review. Only, few aspects are mentioned e.g. in ISO 14040 standard. In this paper, findings from an international survey are presented. The survey's objectives were to get feedbacks from LCA experts on important aspects they checked during their previous reviews with a focus in the European construction sector practices. Results show that most reviewers always check usual aspects of the LCA framework while more specific aspects requiring more background are not. This study can be viewed as a contribution for both general critical review guidelines and improvements of existing review checklist for EPD in the construction sector.

INTRODUCTION

The results of a Life Cycle Assessment (LCA) are highly relying on the quality of both data and the methodology used. To date, different data can be used e.g. for the LCA of building products and building as a whole. These data can come from generic LCA databases or from industry e.g. based on Environmental Product Declaration (EPD) schemes. In order to improve the reliability of LCA studies e.g. applied to the construction sector, users of building LCA tools need to obtain reliable data and results. To do so, data and results have to be clearly documented and consistently reviewed. Yet, at the international level, few guidelines are provided to conduct a critical review. Only, few aspects are mentioned e.g. in ISO 14040 (ISO, 2006; Klöpfer, 2012). This paper presents the findings on an international survey conducted in 2011 and 2012 to get feedbacks from experienced LCA experts and reviewers on the important aspects they checked during their previous reviews.

MATERIALS AND METHODS

An online survey has been established using both the European Commission ILCD review requirements (Chomkhamsri et al, 2011) and a review checklist used when reviewing a French EPD of building products (Chevalier, 2011). The last checklist is used in France by certified verifiers to harmonize the verification of data, calculation rules and results of an EPD. 135 experts from the LCA community were contacted by emails based on author's contacts within the LCA community but also through literature searches (web-based reports, scientific articles published in Int. Journal of LCA / Critical review section), LCA reports and reviews available on the website of the trade unions or companies. In addition, experts involved in EPD applied to the construction sector were contacted as the study has a particular focus in the construction sector. In that way, we gather a broader panel with people conducting reviews and verifications even if these two terms are different (Grahl et al, 2011). The survey is divided into four parts including: general information, critical review and verification expertise, type of criteria assessed during a critical review and the personal opinion of experts regarding the critical review. The use of both ILCD review requirements and the review checklist of French EPD for building products enable to have a broad scope of important aspects concerning the goal and scope definition, the inventory and impact assessment (including LCA methodology, representativeness, plausibility of values and results) and the interpretation stage (e.g. uncertainty analysis). Then, experts were asked to answer whether they always, sometimes or never review some aspects.

RESULTS

Only selective results looking at interesting outcomes are reported below. Out of 135 experts contacted, only 38 answered which means 28%. Even if the feedbacks were not as high as expected, useful results can be obtained as the panel comprises recognized international LCA experts. Generally speaking, for background and experiences, results show that few of LCA experts and reviewers passed an exam to prove their abilities for reviewing a LCA study. Only 5 out of the 38 experts that have replied to the survey actually took an exam (e.g. ACLCA exam, French EPD exam). In addition, most of them (~50%) usually perform full LCA critical review while only 5 experts are involved in the verification of EPDs. Looking at their experience in critical reviews, 42% have more than 10 years, 21% have between 5 and 10 years while 27% have less than 5 years of experience.

Results for LCA methodology, representativeness, plausibility criteria

Results show that a large number of reviewers always check usual aspects of the LCA framework while more specific aspects requiring more advanced knowledge and background are not. Feedbacks from the reviewers showed that they do not share a common view on specific aspects e.g. dealing with the review of an uncertainty assessment. In addition, the feedbacks of the different reviewers reinforce the level of the review depending on the scope of the study e.g. stand-alone LCA, comparative assertions or third party verified EPD. Some requirements from ILCD are not always checked e.g. the resources needed for the study. Looking at plausibility aspects (e.g. is the results of the LCA consistent with previous studies, if deviations can it be explained scientifically?), not all the experts check the general LCA criteria that are proposed based on the EPD checklist.

Results on the personal views on critical reviews and verification procedures

Table 1 presents an overview of experts' feedbacks concerning the aspects usually checked during a critical review. They are not representative of general opinions but much more as empirical knowledge and feedbacks based on their experiences. In addition, table 2 presents other feedbacks and remarks concerning the issues of using LCA for sector-specific applications (limitation in data transparency, availability). The feedback concerned the construction sector where a large number of EPD are available, these EPD being used for building LCA studies. Another general remark is the difficulty to access to the data and software during a critical review either because of time/cost constraints or due to confidentiality of datasets.

Table 1: Overview of expert's feedbacks concerning the representativeness criteria

Criteria	Summary of some expert's personal views taken from the full survey results		
Representativeness aspects	"Intensity of checks should be in relation to the goal and scope. It is impossible to check all data, but only random samples and/or suspicious values..."	"References as well as description of models that are used as data sources should be clearly described and commented. Experience is needed, if three reviewers, different roles are often assigned (e.g. involvement of both LCA data and technology experts."	"Consistency of generic data used in the study e.g. if a data is documented it does not mean that it fits. When generic data are relevant for the result of the study, crosscheck with other sources. It also depends on the source, is it reliable in general?"

Table 2: Additional expert's feedbacks concerning the LCA critical review and verification practices

Issue	Summary of some expert's personal views taken from the full survey results
Conducting a critical review (generally speaking)	"I try to keep the rules given in ISO 14040 7.3.3 and 14044 6.2 as closely as possible. In addition I advise clients to perform the review in an interactive way, as proposed by SETAC A code of practice 1993 (useful booklet). I also propose at one face to face meeting with the full review panel, practitioner and commissioner."
Pre-defined datasets/tools (construction sector)	"In the area of LCA and constructions a lot of LCA's are not done as detailed and transparent as desired. This has often to do with the fact that most studies are not made by LCA experts. Architects using LCA are mainly focusing on the comprehensive list of input materials (e.g. building component or full building) which then are connected to mainly generic LCIA data."

DISCUSSIONS

According to Baitz et al (2013), verification of LCI datasets and the critical review of LCA data in studies are both essential for checking, validating, and reviewing data, results, and conclusions. ISO TC 207 is working on a technical specification to supplement the 'critical review' section of the current ISO standards (ISO, 2013). In the same time, sector-specific actions are in progress to set up verification checklists e.g. the ECO EPD Platform that aims at increasing the mutual recognition of EPD programs of the European construction sector (ECO Platform, 2013). In that platform, works are looking at guidelines for conducting harmonized EPD verifications for consistency purposes across the different national schemes based on the new EN 15804 standard for EPD of construction products (CEN, 2012) and building LCA (EeBGuide, 2013). The results of this survey can thus contribute to set up guidelines and to create a forum of exchange of reviewers at the international level.

CONCLUSIONS

The outcomes of this international survey provide several insights for current and future works e.g. for defining general guidelines for conducting a critical review. It can also support improvement of the verification checklists for EPD that are being developed e.g. in the European construction sector (ECO Platform) linked to the new EN 15804 standard for EPD.

ACKNOWLEDGMENTS

The authors gratefully thank the Chair Bouygues Construction "Sustainable Buildings and Innovation" for the scientific and financial support.

REFERENCES

Baitz, M. et *al* (2013) *LCA's theory and practice: like ebony and ivory living in perfect harmony?* The International Journal of Life Cycle Assessment, January 2013, Vol 18, Issue 1, pp 5-13

CEN (2012) EN 15804 - Sustainability of construction products - Environmental product declarations - Product catagory rules. Mars 2005, 47 p.

Chevalier J. (2011) Checklist for the verification of Environmental Product Declaration of the French EPD program for construction products, CSTB, France.

Chomkhamsri K., Wolf M. A., Pant R. (2011) *International Reference Life Cycle Data System (ILCD) Handbook: Review schemes for Life Cycle Assessment*. Proceedings of the LCM 2011 conference, Berlin, 2011.

EeBGuide (2013) *Operational Guidance for Life Cycle Assessment Studies of the Energy Efficient Buildings Initiative*, Online Info Hub, European Project of the 7th Framework, accessed on 24/05/2013: www.eebguide.eu .

ECO Platform (2013) ECO Guidance Paper Verification, Internal draft document from the WG II of ECO Platform project to initiate the development of a uniform European core EPD for the construction sector.

Grahl B., Schmincke E. (2011) *"Critical review" and "Verification" cannot be used synonymously. A plea for a differentiated and precise use of the terms*. Proceedings of the LCM 2011 conference, Berlin, 2011.

ILCD (2010) European Commission – Joint Research Centre – Institute for Environment and Sustainability (Ed.): *ILCD Handbook. General guide for life cycle assessment: detailed guidance*. First edition. Luxembourg: Publications Office of the European Union 2010. ISBN: 978-92-79-19092-6.

ISO (2006) *Environmental management - Life Cycle Assessment - Requirements and Guidelines - EN ISO 14044*. Genève: International Organization for Standardization (ISO), 2006, 33 p.

ISO (2013) ISO / TC 207 / SC 5 / WG 9 Critical Review, accessed on 24/05/2013: www.iso.org/iso/home /standards_development/list_of_iso_technical_committees/iso_technical_committee.htm?commid=54854

Klöpffer, W. (2012) *The critical review of life cycle assessment studies according to ISO 14040 and 14044*, The International Journal of Life Cycle Assessment, November 2012, Volume 17, Issue 9, pp 1087-1093

RADICALLY REDUCING THE COSTS OF PANEL CRITICAL REVIEWS ACCORDING TO ISO 14040

Bo P. Weidema, Aalborg University & The ecoinvent Centre*
Kim Christiansen, Danish Standards,
Gregor Wernet, The ecoinvent Centre
**Aalborg University, Skibbrogade 5, 1., 9000 Aalborg, Denmark, bo@ilca.es*

Keywords: ISO 14071; quality; panel review; database; software.

ABSTRACT

We suggest a procedure that radically reduces the critical review costs without compromising their thoroughness and overall quality. This procedure has 3 elements: A fixed panel for all reviews, an already critically reviewed background database, and a software-supported review procedure. The presentation discusses these elements in the light of the upcoming ISO 14071 on critical review.

INTRODUCTION TO THE PROBLEM: COSTS AND QUALITY

Critical reviews were adopted as a requirement for LCAs according to ISO 14040 in its first 1996 edition (ISO 1996). The first detailed guideline for critical review of LCA was published by Weidema (1997).

Since then, much experience has been gained with critical reviews in practice, but there is a growing concern about the costs of the reviews. Due to the large variety of data sources and algorithms used by LCA practitioners, a thorough review may sometimes come close to repeating the entire study, and the costs for serious critical reviews are often seen to amount to a substantial part of the overall study budget. This is especially true for panel reviews, which the ISO 14044 standard requires for comparative assertions. This is amplified by the still unfinished debate on whether labelling is to be regarded as a comparative assertion (since it is used to support comparative decisions).

The concern for costs is mirrored by a concern for the quality of the reviews. To keep costs down, it is sometimes practiced to limit the reviews, e.g. to the summary report, thereby by excluding important data sources and algorithms from the review. Such limitations of the reviews are not in the spirit of ISO 14044 and seriously damage the credibility of the review procedure.

SUGGESTION FOR A SOLUTION WITH THREE ELEMENTS

A procedure is required that reduces the costs of critical reviews without compromising their thoroughness and overall quality. This is especially important for organisations that perform a large number of LCAs, such as companies with many products, LCA database developers, and organisations working with environmental labelling or product declarations.

We suggest a procedure with three elements that radically reduces the critical review costs. The three elements of this procedure are the use of:

- a fixed panel for all reviews for the same organisation,
- an already critically reviewed background database, and
- a software-supported review procedure.

THE USE OF A FIXED PANEL

For organisations that perform a large number of LCAs, an important part of the costs of the review procedure is expended for the administrative effort of composing, communicating with, and remunerating the review panels.

One way to reduce this administrative effort, without compromising the quality of the reviews, is to set up a fixed panel with a standardised procedure for the organisation of the review work. By pre-selecting a larger number of independent LCA-experienced domain and topic experts as panel members, and having a fixed procedure for appointing the panel chair, the relevant experts can be involved for each specific review, fulfilling the ISO 14044 requirement of at least 3 panel members in each review, without having to design and implement a specific administrative procedure for each review. It is important that the fixed panel include both LCA expertise and topic expertise for all the technical areas that can become relevant for the LCAs handled by the organisation. A particular concern is the requirement for involvement of "interested parties", since a very inclusive interpretation of this requirement could make the review procedure exceedingly costly. However, the ISO 14040 standard recognizes that budget limitations may determine the size of a panel, and does not require the involvement of specific interested parties. For the credibility of the procedure, the most important issue is the independence and relevant expertise of the reviewers, so that these can take into account the concerns of all relevant interested parties.

THE USE OF AN ALREADY REVIEWED BACKGROUND DATABASE

The second – and most important element – of our procedure is based on the 1:1 relationship between the number of LCAs and the number of unit processes in an LCI database (because the product system for each LCI is composed of the one unit process in which the functional unit is defined and all its upstream and downstream activities). This relationship implies that every time you create a new unit process, you also create a new LCA (for the reference product of that unit process).

The starting point for our procedure is a complete global database where no cut-offs are applied, and where specified algorithms (LCI models) are used for calculating the LCA results. Imagine now that critical reviews have already been performed for each single unit process, essentially ensuring that the unit processes reflect the reality they are intended to reflect. Imagine also that each of the algorithms that the database use for linking the unit processes in to product systems and for calculating the LCA results from the have been critically reviewed, essentially ensuring that the algorithms provide the results they are expected to. This would imply that each single LCA result from this database is already critically reviewed.

When using such a fully critically reviewed database as background database for a new LCA study, it would only be necessary to review the new “foreground” datasets or algorithms that you add for the decision context in which it is used. If this critically reviewed “foreground” dataset is then added to the already existing database of activity datasets, it becomes part of the fully critically reviewed background database and its already existing implicitly critically reviewed LCAs.

By limiting the critical review to the newly added data and algorithms, the costs are obviously radically reduced, without reducing the overall quality of the review. In fact, by ensuring that every single dataset is critically reviewed, the overall quality of the review will be enhanced compared to the present-day situation, where typically only a small sample of the applied data are reviewed – if data are reviewed at all.

THE USE OF A SOFTWARE-SUPPORTED REVIEW PROCEDURE

The third element of our procedure is to perform the reviews purely electronically, as for journal article submission systems. This reduces travel costs, meeting time, and administrative efforts, while ensuring that all comments and communications are documented and stored. Standardised forms may be used to make reviews easier to perform and to make it easier to assemble the documentation into a review report.

IMPLEMENTATION OF THE PROCEDURE

Our proposed procedure can be implemented by large companies with their own background database, and by organisations operating an EPD and other labelling scheme that requires an LCA for each product labelled. It is also being implemented in the ecoinvent database, where a review panel has been established with the database administrator as independent chair, and where all reviews are already performed and documented electronically. The last and most important step of ensuring the completeness of the database and that each and every dataset of the database has been critically reviewed by at least 3 experts is still not finalised and is expected to take some years before it is achieved.

RELATION TO THE UPCOMING ISO 14071

The International Standards Organization is currently developing a technical specification on critical review processes and reviewer competencies to complement the recommendations and requirements of ISO 14044 (ISO 2006). At the time of writing, this technical specification (ISO TS 14071) is still only a working draft, but we may nevertheless consider how our suggested procedure will relate to its expected requirements.

For a standardised review of all the LCAs that are included in a background database of an organisation - be it a company, labelling organisation or dedicated database development organisation like ecoinvent - there will obviously be a lot of documentation which is identical for all the reviews made, such as the statements in the Critical Review statement of the identity of the panel chair and that the review is:

- performed based on paragraph 6.3 of ISO 14044,

- performed at the end of the study,
- based on a previously reviewed database context and LCI model,
- a review of a specified individual dataset or set of algorithms,
- finding the study to be compliant with ISO 14044.

Such documentation, therefore, can be prepared as a general statement and can become part of every review without the need for rewording.

Compared to the current procedure at ecoinvent, the current draft of ISO TS 14071 includes a requirement for an extra round of approval of the Final Critical Review Statement by all reviewers, even when the statement is just a summary of all the comments made earlier. This will unfortunately mean an unnecessary additional delay and cost increase for the review.

REFERENCES

ISO (1996). International Standard ISO 14040. Environmental management - Life cycle assessment - Principles and framework. *First edition. Geneve: International Organization for Standardization*.

ISO (2006). New Proposal ISO TS 14071. Environmental management -- Life cycle assessment -- Critical review processes and reviewer competencies: Additional requirements and guidelines to ISO 14044:2006. *Geneve: International Organization for Standardization*.

Weidema B P. (1997). Guidelines for critical review of life cycle assessments. *Brussels: SPOLD. 15 pages*. http://www.lca-net.com/publications/critical_review/

THE CRITICAL REVIEW ACCORDING TO ISO 14040+44 - HOW AND WHY IT CAME ABOUT

Walter Klöpffer, LCA Consult & Review. Am Dachsberg 56E, D-60435 Frankfurt/M, Germany. Walter.kloepffer@t-online.de

Keywords:Life Cycle Assessment; LCA; critical review; ISO 14040; ISO 14044

ABSTRACT

The revision of the ISO standards in 2006 brought changes to the critical review process of the older series (1997-2000). A peer review for LCA-studies was first proposed in the earlier SETAC document (1993). The ISO 14040 standard (1997) took up this proposition and described three types of "Critical review" which are optional in general, but mandatory "for LCA studies used to make a comparative assertion that is disclosed to the public". This strong prescription was further reinforced in the revised standards and stricter, unambiguous formulations were added. The main reasons for introducing the critical review are the improvement of LCA studies, especially if they contain comparative assertions, and the high potential misuse of LCA studies in marketing.

INTRODUCTION

The pioneering "proto-LCA" work, which started around 1970 in the United States, was soon followed by Europe. There was not much growth in the first 15 years, but by the end of the 1980s an unexpected boom occurred. It soon became clear that the new method had a very high potential of misuse, above all in marketing. SETAC recognized the problem and organized workshops, and published frameworks and guidelines. After a few years, the LCA Code of Practice appeared (SETAC 1993; Klöpffer 2006). A Peer review (the term "Critical review" was introduced later by ISO) was suggested to improve the quality and credibility of LCA studies. Although SETAC had proposed an interactive review process, ISO also allows a critical review at the end of the study ("a posteriori"). The ISO standardization process started immediately after the Code had been published. It served as a kind of blue print, but it took seven years (1997 – 2000) to finish the first series of LCA standards 14040-14043 (Marsmann 1997, 2000). The standards were revised only once, in 2006 (Finkbeiner et al. 2006).The only significant change was a tightening of the critical review process. The critical review has not received much attention in the scientific literature, although it plays an important role in the quality assurance of LCA studies (Klöpffer 1997, 2005, 2012; Fava and Pomper 1997; Koffler 2013).

METHODS

The new ISO framework standard (2006) is again called 14040. It cannot be used alone for a full LCA study, since there is one "shall" requirement saying that ISO 14044 shall be used if an actual LCA is done according to the standards. This excludes the possibility that the relatively open standard 14040 is used to invent a less rigorous LCA method “in the spirit of ISO”, at least not for public use.

The critical review is defined in the international standard as a “process intended to ensure consistency between an LCA and the principles (14040) and requirements (14044) of the International Standards in life cycle assessment”. This reads simply, but is often very difficult to fulfil in practice.

There is a very convenient list of criteria to be used in each critical review. It can serve as a kind of backbone for the review report:

"The critical review process shall ensure that:

- the methods used to carry out the LCA are consistent with this International Standard;
- the methods used to carry out the LCA are scientifically and technically valid;
- the data used are appropriate and reasonable in relation to the goal of the study;
- the interpretations reflect the limitations identified and the goal of the study; and
- the study report is transparent and consistent."

The emphasis is on consistency with the standard. The report should not include unreasonable claims of absolute truth and precision, which can hardly be fulfilled in any study.

The revised definition (2006) for the panel method reads:

“LCA intended to be used for a comparative assertion intended to be disclosed to the public.“

This is a very difficult requirement to meet. Alone the intention to derive comparative assertions and the intention to disclose them to the public is sufficient to require the panel method with at least three reviewers (including the chairperson).

The less demanding version of the critical review can now be done by an independent expert, internal or external, who is familiar with LCA and have scientific and technical expertise. Actually, LCAs reviewed according to this requirement are not necessarily small and there may be more than one expert, frequently two (e.g. an LCA expert and a technology and data expert). This version can be used if there are no comparative assertions “intended”.

There exists an inconsistency between the title “Panel of interested parties” (14040: 2006 7.3.3) and the text:

“An external independent expert is selected by the original study commissioner to act as chairperson of a review panel of at least 3 members. Based on goal, scope and budget available for the review, the chairperson selects other independent qualified reviewers.

This panel may also include other interested parties affected by the conclusions drawn from the LCA such as government agencies, non-governmental groups, competitors and affected industries."

The discrepancy between the title and the content is the same as in the original version of 1997.

RESULTS

The original claim by SETAC – enhance the quality and thus the credibility – can be achieved by a critical review.

A careful critical review always improves the quality of the LCA study report. Since the results of the review are documented in the review report, the arguments can be checked by the readers. If there is dissent between the critical review panel (or independent expert(s)), the practitioner and/or commissioner can write their position(s) which are also included in the study report.

Due to this transparency, it is hardly possible to make wrong claims using LCA studies – or at least it is much more difficult compared to the time before SETAC and ISO harmonisation and standardisation of LCA.

One element not yet mentioned is the interplay between Commissioner, Practitioner and the Critical review panel (or independent expert). There should be good communication between the three actor groups and especially between the chair of the panel, the leader of the LCA team and the project leader of the commissioner. One or two face-to-face meetings help to create a good climate. A data expert in the review panel may directly communicate with the experts of the practitioner and the commissioner, within the "critical review triangle" (Klöpffer 2005, 2012). Clearly, the triangle collapses if the commissioner does not actively cooperate in the review process. In this case, the critical review process is a dialogue between the independent expert or the review panel and the practitioner. This arrangement often works well, but there are instances where problems arise (Klöpffer 2005).

DISCUSSION AND CONCLUSIONS

The description of the critical review process in ISO 14040 and 14044 (2006) is relatively short and partially inconsistent. This should be improved in the next update of the standard. An important step into this direction is the elaboration of a "Technical specification (ISO TS 14071)" on Critical review processes and reviewer competencies - Additional requirements and guidelines to ISO14044:2006 (ISO 2013), presently (May 2013) at the stage of the third working draft (WD3). The proposed TS gives detailed requirements about many aspects of the Critical review process without changing its original aim and goal.

Although primarily designed for ISO 14044, the TS 14071 could become the basis for improving the review process of other life cycle based standards, e.g. ISO 14046, ISO 14067 and ISO 14025, referring to ISO 14040ff as the base standard.

Particularly in the verification process of Environmental Product Declarations (EPD) according to ISO 14025 the role of the Critical Review needs some clarification. Basis of an EPD is, beside other product specific information, an LCA according to ISO 14040/44. ISO 14025 only addresses the verification of the EPD according to the LCA and respective Product Category Rules. The quality assurance of the underlying LCA is not explicitly addressed in ISO 14025 but in the spirit of ISO 14040/44, the reference document in ISO 14025, it should be a Critical Review (Grahl and Schmincke 2011). Because an EPD is a declaration for only one product and thus a comparative assertion of competing products of different producers is not included, in ISO 14025 a panel for EPD verification is not foreseen and it is usually conducted by one expert. Nevertheless comparison of different EPDs is intended. The application of ISO TS 14071 to the procedure included in ISO 14025 could result in some clarification.

REFERENCES

Fava J, Pomper S (1997) Life-cycle critical review! Does it work? Implementing a critical review process as a key element of the aluminium beverage container LCA. Int J LCA 2, 144–153

Finkbeiner M, Inaba A, Tan RBH, Christiansen K, Klüppel H-J (2006): The New International Standards for Life Cycle Assessment: ISO 14040 and ISO 14044. Int J LCA 11, 80-85

Grahl B; Schmincke E (2011): “Critical review” and “Verification” cannot be used synonymously. A plea for a differentiated and precise use of the terms. LCM Conference Berlin 2011; Download: http://www.lcm2011.org/papers.html; Session: Critical Review and Verification of LCA

International Standard Organisation (ISO) (2013): Environmental management - Life cycle assessment – Critical review processes and reviewer competencies - Additional requirements and guidelines to ISO14044:2006, ISO TS 14071 WD3. Geneva

Klöpffer W (1997): Peer (Expert) Review According to SETAC and ISO 1440. Theory and Practice. Int J LCA 2, 183-184

Klöpffer W (2005): The Critical Review Process According to ISO 14040-43: An Analysis of the Standards and Experiences Gained in their Application. Int J LCA 10, 98-102

Klöpffer W (2006): The Role of SETAC in the Development of LCA. Int J LCA 11 (Special Issue 1), 116-122

Klöpffer W (2012): The critical review of life cycle assessment studies according to ISO 14040 and 14044: origin, purpose and practical performance. Int J Life Cycle Assess. 17, 1087-1093

Koffler C (2013): Regarding your article „The critical review of life cycle assessment studies according to ISO 14040 and 14044 – origin, purpose and practical performance“, Int J Life Cycle Assess (2012) 17:1087-1093. Letter to the editor. Int J Life Cycle Assess 18, 300-301

Marsmann M (1997): ISO 14040 - The First Project. With a foreword by Angela Merkel. Int J LCA 2, 121-123

Marsmann M (2000): The ISO 14040 Family. Int J LCA 5, 317-318

Society of Environmental Toxicology and Chemistry (SETAC) (1993): Guidelines for Life-Cycle Assessment: A "Code of Practice". From the SETAC Workshop held at Sesimbra, Portugal, 31 March - 3 April 1993. Edition 1, Brussels and Pensacola (Florida)

THE ROLE OF COMMUNICATION IN LCM

Monday, Aug 26: 3:30 pm - 5:00 pm

Session chairs: Christina Scandelius, Brunel Business School, United Kingdom
Johan Widheden, AkzoNobel, Sweden

CALCULATING THE CARBON FOOTPRINT OF ECO-SCHOOLS

Hogne Nersund Larsen [a], Carine Grossrieder [a], Christine Hung [a], Jan Brataas [b]*
[a]MiSA- Environmental Systems Analysis, [b]FEE NORWAY
**Innherredsveien 7b, 7014 Trondheim, Norway, e-mail: hogne@misa.no*

Keywords: Carbon Footprint; Eco-Schools; EEIO modeling.

ABSTRACT

MiSA – Environmental Systems Analysis has developed a model to effectively calculate the carbon footprint (CF) of individual public entities using EEIO modeling. In a project commissioned by FEE (Foundation for Environmental Education) Norway, we apply the model to individual schools in Trondheim. The aim is to identify important contributors to the CF, and to communicate results in a manner that generates curiosity and user involvement. For the latter, the development of an online interactive CF calculator has been identified as an important part of the project. Results indicate the CF of schools consists of a mix of contributions; although the public education sector is fairly building and energy intensive, a wide range of consumable categories also contribute significantly.

INTRODUCTION

A wide range of sub-national initiatives aimed at climate mitigation and other environmental issues have increasingly filled the void left by a lack of national commitments. FEE (the Foundation for Environmental Education) is one imitative that promotes sustainable development through environment-related education. Eco-Schools is one of four programs initiated by FEE. The program aims to improve sustainability through action oriented learning and is engaging eleven million students in 52 countries. The Eco-School program has been very popular in Norway, involving more than 900 kindergartens and schools. In Trondheim, the 3rd largest city in Norway, all elementary and lower secondary schools participate in the program and have been awarded the well-recognized "green flag" certification.

The 51 elementary and lower secondary schools of Trondheim is the target in this project. The aim is to assemble complete Carbon Footprints (CFs) covering all greenhouse gas (GHG) contributing elements, including the purchase of a wide range of goods and services. Further, the project aim to present the results in an interesting and educational manner to trigger user involvement and curiosity among pupils. Results will therefore be presented in an interactive online GHG calculator.

METHODS

MiSA - Environmental Systems Analysis has developed a model aimed at calculating carbon footprints (CF) (Peters, 2010) using environmentally extended input-output (EEIO) modeling (Minx et al., 2009) at the sub-national level. The model has been applied to municipalities

(Larsen & Hertwich, 2009, 2010b, 2010c), counties (Larsen & Hertwich, 2010a), and national governmental service entities (Larsen, Pettersen, Solli, & Hertwich, 2011). The strength of the model is to effectively derive carbon footprint estimates using financial accounts for the purchase of goods and services. These data are often more readily available, and in standardized formats, in comparison to more traditional bottom-up LCA calculations. However, life cycle assessment (LCA) data are included in EEIO analyses for some important contributing elements – typically energy use, waste generation and transport – in order to increase the accuracy of the calculations. Such an analysis, called hybrid-LCA (Lenzen, 2002; Suh & Nakamura, 2007), has the completeness and effectiveness of top-down EEIO modeling and detail of bottom-up LCA, hence combining the strengths of both methods into a single approach.

RESULTS

The municipal financial department of Trondheim provided an export of the financial information on the purchase of goods and services for each individual school in Trondheim. This enabled us to efficiently calculate carbon footprint results using the EEIO model outlined above. Supplementary data on the energy use, waste generation and an estimation of private transportation of pupils were then added to the calculations. Results show fairly large variations in the normalized carbon footprint, as illustrated in Figure 1.

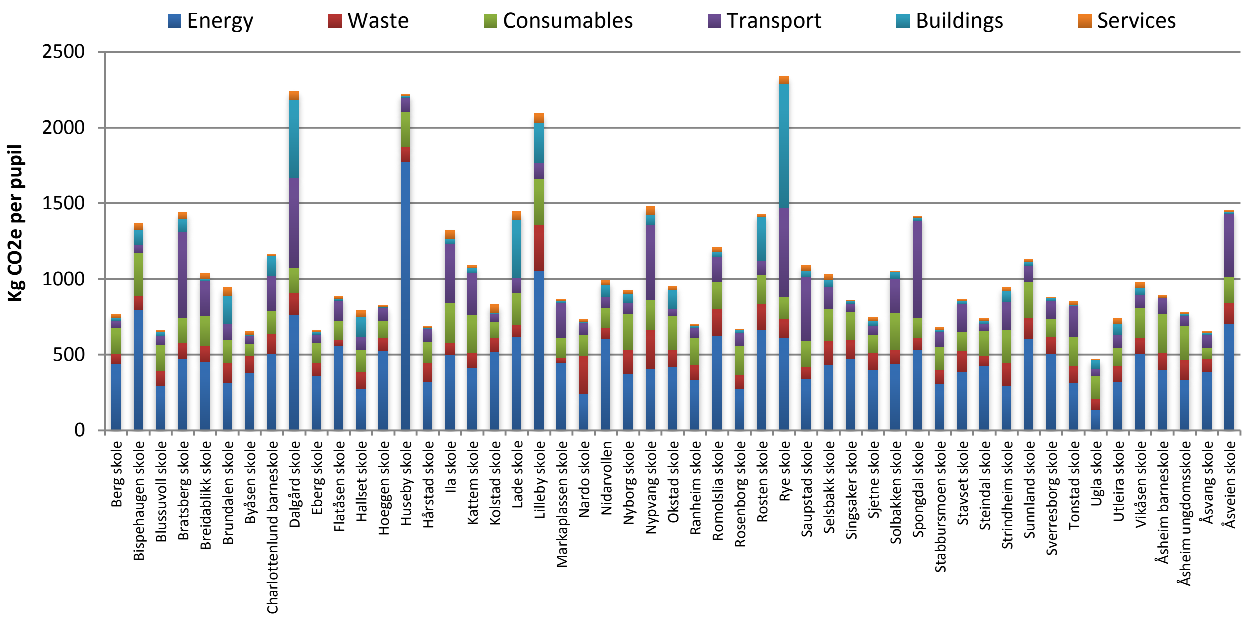


Figure 1: Normalized carbon footprint of all schools investigated. Preliminary results, further refining may be provided.

Most of the large variations and deviations have obvious causes. For example, the large contribution of energy to the carbon footprint of Huseby skole is due to a large swimming facility located at the school; renovation processes contribute to building related carbon footprints, while schools in the outskirts of Trondheim with low population density have a high contribution of transport related carbon footprint. Bratsberg and Rye schools are examples of the latter. In other cases, we find differences that more difficult to explain, and more detailed investigations into these are necessary. The overall structure of the carbon footprint is illustrated in Figure 2. Energy is identified as the highest contributor to the carbon footprint. A mix of consumables (paper, food, furniture, office machinery, etc.) is ranked second, while building-related carbon footprint is ranked third. Building-related carbon footprint typically consists of construction materials in renovation processes, but also includes daily management of buildings, such as cleaning services.

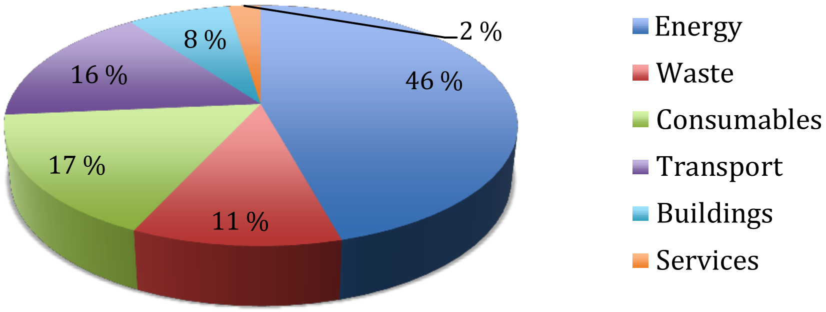


Figure 2: Overall carbon footprint structure

The large amount of data produced from the model developed has proved challenging in previous studies. Being able to communicate the results efficiently has therefore become one of the main objectives of this project. An online interactive carbon footprint calculator is under development in order to meet this need. The screenshot below shows an early version of this calculator. Note that only selected items are translated into English. The calculator will consist of two main parts: one illustrating the carbon footprint of the individual schools (left in Figure 3), and one that performs interactive calculations, showing the effect of suggested mitigation actions on the different sectors in the carbon footprint (right part of Figure 3). The effect of generating less waste, reduced car transport, and reduced/different sources of energy, are some of the available actions that are included.

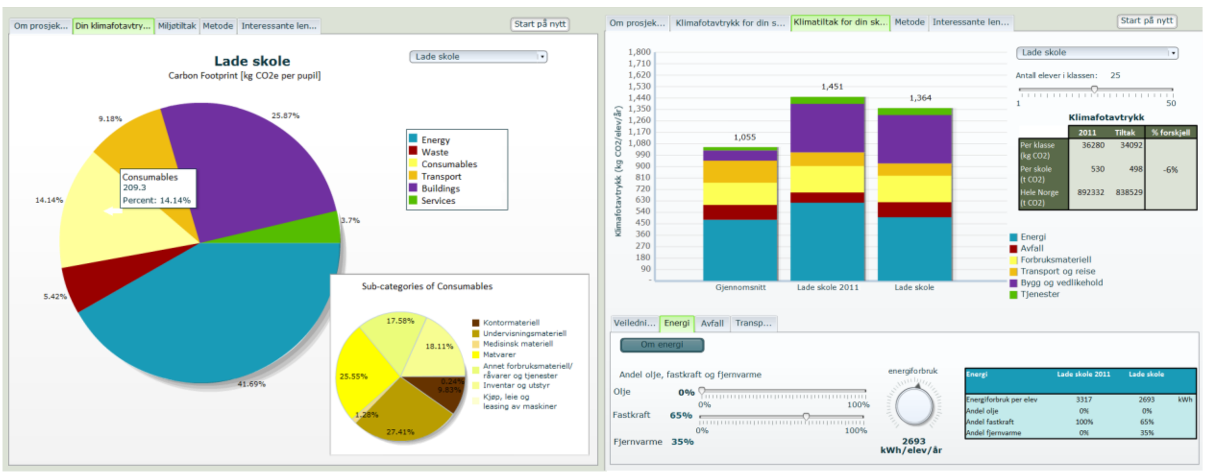


Figure 3: Screenshot of the online interactive carbon footprint calculator

DISCUSSION

Providing education is one of the main service areas of government activities. In Norway, the municipal provision of kindergarten, elementary, and lower secondary educations amounts to a total carbon footprint of 1.3 million tonnes of CO_2 equivalents. This is the largest contributing municipal services area (28 percent) and approximately two percent of the total carbon footprint of Norway, including all private and public consumption. In addition, there is obvious extra potential in directing mitigation and education strategies at pupils at such a young age that one might be able to influence their future behavior towards reducing their personal carbon footprint. Future work should aim at standardizing the GHG inventory further. The large fraction of indirect GHG emissions (scope 3, as defined by the GHG protocol (WRI & WBCSD, 2004)) embodied in e.g. consumables, building materials and waste generation clearly identify the need for the life cycle perspective. The use of EEIO modeling to cover large parts of the carbon footprint has in this project proved very useful.

CONCLUSIONS

In this project, we have calculated the carbon footprint of 51 schools in Trondheim. Results show that there is a significant variation in the normalized carbon footprint, ranging from 500 to more than 2000 kg CO_2 equivalents per pupil per year. However, in most cases, we identify reasonable probable causes of higher carbon footprints. This indicates that results should mainly be used for identifying the main target areas for the individual schools in further mitigation strategies. Overall results could further indicate potential general target areas for the entire school sector. As indicated in Figure 2, we find energy use to be a significant part of the carbon footprint of schools, so improving the energy efficiency within school buildings would be an obvious approach. Also, we see a large contribution of consumables, a category that includes paper, food, computers etc. that indicates the need for actions on green procurement.

REFERENCES

Larsen, H. N., & Hertwich, E. G. (2009). The case for consumption-based accounting of greenhouse gas emissions to promote local climate action. *Environmental Science & Policy, 12*(7), 791-798.

Larsen, H. N., & Hertwich, E. G. (2010a). Analyzing the carbon footprint from public services provided by counties. *Submitted to: Journal of Cleaner Production*.

Larsen, H. N., & Hertwich, E. G. (2010b). Identifying important characteristics of municipal carbon footprints. *Ecological Economics, 70*(1), 60-66.

Larsen, H. N., & Hertwich, E. G. (2010c). Implementing Carbon Footprint-based calculation tools in municipal GHG inventories: The case of Norway. *Journal of Industrial Ecology*.

Larsen, H. N., Pettersen, J., Solli, C., & Hertwich, E. G. (2011). Investigating the Carbon Footprint of a University - The case of NTNU. *Journal of Cleaner Production, Article in press*.

Lenzen, M. (2002). A guide for compiling inventories in hybrid life-cycle assessments: some Australian results. *Journal of Cleaner Production, 10*(6), 545-572.

Minx, J. C., Wiedmann, T., Wood, R., Peters, G. P., Lenzen, M., Owen, A., et al. (2009). Input-Output Analysis and Carbon Footprinting: An Overview of Applications. *Economic Systems Research, 21*(3), 187-216.

Peters, G. P. (2010). Carbon footprints and embodied carbon at multiple scales. *Current Opinion in Environmental Sustainability, 2*(4), 245-250.

Suh, S., & Nakamura, S. (2007). Five years in the area of input-output and hybrid LCA. *International Journal of Life Cycle Assessment, 12*(6), 351-352.

WRI, & WBCSD. (2004). The Greenhouse Gas Protocol - A Corporate Accounting and Reporting Standard: World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD).

CHALLENGES AND OPPORTUNITIES IN COMMUNICATING LCM ISSUES AMONG ACADEMIA, POLICY MAKERS AND INDUSTRIES IN THE REGION OF WESTERN BALKANS

Srdjan Glisovic[1], Evica Stojiljkovic[1], Vesna Zikic[2], Predrag Stojiljkovic[3]*
**[1]University of Nis, Faculty of Occupational Safety, Carnojevica 10a, 18000 Nis, Serbia*
srdjan.glisovic@znrfak.ni.ac.rs
[2]Regional Environmental Center, Szentendre, Hungary
[3]Association for Electric Energy Distribution "Jugoistok" d.o.o Nis, Branch ED Nis, Serbia

Keywords: LCM; dissemination; SME; communication; West Balkans.

ABSTRACT

The paper describes a search for adequate vehicles and tools to support improving Life Cycle Thinking practices in the region, and foster dialogue on the issues between industries, SMEs, and policy makers. The aim is to disclose potential channels of communication among stakeholders and describe an algorithm for disseminating information on significance, structure and market potential of applying LCA approach among regional manufactures. Channels for informing consumers on life cycle approach and environmental features of products have been suggested, since the pressure from consumers might be important incentive for manufacturers to take into account environmental issues.

INTRODUCTION

The significance of sustainability issues has been recognized among major corporate players and industrial sectors of developed world. Progressive companies are motivated to communicate the environmental performances of their environmentally friendly products and services, since the most developed markets worldwide have accepted environmental friendliness as an important mark of quality. Consumers learn how to distinguish environmental features of product and services they acquire, and how to make informed choice on the market. Methodologies for quantifying product environmental attributes such as LCA have matured and comparing eco-features of specific products has become increasingly common (Ingwersen & Stevenson, 2012). Environmental issues are of particular importance for West Balkans transition countries striving to enhance resource efficiency in accordance with EU policies that significantly influence regional decision makers. Since the beginning of the second phase of UNEP Life Cycle Initiative, some sporadic and rather isolated, but yet significant steps toward dissemination of LCM thinking have been noticed. For instance, regional LCA network for Central and South East Europe has been established in Novi Sad, Serbia in 2011, academic subjects and programs on LCA are being taught at University of Nis (Faculty of Occupational Safety, Dept. of Environmental Studies), University of Novi Sad (Faculty of Technical Sciences), University EDUCONS (Faculty of Environmental Studies), and certain groups (e.g. Cluster of Automotive Manufacturers) have organized workshops on

Life Cycle Approach. Some other multi-stakeholder organizations have organized several training programs with content that comprised themes like LCA, resource efficiency, Environmental impact assessment, etc. However, lack of broader knowledge on LCM principles and application remains noticeable throughout the region, in spite some obvious signs of progress in quite isolated circles.

METHOD

A pilot, web based survey, has been designed and carried out as a part of a supervised student assignment. With the intention to collect as much possible information on the subject in given circumstances, a study was launched. Appropriate questionnaire, aimed to reveal general awareness of LCA significance among local industries and services, was designed and distributed to 120 SME's, larger enterprises (some of which operate in other countries in the WB region as well) and certain public institutions in south-east Serbia. As for temporal range, the survey spanned from early November to late December 2011. Participants comprised random representatives from trade, industry, various agencies and public utility services (Glisovic, 2013). Return rate was mere 24%, mostly due to inadequate timing and rather week explanatory activities. As a preliminary, pilot survey, this scanning did not aim to be a statistical representative study of society, which would certainly require a much larger sample and somewhat different data processing. In this stage, the main purpose was to get fast, although superficial, but yet quite clear insight in the regional perception of LCA approach. The survey was primarily aimed to motivate efforts for identification of appropriate channels for communicating information and spreading knowledge on LCA practices in the region.

RESULTS

The preliminary survey has revealed significant lack of information on the subject among representatives of different industrial sectors. It seems that LCA procedures remain widely unknown or at least seldom applied in the region of West Balkans. Furthermore, it seems that manufacturers do not fully recognize potential of LCA practices to boost environmentally friendly product presence on the regional markets. In order to validate and evaluate preliminary findings, a more extensive and demanding survey has been suggested. However, one such endeavor requires full collaboration of different players, such as Regional Chambers of Commerce, associations of different industrial sectors, Consumer Protection Organizations, national Environmental Protection Agencies and alike. Preliminary contacts with all relevant players have been established and a new, redesigned survey of a kind is on the way. Expected results should reveal the weakest players in supply chains, as well as the most motivated companies to start with a novel program of trainings. Subsequently, a series of tailor-made information sessions should be arranged for industrial sectors, and in particular for SMEs (Small and Medium Enterprises), and web based and printed materials should be designed and distributed trough Consumer Protection Organizations.

In spite of certain shortcomings and limitations of described preliminary survey, it became clear that even those SMEs representatives that declared certain familiarity with LCA concept did not realize that environmental superiority of their products or services could provide them better market position on the long run. Thus, life cycle approaches did not become part of the daily industrial and business activities in transitional countries of the West Balkans. A lot of information on LCM concept is yet to be communicated between industrial sector and various players from different levels of government, economy and academia. A web for distribution of LCA practices (expertise and data flows) is suggested as shown in the Figure 1 (Glisovic, 2013). Therefore, there is plenty of room for two-way communication between industry and academia, with necessary institutional support from policy makers. Integration and mainstreaming of life cycle thinking among a wide range of local industries, trade organizations and business supporting bodies is obviously needed.

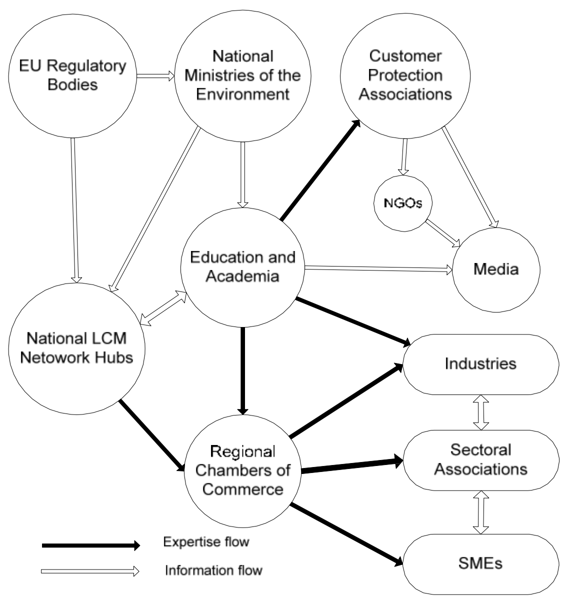


Figure 1. Distribution of LCM Practices – Expertise and Data Flow

The introduction of LCA can take place both by a 'top-down' approach (by the order from top management) or by a 'bottom-up' approach (by the initiative of the designer, or other employee). LCM adoption patterns and integration of LCM principles in decision-making processes comprise a learning process, organizational changes and certain structural challenges. Subjective factors are also of crucial importance, since it is all about evolutionary changes in the attitude of the company or association.

DISCUSSION

It is understandable that governing bodies of weak economies in times of global economic crisis are focused on more immediate priorities than environmental issues seem to be from their prospective. In those circumstances, LCM information and communication should emphasize resource efficiency, as it is usually easily noticeable benefit for policy makers.

Small and medium enterprises would certainly need a kind of hub to exchange their experience and compare results of life cycle based activities with other companies and academia. National associations of LCA consisting of representatives from industry, academia, public authorities, consumer associations and research centers, exist for years in Japan, Korea, India, Italy, and France, giving huge support to spreading the concept nationwide (Frankl, 2001). It is obvious that multi-stakeholder associations of the kind might have the crucial role in dissemination and mainstreaming of LCM practices in West Balkans. It should:

- support capacity building and training of professionals, particularly those from SMEs
- develop standardized and simplified screening procedures, suitable for SMEs;
- provide education for consumers, increasing their ability to make informed choice;

Permanent communication between all the involved stakeholders (foremost, between industry, authorities and consumers) is essential for the future diffusion of LCM practices.

CONCLUSIONS

Promotion of LCA concept is of particular importance for the countries in transition and their environment, since they could be heavily impacted by emerging consumerism. LCM based communication tools could be applied to protect developing markets against the unfair competition by manufacturers that supply low priced products, but with higher environmental externalities (Blengini & Shields, 2010). Instead of remaining passive, waiting for environmental impacts to strike, those vulnerable societies should undertake adaptation, based on acquired knowledge about eco-effectiveness and resources management. Academia, governmental agencies and consultant firms should couple efforts in popularization of this important system approach in the region of West Balkans in order to facilitate timely implementation of life cycle management principles. The process of communicating introductory LCA practices between West Balkans institutions and industries is obviously not yet done, and it is still needed in order to strengthen the potential of local, administration, research and education, to forward life cycle thinking to industries and SMEs.

Dissemination of information on benefits that LCM could bring to manufacturers, consumers and entire society is of great importance for both environment and economy of Western Balkans. Export oriented manufacturers would faster learn how to cope with ever more stringent rules of the most demanding markets. Additionally, the very activities on preparing a LCA would reveal the weakest environmental features of a product and thus support environmentally friendly product design procedures and direct design changes. One such approach would certainly lead, step by step, toward increased resource efficiency, better material choice, and improved energy efficiency of products and manufacturing processes.

REFERENCES

Blengini, G. A., & Shields, D. J. (2010). Green labels and sustainability reporting: Overview of the building products supply chain in Italy. *Management of Environmental Quality: An International Journal*, *21.4*, 477-493.

Frankl, P. (2001). Life Cycle Assessment as a Management Tool, In *A Handbook of Industrial Ecology* (pp. 32-33). Northampton, Massachusetts: Edward Elgar Publishing.

Glisovic, S. (2013). The Art of Spreading Good News – The Lessons on EPDs for the Western Balkans Manufacturers and Consumers. *Proceedings of the Conference "Reporting for Sustainability 2013"* (pp 437-441). Becici, Montenegro: Regional Environmental Center. ISBN 978-86-7550-070-4.

Ingwersen, W. W., & Stevenson, M. J. (2012). "Can we compare the environmental performance of this product to that one? An update on the development of PCRs and future challenges toward alignment". *Journal of Cleaner Production*, *24*, 102-108.

CROSS-MEDIA TRAINING CONCEPTS FOR THE SWIFT KNOWLEDGE TRANSFER OF COMPLEX LIFE-CYCLE-ASSESSMENT GUIDELINES FOR ELECTRIC VEHICLES

Mieke Klein (ifu), Martina Prox (ifu), Martin Ramacher (ifu), Alexander Scheibner (ifu), Marten Stock (ifu), Tobias Viere (ifu)*

**Institute for Environmental Informatics (ifu) Hamburg GmbH, Max-Brauer-Allee 50, DE-22765 Hamburg, m.ramacher@ifu.com*

Keywords: eLCAr; Life Cycle Assessment; electric vehicles; training concept; cross-media.

ABSTRACT

Within the eLCAr project new knowledge in the field of LCM is created: Guidelines based on the ILCD Handbook, tailored to the needs of LCA practitioners in the field of electric vehicles. Additionally, a set of training materials was produced and applied within this project. The materials consider individual learning preferences. In consequence, a cross-media training concept based on a blended approach of different media types has been developed: Self-learning script, seminar training and e-learning media. All media follows the same modular outline, thus allowing switching between and combining the different training media. This flexible set-up allows an optimised knowledge transfer and thereby enriches the outcome of the newly created eLCAr guidelines.

INTRODUCTION

Topics and issues from the field of Life Cycle Management (LCM), like new concepts, regulations and standards, are often complex. Their correct and successful implementation requires a good understanding and knowledge. An insufficient infrastructure for knowledge transfer often prevents to fully benefit from new and innovative topics and issues.

Within the E-Mobility Life Cycle Assessment Recommendations project[1] (eLCAr), guidelines for the Life Cycle Assessment (LCA) of electric vehicles based on the framework established by the International Reference Life Cycle Data System (ILCD; European Commission, 2010) were developed to support LCA practitioners in the European Green Cars Initiative (EGCI; European Economic Recovery Plan, 2008). In addition, the guidelines were formulated to create a common framework concerning methodological choices for LCAs of electric vehicles that will ultimately enhance the quality of studies performed within the EGCI. To achieve this, the general guidance provided by the ILCD Handbook was tailored to the specific case of electric vehicles. While these tailored guidelines are the major outcome, to promote their accessibility and allow for a swift dissemination, a training concept was developed in line

[1] The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013).

with the eLCAr guidelines. The development of the training concept refers to the core question of this poster presentation: How to enable a swift dissemination and knowledge transfer of complex Life-Cycle-Assessment guidelines for electric vehicles? This set of training materials was designed for an optimised knowledge transfer taking into account the variety of possible users. Within the cross-media training concept of the eLCAr project, a blended approach of different media types (Kitchenham, 2011) was developed including self-learning script, seminar training and e-learning media. The training modes follow the same modular outline, thus allowing switching between and combining the different training media. Trainers are provided with the necessary infrastructure and materials to perform target group specific trainings. Self-learners are enabled to gain the new knowledge according to their individual preferences. This flexible set-up allows for a swift knowledge transfer and thereby enriches the outcome of the newly created eLCAr guidelines for LCA of electric vehicles.

CROSS-MEDIA CONCEPT

The didactical structure of the cross-media training concept is designed for an optimised knowledge transfer and to address all possible applicants within the EGCI. Thus, the development of the training materials started with the definition of the target group. As a consequence different training modes were developed (Brookfield, 2013). In addition, the training concept follows a modular approach whenever possible to count in the different needs and pre-existing knowledge within the target group.

Target Group

The main target group of the developed training materials are practitioners from EGCI projects. All potential training participants and learners have in common basic background knowledge of LCA and/or electric vehicles and their components. Still, they may have different approaches and background knowledge in terms of LCA methodology, technical background, experiences in certain electric vehicle component assessment or full vehicle assessment. The target group includes LCA experts with little knowledge on electric vehicles as well as experts on e-mobility who are new to LCA. The training materials can be used by learners who need to conduct an LCA study as well as those who are looking for basic knowledge in order to understand the outcomes.

Modular Approach

The eLCAr training concept follows a modular approach (see Fig. 1), meaning that the content of every part of the training can be accessed individually (Ambrose, 2010). Where possible, every module is designed as a self-contained unit so that it can be understood based on knowing the fundamentals of LCA. Thus the modules can be assessed in any order.

For more experienced users, the modular approach, offers the possibility to take short cuts to complete the training more quickly or to assess only the topics they want to focus on.

Figure 1: Modular approach, ©ifu

Training Modes

The target group differs not only in background knowledge but can be segmented further according to different learning preferences: Whereas some individuals may prefer to learn as a group in seminar trainings, others prefer to learn on their own with accompanying training materials (Moreno & Mayer, 1999). Consequently, different training modes were developed to meet these preferences.

In general, all training types aim at supporting written information with graphical representation wherever possible to facilitate a good memorising of the content. Moreover, all training modes include interactive elements to help deepen the newly acquired knowledge (Driscoll, 2002). The interactive elements sometimes vary between the offered learning modes. For instance, questions animating group discussions are mainly anchored in materials for seminar trainings. Nevertheless, sometimes similar questions also appear in the self-learning script. Depending on the demands of the target group customising the interactive part is possible so that it fits best to the given conditions is possible.

To take into account that the potential target group not only differ in its background knowledge but also in its preferences about how to learn, the training materials concept includes a set of different training modes, following a modular approach. Besides the seminar training mode, a self-learning script and e-learning is offered (see Fig. 2).

For learners who prefer to assess new topics together with others, the *seminar training* is a suitable learning method (Laszlo, 2006). The seminar training is one of the cornerstones in the offered training concept for the eLCAr project. Goal of the provided seminar training materials was to develop an infrastructure that facilitates trainers to conduct seminars. This infrastructure includes: presentation slides including all necessary information; presentation texts providing import information that should be included in the oral presentation of the slides; group exercises to be conducted by the seminar participants.

Figure 2: Training modes, ©ifu

The *self-learning script* is a working book that offers exercises related to the different modules of the training concept (Harrison, 1999). Exercises for different level of learners are included. For all tasks, sample answers are given in the annex and additional information (e.g. links to interesting papers or websites) is included for almost modules.

The *e-learning* is made available via the web platform 'moodle' (Rice, 2011). For every module, a so called Web-based-training (WBT) is available. A WBT is principally a power-point presentation combined with narration (Driscoll, 2002). The user himself clicks through the slides so that the speed is always appropriate. So-called quick-tests are provided after each module as interactive elements to check the submitted knowledge. Additionally a forum can be assessed to get in contact with other learners to discuss questions or to exchange knowledge and experiences.

A supplementary training mode is the trainer-accompanied eLearning (Arnold, 2013). Here, a copy of the moodle is made available for a trainer. Thereby, the trainer enrols participants and can adjust the contents according to the layout of the course.

CONCLUSIONS

In the eLCAr project, training materials were developed in line with the actual project outcome, the guidelines, to enable a swift dissemination and knowledge transfer. First tests during stakeholder workshops revealed a positive reaction to the cross-media training concept. Still, the impact and results of the selected approach have to be evaluated after the launch of the training materials together with the publishing of the new eLCAr Guidelines.

REFERENCES

Ambrose, S. A. (2010). How learning works: Seven research-based principles for smart teaching (1st ed.). The Jossey-Bass higher and adult education series. San Francisco, CA: Jossey-Bass.

Arnold, P. (2013). Handbuch E-Learning: Lehren und Lernen mit digitalen Medien (3rd ed.). Bielefeld: Bertelsmann.

Brookfield, S. D. (2013). Powerful Techniques for Teaching Adults (1st ed.). The Jossey-Bass higher and adult education series. s.l: Jossey-Bass. Retrieved from http://ebooks.ciando.com/book/index.cfm/bok_id/489013

Driscoll, M. (2002). Web-based training: Creating e-learning experiences (2nd ed.). San Francisco: Jossey-Bass/Pfeiffer.

European Commission. (2010). ILCD handbook: International Reference Life Cycle Data System: General Guide for Life Cycle Assessment - Provisions and action steps. Scientific and technical research series. Luxembourg: Publications Office of the European Union.

European Economic Recovery Plan. (2008). European Green Cars Initiative. Retrieved from http://www.green-cars-initiative.eu/about

Harrison, N. (1999). How to design self-directed and distance learning: A guide for creators of web-based training, computer-based training, and self-study materials. New York: McGraw-Hill.

Kitchenham, A. (2011). Blended learning across disciplines: Models for implementation. Hershey, Pa: IGI Global (701 E. Chocolate Avenue, Hershey, Pennsylvania, 17033, USA).

Laszlo, P. (2006). Communicating science: A practical guide. Berlin: Springer.

Moreno, R. & Mayer, R. E. (1999). Cognitive principles of multimedia learning: The role of modality and contiguity. Journal of Educational Psychology, 91(2), 358–368. doi:10.1037/0022-0663.91.2.358

Rice, W. (2011). Moodle 2.0 e-learning course development: A complete guide to successful learning using Moodle. Packt Open Source. Birmingham: Packt Publishing.

ENVIRONMENTAL FOOTPRINT CALCULATOR

Lars Mårtensson, VolvoTrucks, BC10110 VLH5B, 405 08 Gothenburg,
lars.martensson@volvo.com

Keywords: LCA; truck; customer; society; tool.

ABSTRACT

Volvo has since early 90's used the LCA methodology. In 2001 Volvo Trucks launched the first so called environmental product declaration for the FH and FM trucks, which is still unique for the truck industry. In this tool anyone, e.g. a customer, can easily calculate environmental quantities through choosing type of truck and make comparisons e.g. between hybrids and alternative fuels. Volvo Trucks acknowledge that transports are parts of most product life cycles and that we can contribute to the LCM work in companies. But maybe the most important usage is to raise the level of knowledge within Volvo Trucks, among our customers and society in general about the areas to focus and to have a holistic view.

INTRODUCTION

The Volvo Group Environmental Policy states "In our efforts to reduce environmental impact of our products, operations and services we shall take account of the complete life cycle". Volvo Group has since early 90's used the LCA methodology to identify and work to minimize environmental hot spots, and to assess improvements.

In 2001 Volvo Trucks launched the first so called environmental product declaration for the FH and FM trucks and was and still is unique for the truck industry.

In this tool (Environmental Footprint Calculator) today anyone, e.g. a customer, can easily calculate environmental quantities through choosing type of truck and fuel consumption and make comparisons between trucks, 10 years old up to new models, hybrids and alternative fuels.

MATERIALS AND METHODOLOGY

Volvo Trucks believes that there is a need among customers and in the society about quantative information about the environmental aspects of trucks and transports. The first environmental product declaration was based on a screening LCA for the Volvo trucks FH and FM in Europe. The study was split in parts covering each one of the sixteen modules of the trucks. The system was divided in three areas:

- Production

- Usage
- End-of-life

The results vary considerably depending on the in-put data, the most important of which are fuel consumption, mileage, engine and fuel. These are some of the parameters used as input in the calculation tool on the web. Depending on the data the user can calculate a single transport, the complete truck life cycle or a comparison between different alternatives.

The environmental product declaration and the calculation tool serve as important tools to raise the awareness and knowledge about the environmental aspects of trucks and transports internally within Volvo Trucks as well as externally among customers, transport buyers and society in general.

Volvo Trucks has today conducted screening LCA for the trucks FL, FE, FE-hybrid, FM MethaneDiesel and the new FH. It means that all trucks sold on the European market are today available in the environmental footprint calculator on the web. Since the launch of the web tool, it has also been translated to most European languages in order to support local usage.

RESULTS

The usage of screening LCA has successfully resulted in identification of environmental hotspots and work to minimize and assess improvements.

The environmental footprint calculator has raised the level of knowledge within Volvo Trucks, among our customers and society in general about the most important areas to focus and the importance to have a holistic view.

DISCUSSION

Volvo Trucks is today the first and only truck manufacturer who has made the data from screening LCA available in a calculation tool. It is only possible to compare Volvo trucks and different alternatives. This has been a challenge since the data quality, methodology development and general knowledge has changed over time and the difference between old and new studies had to be handled in order to make it possible to compare. This will remain as a challenge also in the future.

CONCLUSIONS

Screening LCA can successfully be translated in to a useful tool for customers, transport buyers and other stakeholders in the society. The environmental footprint calculator has raised the level of knowledge and resulted in activities to reduce the environmental impact.

REFERENCES

Lars Mårtensson, Volvo Trucks, 2013 www.volvotrucks.com/trucks/global/en-gb/values/environment/footprint-calculation/Pages/Footprint_calculation.aspx

Volvo Trucks, Press release, 2011, New environmental footprint calculator from Volvo Trucks helps lower emissions

FOOD CONSUMERS LCA: FORM CONSUMERS SURVEY TO ENVIRONMENTAL IMPACT ASSESSMENT

*Saioa Ramos**, Maruxa Garcia and Jaime Zufia. AZTI-Tecnalia, Food Research Division*

**Bizkaia Technology Park, Astondoa Bidea edif. 60, 48160 Derio (Spain) - sramos@azti.es*

Keywords: Ready-to-eat dish; environment; consumer; LCA

ABSTRACT

Food consumption is one of the most influential stages when classifying the impact of a food product. However, it is generally difficult to take this stage into account because most consumers do not follow a unique buying pattern. Therefore, the aim of this study is to perform a detailed consumer study and a LCA in order to describe consumer behavior from an environmental point of view. For this research, we have selected a dish prepared with fish as an unit and a study because of its versatility. Overall, it is concluded that heating is the most influential stage on the impact assessment due to electricity use. Moreover, heating in microwave is the most environmentally friendly choice.

INTRODUCTION

It is widely accepted that Life Cycle Analysis (LCA) is an useful tool which measures the potential environmental impact of a food product. Moreover, it has been established that the food consumption is one of the most influential stages when classifying the impact of food (Jungbluth et al, 2000). However, it is generally difficult to take this stage into account on a conventional LCA due to variability of the data.

Most consumers do not follow a unique buying pattern mainly due to the wide variety of purchase options that exist today. Consumers can not only choose where to make their purchase (super, hyper, on-line), also the selling format (individual or family package, etc.), the conservation mode, or the product packaging. All these variables affect significantly the final environmental impact of products (Vazquez-Rowe et al, 2013)

Although LCA provides the data on environmental impacts that environmentally conscious consumers need, the form in which it is provided is yet highly inaccessible. Published LCA reports are extremely technical, featuring long lists of environmental pollutants and abounding with technical terms. They are not directed at lay people who need to get a quick overview of the most important issues and make decisions on a day-to-day basis. So, developing accessible information is thus a key priority. Before that, it is necessary to know the consumer behavior in terms of environmental impact.

The main objective of this article is to perform a detailed consumer study and a LCA which describes consumer behavior from an environmental point of view. For this study, we have selected a dish prepared with fish as a unit because of its versatility as a product.

MATERIALS AND/OR METHODS

With this frame, an online survey to food consumer has been made in order to describe the consuming behaviour about prepared dishes based on fish. After that, data provided by the study have been translated to environmental impact throughout a life cycle assessment.

Consumer Survey

The questionnaire was conceived as a thorough assessment of the habits and beliefs of individual consumers among the Spanish population. The questionnaire was anonymous in order to guarantee a higher level of participation and honesty. The number of questions was forcefully limits, there by requiring a pondered choice of the questions and of the wording. For this reason, each question was debates by a multidisciplinary team composed of marketing, survey and consumer behaviour specialists, representatives of commercial companies, statisticians and people experienced in the LCA sector. Finally, the survey was divided into four main sections: buying, storage, preparation and final disposal habits.

The next step after formulation of the questionnaire was to choose an adequate dissemination media for the survey. In order to reach a large universe and different geographical regions of the country, a web online medium was the natural option. Mundosabor® allows simple writing procedures in order to make the questionnaire available in the internet. Afterwards, it is only necessary to send the questionnaire among consumer community registered and selected in the database Mundosabor® Platform.

To face this challenge we examined consumers' habits and beliefs about food consumption. Questionnaires were posted to 400 randomly selected adults, with 180 questionnaires completed. They were required to be ready-to-eat fish dish consumers. Analyses were conducted with R-project statistical software (v 2.11.0).

Life Cycle Assessment

- Goal and scope definition: The object of this study is a cradle-to-gate attributional life cycle assessment of the consumption of an individual portion of a ready-to-eat fish meal.

  The life cycle inventory only takes into account the consumer stage of the product; fishing, processing and retailing stages are out of the study since no specific product have been selected.

  The first step is buying the dish at the supermarket or store. Then the consumers transport either by car, public transport or walking from supermarkets to home. Once at home, consumers store the product for a specified time in the refrigerator until consumption. So, different heating scenarios were analysed to compare different behaviours. Since there are different products on the shopping cart, mass allocation has been followed for this study.

- Data Quality: Foreground inventory data are provided in a questionnaire by Mundosabor® Platform and it is referred to 2012 year. Foreground data include: (i) transport distance and vehicle type to the store; (ii) time needed for heating (iii) way of washing up (machine or by hand); and (iv) recycling rates.

  The primary source of background inventory data used in this study is the ecoinvent data v2.2 (ecoinvent Centre 2010), which contains inventory data of many basic materials, energy carriers, waste management and transport services.

- Selected impact categories: A number of impact categories from ReCiPe methodology have been selected for the impact assessment: Global Warming potential (GWP); Ozone layer Depletion potential (ODP); Terrestrial Acidification Potential (TAP); Freshwater Eutrophication Potential (FEP); Human Toxicity Potential (HTP); Photochemical Oxidation potential (POP); Particulate Matter formation potential (PMF); Terrestrial Ecotoxicity potential (TET); Freshwater Ecotoxicity potential (FET); Marine Ecotoxicity potential (MET): Water Depletion Potential (WDP); Fossil Depletion potential (FDP)
- Inventory: Once the consumer study concluded, the obtained data was adapted into energy, water and material input and output for an LCA system.

RESULTS AND DISCUSSION

Consumer survey

The survey about environmental impact assessment relation with the consumer behaviour in the Spanish population was successfully carried out, thereby yielding a total of 173 valid filled questionnaires. This total number of answers was analysed and characterized.

Regarding buying habits, most people buy in super or hypermarket once or twice each month. The distance to the buying place was about 3km and more than 50% of people use the car. The consumers usually carry a weight of 3% of fish dish prepared in the total of the purchase. Moreover, the 42.13% of consumers stated that the packaging is the most important environmental factor in the completion of the purchase.

Surveyed Spanish consumers also display relevance characteristics in storage. More than 50% of those polled maintain the dish on the freezer for a maximum of 10 days. After the storage, they cooked or heat up the dish mainly on the microwave for six minutes. Regarding the disposal, most people do the washing up on the dishwasher and always recycle the packaging.

Life cycle impact assessment

The Global Warming Potential (GWP) of the consumption of the fish based ready-to-eat meal is about 0,35 kg CO_2 eq. The electricity used for heating is the main contributor to this impact due to the combustion of coal and natural gas. Furthermore, almost all the impacts categories are mainly influenced by the cooking or heating stage (>75%) (Figure 1).

However, Ozone Layer Depletion Potential (ODP) and Photochemical oxidation Potential are mainly influenced by the exhausted fumes from passenger car engines. It is also remarkable the water depletion impact assessment on the washing up stage. However, for this specific impact a regionalized inventory and impact potential is recommended.

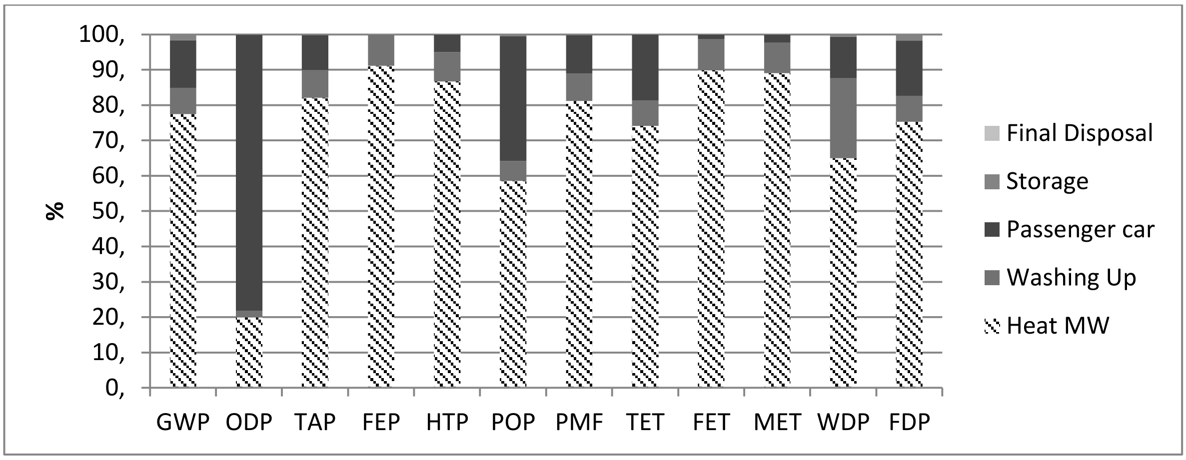


Figure 1: Environmental impact assessment of the consumption stage of fish based ready-to-eat meal.

On the other hand, when comparing this microwave heating scenario with the oven heating or cooking scenario, a significant improvement of 30% in most of selected impacts categories have been observed (figure 2).

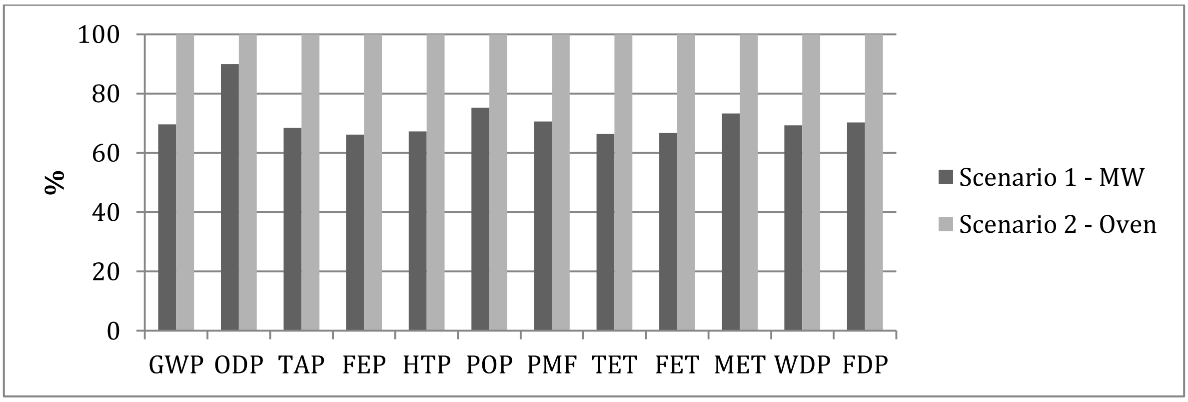


Figure 2: Comparative environmental impact assessment of the consumption stage of fish based ready-to-eat meal where in scenario 1 heating by microwave is taken into account and in scenario 2 heating in the oven

CONCLUSIONS

On one hand, this study concluded that although most consumers are environmentally aware, most of them, do not have enough information to make a responsible food choice. On the other hand, it is shown that the heating is the most influential stage on the impact assessment due to electricity use.

REFERENCES

Jungbluth, N, Tietje, O., and Scholz, R.W..(2000). Food Purchases: Impacts from the Consumers' Point of View Investigated with Modular LCA. Int. J. LCA 5 (3) 134-142

Vazquez-Rowe, I., Villanueva-Rey, P., Moreira, M.T., Feijoo, G. (2013) The role of consumer purchase and post-purchase decision-making in sustainable seafood consumption. A Spanish case study using carbon footprinting. Food Policy 41 (2013) 94–102

FROM BURDENS TO BENEFITS: QUANTIFYING THE AVOIDED CLIMATE IMPACT OF SOLUTIONS IN THE SKF BEYONDZERO PORTFOLIO

Davis, J.*[1], Löfgren B.[1], Berglund M.[1], Sjölin M.[1], Nilsson J-A[1], Rosén M.[2]

[1]SKF Group Manufacturing Development Centre, [2]SKF Group Corporate Sustainability, SE-415 50 Göteborg, Sweden

*Jennifer.Davis@skf.com

Keywords: Green portfolio; avoided climate impact; SKF BeyondZero.

ABSTRACT

An increasing number of companies actively communicate their 'net positive' impact on the environment. Based on the experience of developing the SKF BeyondZero portfolio, this paper highlights a few challenges and opportunities of shifting environmental communication from burdens to benefits. We show how SKF defines and uses a baseline for comparison of new and conventional solutions, how system boundaries are set, the iterative process of collecting data, and how SKF applies the methodology. We conclude the paper by discussing risks and opportunities of avoided emissions calculation and communication.

INTRODUCTION

Since the 90s environmentally conscious companies have published environmental reports with indicators of environmental behaviour. Reports, often following the international standard given by the Global Reporting Initiative (GRI, 2011), display how the companies strive to reduce their environmental impacts towards zero. The greenhouse gas (GHG) protocol (World Resources Institute and World Business Council for Sustainable Development [WRI/WBCSD], 2004) is a widely applied industrial standard that supports this by providing a framework for the accounting of the greenhouse gas emissions of an organization. However, an increasing number of companies actively communicate their 'net positive' impact on the environment (e.g. Siemens, 2013; BASF, 2013), something not currently supported by publicly available standards. For the purpose of contributing to the development in the area, this paper outlines a few of the challenges when turning communication from burdens to benefits, based on the experience of SKF.

In 2005, SKF launched the business strategy SKF BeyondZero to direct the global organization towards innovating solutions to help customers reduce their environmental impact. It was a game changing addition to the previous environmental strategy that aimed at continuously reducing the impact of SKF's own processes and supply chains. At the company's 100 year anniversary, two years later, a new energy efficient product range was introduced. In 2012, the next step was taken when the SKF BeyondZero portfolio was made public, containing products, services or solutions delivering significant environmental benefits without serious environmental tradeoffs.

The scope of environmental improvements enabled by these portfolio products is broad. It includes for example helping customers to preserve the balance of the atmosphere, promote efficient and responsible use of resources, and avoid discharges into water. In the portfolio management process, business considerations (e.g. market potential) and environmental aspects (e.g. material selection, energy efficiency, and reduction of lubricant leakage) are evaluated in parallel. The method presented in this paper currently focuses on the quantification of the offers' potential to avoid contributing to climate change, using an approach involving a number of methodological choices that requires attention and discussion. A major challenge is to find an acceptable compromise between providing credibility through detail and completeness in the analysis; at the same time as the assessment is pragmatic and time efficient.

In the following we show how SKF defines and uses a baseline for comparison of new and conventional solutions, how system boundaries are set, the iterative process of collecting data and how SKF applies the methodology. We conclude this paper by discussing the risks and opportunities related to avoided impact calculations and communication.

DEVELOPMENT OF THE QUANTIFICATION METHOD

The method has been developed through an iterative process during which learning from actual case studies have provided input to evolve the method. The aim has been to reach a sound balance between credibility and pragmatism. The method covers GHG emissions measured in kg of CO_2e. A key aspect of the method is that it quantifies avoided emissions, that is, the difference in emissions between the SKF solution and a defined baseline solution.

Definition of the baseline

The definition of a baseline solution significantly impacts the results of the calculations. Here, the baseline is set to the most common solution on the market, taking into account only products and solutions that are sold in the present market. This could be a previous SKF solution, or a solution providing an equivalent function that is sold by another company. A practical guidance to actually identify a relevant baseline solution is to try and find out what alternative solution the customer likely would have bought if they had not bought the SKF solution. An implication of this definition is that the baseline will change over time. Therefore, the baseline needs to undergo reoccurring evaluation and the quantified results need to be updated accordingly.

System boundaries

The second aspect to be carefully considered is how different parts of the system should be accounted for in the analysis. A life cycle perspective is applied when exploring the solutions. All parts or processes that are the same in both solutions being compared are excluded; see an example of this in Figure 1 where production (2) and end-of-life handling of the car (5) are excluded.

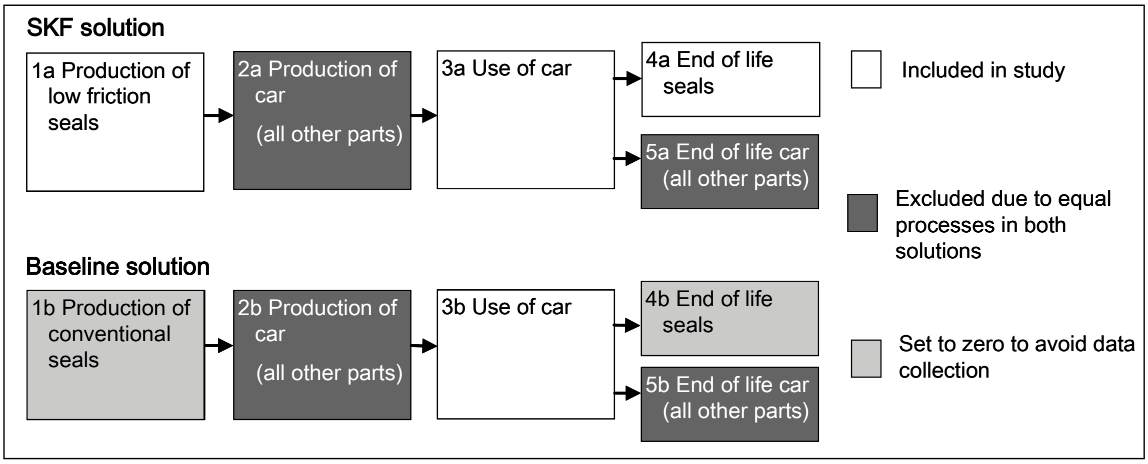


Figure 1. System boundaries for studied solutions (one example case)

Iterative data collection process

After excluding identical parts, the next step is to make sure that the data collection focuses on the processes that impact the result the most. The following work procedure is performed in order not to overestimate the CO_2e-saving, while at the same time limit the data collection to parts where it is most needed.

First, the emissions for the lifecycle step where the most obvious improvement lies are quantified, in the example in Figure 1 this is the use phase (3). Then, the impact for the rest of the life cycle steps for the SKF solution are quantified (1a and 4a in Figure 1), using generic data from databases, while assuming zero impact for the rest of the life cycle steps for the baseline solution (1b and 4b). If the impact from the other life cycle steps for the SKF solution represents less than 10% of the overall improvement, no more data collection is undertaken. In this way, detailed data is collected for all life cycle steps that together contribute to more than 10% of the overall improvement, while life cycle steps that contribute to less than 10% are either treated by using generic data (the SKF solution) or set to zero (the baseline solution). The baseline solution is set to zero to avoid overestimating the effect.

For many SKF solutions the main saving in greenhouse gas emissions is found in the use phase, i.e. when running the application, so in practice this means that in many cases the emissions associated with producing and handling the product at the end-of-use, may be modelled with generic data (and set to zero for the baseline solution). However, there are also cases where the production and end-of-use phases are the most prominent life cycle stages, in terms of emission savings.

APPLICATION OF METHOD TO PORTFOLIO SOLUTIONS

The method described in this paper is applied on solutions that are included in the SKF BeyondZero portfolio. In practice, the quantification process starts with a meeting between the solution owner and the specialist engineer responsible for the calculation, in which the system boundaries and functional unit are set and the relevant baseline solution defined. Then, the required data is collected by the solution owner (e.g. material composition and service life of the solution, documentation of test results, simulations etc.) and all data is documented in a common template. When material and energy use is determined for the studied systems, this is translated into GHG emissions, by using life cycle inventory (LCI) data from commercial databases, as well as data collected by SKF. The final result is summarized in a short memo, and communicated internally to the solution owner, the SKF BeyondZero portfolio board, and to colleagues within marketing and communications.

The method is developed centrally and can be applied by various engineering functions supporting SKF business processes.

IMPLICATIONS OF THE APPROACH

Traditional lifecycle based environmental assessments provide highly credible results but require a lot of time and resources. In the development of this method we have strived for safeguarding the strengths of life cycle thinking while making it more efficient from a time and resource perspective. This has been a balancing act and the resulting approach has some implications, these are:

(1) The method focuses on differences between an SKF solution and a baseline solution. It is thereby possible to demonstrate the amount of avoided emissions. However it is not possible to determine the improvement relative to the complete system.

(2) The approach presented in this paper is based on a streamlined data collection procedure where we focus on details where details are needed, at the same time avoiding details where they are not needed. This makes the calculations efficient while not sacrificing the credibility of the results. In this way it has been proven possible to manage a large number of calculations with limited resources.

(3) By setting the impact of some life cycle steps of the baseline solution to zero while always accounting for the impact of the SKF solution, we help to avoid overestimations and thereby contribute to making the environmental claims made by the SKF Group conservative.

By employing this quantification approach, SKF can communicate the avoided GHG emissions of an entire product portfolio, internally as well as externally. By visualizing the avoided emissions in actual numbers, the effect is inevitably more tangible, compared to if a general statement is made.

Future development of the quantification method includes a widening of the scope so that other environmental impacts than GHG emissions can be quantified. Also, continued build up of LCI data on materials and production routes for SKF solutions, as well as typical use profiles in the various applications, will further facilitate the calculations.

REFERENCES

BASF. 2013. BASF Report 2012 (p.103). Retrieved from www.basf.com

GRI. 2011. Sustainability Reporting Guidelines, version 3.1. Global Reporting Initiative, PO Box 10039, 1001 EA Amsterdam, the Netherlands. Retrieved from www.globalreporting.com.

Siemens. 2013. Sustainability report 2012. Key performance indicators (p.2). Retrieved from www.siemens.com

WRI/WBCSD. 2004. World Resources Institute and World Business Council for Sustainable Development. The Greenhouse Gas Protocol - A Corporate Accounting and Reporting Standard, revised edition.

INTERACTIVE WAY TO TEACH ABOUT LIFE CYCLE THINKING AND ASSESSMENT

Jean-Pierre THERET, Dassault Systèmes; 10 rue Marcel Dassault, 78140 Velizy, France ; Tel: +33(0)6 2080 5969; e-mail: jeanpierre.theret@3ds.com*

Keywords: Life Cycle Thinking, Teaching, Learning, Map minding

ABSTRACT

Life Cycle Thinking for product development is part of the fundamentals for better practices in design. This approach is not so easy to communicate even to Designers or to Engineers, because it requires an holistic view on the product from raw materials apportionment to the product end-of-life.

Communicating and teaching on this approach may benefit of innovative method, like the one coming from the mind mapping.

This paper describes a way to explain the main concepts and features of the Life Cycle Thinking with a very simple good: the shampoo. Three scenarios are investigated: assess the environmental performance of the shampoo; compare it to another one; enhance the product.

INTRODUCTION

Life Cycle Thinking (LCT) is not so easy to understand for all actors in the Value Chain, as well as the Life Cycle Approach (LCA) to assess to environmental performance of a Product during its development or for a communication purpose.

One way is to teach and to train about “Design for Environment” and “Life Cycle Assessment” based on the ISO 14040 / ISO 14044 norms, the ELCD Hand-Book and other guidelines… explaining principles, concepts, and presenting methods and tools. Then the Value Proposal may be illustrated by several successful eco-friendly products development.

But like this, many new concepts and information should be learned at a time with difficulties to understand them at a whole.

New teaching approaches need to be tested for more efficiency and a better audience.

METHODS

A new way to teach and to learn may be an interactive one between the trainer and the trainees driven to make the attendees discovering on their own the Life Cycle Approach principles, considering common goods, like shampoo.

The trainer would use:

- Three shampoos (see Figure I): one with a secondary paper packing, one without, and one soap for the three phases of the presentation: evaluate, compare and enhance;

Figure I. Three shampoos

- One map minding tool, the open source FreePlane (…).

The approach for this short training (2 to 3 hours as an overview) is based on self-discovering by the trainer of the principles: environmental impacts & indicators, life cycle, stages, function & functional unit, materials & energy flows, inventory, load factors, mid-points and end-points indicators, 4 levels of the design for the environment…

This approach is also progressive in addressing concepts through three cases treated separately: how to assess the environmental performance of a product, how does it compare to another product, how to improve a product from an environmental point of view?

(Flore Vallet, 2012) has proposed a framework for EcoDesign that may be used for training and that includes three dimensions:

- Dimension related to the designed process of products: several criteria and all phases of the product life cycle should be considered;
- Dimension related to the Supply Chain: many actors are involved in the development of the product all along its life cycle;
- Dimension related to the context of the development of a new product: level from continuous enhancement, re-engineering, new concept to system change; and the different steps of the environmental design.

The proposed approach for training covers for sure the two first ones, and may include the third one depending on the complexity of the case and the available time for the training session.

This approach also falls under the "method by example" category where the activity is carried on a concrete example from where concepts and principles are identified and explained. The trainees know the shampoo, but the trainer should make them discover the hidden face of the shampoo to understand what are the environmental impacts of it with an holistic approach considering the whole life cycles of its components and the product itself.

RESULTS

With this method, start simple with the basic map including the three activities “Evaluate”, “Compare” and “Enhance” like Figure II.

Figure II: Starting map.

The trainer role would be to ask questions to the trainer and assess if there are skilled people among them to organize knowledge transfer between them and the beginners. The training is much more efficient when trainees exchange their knowledge.

The trainer is the animator and would ask questions in cascade to make concepts discovered when studying the shampoo: What are the shampoo environmental impacts? What is a shampoo made of? Why the shampoo causes impacts? Etc.

For that consider the first shampoo sample, the one with the secondary packing which is supposed to be the more impacting one.

Make all the Life Cycle Assessment features be discovered in any order and that is a very powerful capability of the mind mapping tool.

The result may be like Figure III for "Evaluate", or any other map, because the most important is that the trainee discover a bit of the Life Cycle Thinking, not the full picture in once!

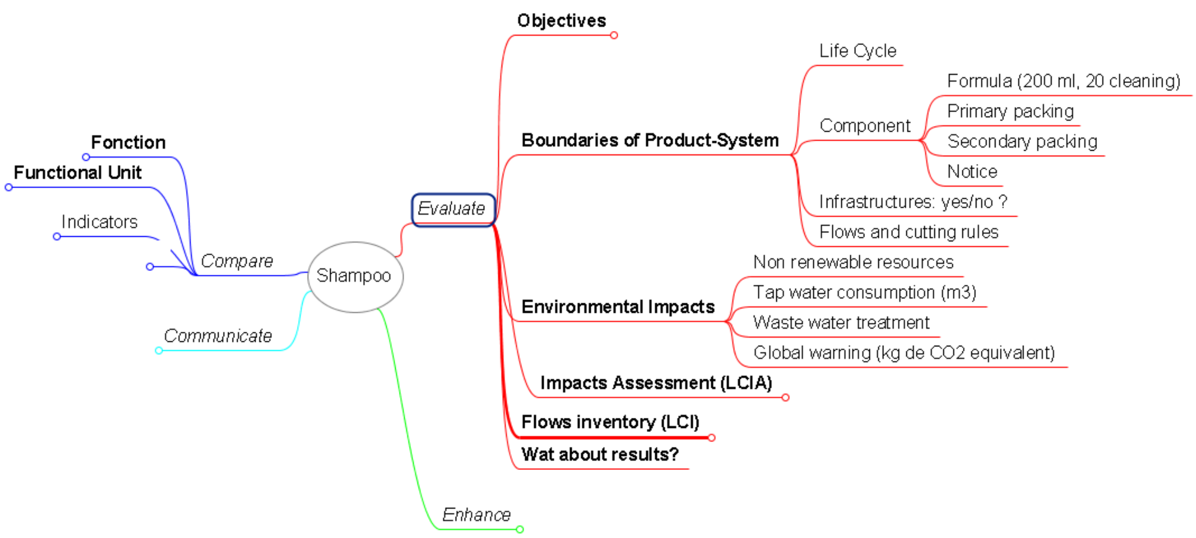


Figure III: Map for Evaluate the shampoo

Function, Functional Unit and other main concepts for LCA may discover later with the second step: Compare the packed shampoo with the second one with no secondary packing.

Then the last proposed step will be to discover how to enhance the two first products; don't show the soap at the beginning but at the end as a new possible product that is functionally equivalent to the two other shampoo (ask to your local drugstore to explain that to you before).

You can also with that way investigate other activities: how to communicate? How to capitalize? Etc.

DISCUSSIONS AND PERSPECTIVES

This approach has been experimented several times for first teaching or overview about Life Cycle Thinking & Assessment of products with success. Feedbacks from the attendees where goods; some of them have required again this training session for other conferences or workshops.

It would be interesting to investigate such training approach for longer and more complete training and study how the trainees can appropriate the mind mapping approach for their own knowledge transfer to other trainees, and also the tool (FreePlane, 2012) for an advanced usage of it.

Please send me back your experiences with similar approach!

REFERENCES

Flore Vallet, 2012, Characterization of best practices in eco-design for training of engineers designers: synthesis of dimensions, methods, tools and activities. Ph D Université de Technologie de Compiègne, France

Zoé Bezpalko (2012), Sustainability Design Guide. http://www.solidworks.com/sustainability/sustainable-design-guide.htm

FreePlane (2012); Free Plane extensions; http://freeplane.sourceforge.net/wiki/index.php/Freeplane_Tutorial_Extensions

SCIENTIFIC DISCLOSURE OF LIFE CYCLE ASSESSMENT IN BRAZIL

Wladmir H. Motta - SENAI/CETIQT

Rua Magalhães Castro, 174 Rio de Janeiro – Brazil. wmotta@cetiqt.senai.br

Keywords: scientific disclosure; life cycle assessment (LCA); IBICT; ABCV; Brazil.

ABSTRACT

The subject life cycle assessment is relatively recent and its practices are still poorly distributed in some nations, is the case of Brazil, where some initiatives have sought to publicize the subject and its practices. This article discusses the role of science communication in the dissemination of LCA in Brazil. The object of this work was conducted on the proposal by the Brazilian Institute of Information in Science and Technology (IBICT) and also the proposal of the Brazilian Association of Life Cycle (ABCV). This study intent to bring, through a bibliographic research, the concepts of scientific publication, pointing out the role of IBICT and ABCV in the disclosure of the subject in Brazil and show the importance of the subject.

INTRODUCTION

The theme of sustainability, where the idea of a compromise between the interests of economic, ecological and social ranks extremely important role, this issue comes punctuating increasingly actions of governments, companies and researchers. In this sense, the proposed LCA, this approach directly addresses environmental conservation and sustainability.

Moreover, this methodology and its practices are still recent, little known and little used in some countries. Brazil is one of these cases, because despite having a significant interest in regard to Latin America, there is still much to do and at present the disclosure of the subject and their practices can be considered one of the most important actions in regarding the subject LCA.

The relationship between science and society has undergone changes and has narrowed increasingly, scientific disclosure can be considered as a good example of how to find this correlation. What was hitherto presented through isolated initiatives passed, gradually, especially after the scientific revolutions of the sixteenth and seventeenth centuries, to become a real and contemporary social demand.

The Brazilian Institute of Information in Science and Technology (IBICT), an agency directly linked to the Ministry of Science and Technology (MCT) of Brazil, has among its basic tasks, providing scientific and technological information, as well as promoting the exchange of information. Activity that IBICT has been doing since 1972, with regular publication of the Information Science journal, with the purpose of disseminating scientific information and technology in Brazil. Other proposals are made by IBICT regarding scientific communication, this study aims to address the work of the Institute in its virtual environment for the Life Cycle Assessment (LCA).

Another institution that has promoted the LCA in Brazil is the Brazilian Association Life Cycle (ABCV), which unlike IBICT, is a civil society, and also nationwide and nonprofit. Founded on November 29, 2002 that works with companies and academic institutions for teaching and research, government and organized society, aims to facilitate the dissemination and consolidation of Management Life Cycle.

As a proposal, somehow new and still little known, the role that IBICT and ABCV are doing in spreading the LCA in Brazil, has a great relevance to gather basic information and expertise on the subject for the general public as well as to experts. This paper seeks to clarify, through a literature review, the concepts of scientific disclosure, the IBICT and ABCV role in publicizing the issue LCA in Brazil and the importance of this issue for society in general.

SCIENTIFIC DISCLOSURE AND TECHNOLOGICAL AND SCIENTIFIC POLICY IN BRAZIL

The scientific dissemination in contemporary societies, where knowledge of science and technology plays a key role in order to understand the complexity of the contemporary world and to assist in decision-making, is given a central role in the dissemination of this knowledge which become essential elements for social inclusion and effective exercise of citizenship. Thus, the scientific disclosure made in various means and media is increasingly present in our daily lives and has been discussed and presented by different professionals within the most diverse perspectives.

According to Pinheiro et al. (2009), science communication involves the transformation of a specialized language in a non-specialized language, with the goal of making the content accessible to a wide audience. For Valerio and Pinheiro (2008), when it comes to scientific communication, the application of new technologies and innovations in general, promote the emergence of opportunities that would foster a narrowing in the gap between those who do science and those that absorb.

Considering the science and technology policies, according to Moreira (2004), recent years have been marked by numerous scientific experiments disclosure in Brazil. For the author, some objectives to guide a national policy began to be drawn, namely:

- Increase the collective appreciation of the value and importance of science and technology;
- To stimulate the creativity and innovation;
- Provide greater presence of the Brazilian science and technology in the media;
- Contribute to the improvement and upgrading of science teaching;
- Stimulate the science communication activities also incorporate the social sciences;
- Encourage people's participation in the debate on the impacts resulting from science and technology.

To Moreira (2004), extend and improve the quality of science communication in the country is important to strengthen a scientific culture. Also emphasizing that this task is only possible from a broad collective process involving various segments of society such as: research institutions, universities, scientific society, government, journalists, educators and students.

METHODOLOGY

This study is classified as exploratory research. As for the means of research, it can be classified as a literature search. In this work, based on published articles and research, we tried to point out the definitions and present the reality lived in Brazil considering science communication, particularly in relation to disclosure of the LCA, the proposal made by IBICT and ABCV through the activities in which both act disclosing LCA and also through their homepages: http://acv.ibict.br and http://www.abcvbrasil.org.br/.

SCIENTIFIC DISCLOSURE OF LIFE CYCLE ASSESSMENT (LCA) IN BRAZIL

The advent of the internet phenomenon, according to Neves (2004), brought revolution in the arrangement of things in the world of information and knowledge, where barriers are down, shortened distances, broken paradigms and behaviors modified. According Massarani (2004), many of the science communication activities developed in Latin America make use of new technologies, especially the internet.

This is the proposal of IBICT and ABCV, as their web pages related to LCA. The LCA methodology is directly related to the sustainable development proposals. The debate on the subject environmental sustainability globally, gained undisputed centrality and strength in recent years. In 1997 he published the first standard of the ISO 14040 family, directly related standard LCA. In Brazil the translation is released in November 2001, being held by the Brazilian Association of Technical Standards (ABNT), which is the body responsible for technical standardization in the country, providing the necessary basis for the Brazilian technological development, standards are: ISO 14040:2009 environmental management - life cycle assessment - principles and framework and ISO 14044:2009 environmental management - life cycle assessment - requirements and guidelines.

The LCA, according Valt (2004), study the complex interaction between a product and the environment, taking into account the evaluation of the environmental aspects associated with the life cycle of the product. Taking into account the entire supply chain of this product, so a proposal very complete and complex, involving several variables.

The IBICT and ABCV webpages about ACV, proposes to disclose the methodology of LCA for both the lay public and for specialists, including in this target industries and Brazilian companies. The pages provide: newsletters, success stories, tips, environmental education for elementary education, events related to LCA; LCA courses; community outreach; community forum, news about ACV; publications and other sites with more information related to LCA, all this information can be found for free at the IBICT webpage and some of this information can be found at the ABCV webpage, with most of it restricted to associated members.

CONCLUSIONS

The rapprochement between science communication and science disclosure derived mainly from the use of the internet, which is nothing but a conglomeration of communications networks worldwide that has enabled thousands of new users of the information could travel on the network, significantly expanding this audience, a reality which has been observed in recent years, bringing greater attention to the new information technologies. In this sense, the role of IBICT as manager of information system of science and technology in Brazil, now has a great importance for the advancement and strengthening of production and dissemination of new knowledge related to science and technology. Serving as a tool to create greater social awareness of scientific activity, clarifying their role and importance to society.

This study sought to present the scientific disclosure of Life Cycle Assessment conducted by IBICT considering the IBICT webpage on LCA as an environment where the general public can have: access to scientific information on the subject through publications; best practices performed information; possibilities for exchange of information through forums, access to information about events related to the subject; access to material relating to environmental education for elementary education and information on other websites with more information related to LCA. The ABCV, also collaborating in this release, providing information on the basis of LCA and its applications, links to the area, event information and a database of theses and dissertations that members can access.

This paper attempted to highlight the importance of IBICT and ABCV web pages, to be disclosing such information on the subject as relevant as the LCA, this issue is still little known and not yet widespread in Brazil. Thus, to be linked directly to environmental proposals, the importance of this scientific publication meets social expectations about sustainable practices and has a political importance as well, since the proposed development is consistent with sustainable prospects governmental and environmental policies.

As the subject is quite comprehensive scientific disclosure and its relationship to sustainability can still be considered fresh, new studies on the subject and in particular on the dissemination of scientific analysis of the life cycle should occur so that we can better understand how this disclosure this occurring and what a way to maximize the expected results regarding access by the general public.

REFERENCES

MASSARANI, L. 2004. Desafios da divulgação científica na América Latina in: Guia de Divulgação Científica SciDev.Net.

MOREIRA, I. de C. 2004. A divulgação científica no Brasil. FAPEMIG, n 18, p-1-2.

NEVES, T.M.G. 2004. Livre acesso à publicação acadêmica, ci.inf., Brasília, v.33, n.3, p.116-121.

PINHEIRO, L.V.R.; SILVA, M.R.; SOUZA, S.B.; BARROS, R.S.; GUERRA, C.B. 2009. Experiência inovadora do Canal Ciência: instrumento pedagógico para aproximar ciência e sociedade, conhecimento e informação. DataGramaZero – Revista de Ciência da Informação – v.10 n.9.

VALERIO, P.M. e PINHEIRO, L.V.R. 2008. Da comunicação científica à divulgação Transformação, Campinas, 20 (2): 159-169.

VALT, R.B.G. 2004. Análise do Ciclo de Vida de Embalagens de Pet, de Alumínio e de Vidro para refrigerantes no Brasil Variando a Taxa de Reciclagem dos Materiais, Dissertation presented to the graduate program in Engineering of Thermal Processes and Chemicals, UFPR, Curitiba.

STATISTICAL APPROACH TO HANDLING UNCERTAINTY IN LCA

Ananda K. Sekar[*]*, PS Sreenivasan, Sivakumar S., Utpal M. Vakil, Shyamal Gondkar*

**SABIC Research & Technology Pvt. Ltd.*

Plot 81-85, Chikkadunnasandra village

Anekal Taluk, Off-Sarjapura-Attibele State Highway

Bangalore 562125 India Ananda.Sekar@sabic-ip.com

Keywords: LCA, uncertainty, communication, bootstrapping, Monte Carlo

ABSTRACT

LCA has been widely used for assessment of environmental performance of product life cycles. Whenever LCA is used in environmental evaluation of alternatives, it is critical for target audience to know the uncertainties associated with reported impacts. This work aims at proposing approaches that companies can adopt to make statistically valid evaluation of alternatives. Another key objective is to conclude if universal "difference thresholds" can be set for claims. For instance, is 10% lower carbon footprint of a product against competitive product adequate for a statistically valid claim? Monte Carlo and Parametric bootstrapping techniques have been used for the proposed approaches. This study also concludes that setting universal "difference thresholds" may not be statistically valid all the time.

INTRODUCTION

LCA is a powerful environmental tool that is used in marketing, framing of policies, apart from use by leading companies in their external communication on sustainability. As its role is linked to functions of strategic significance (policies and regulations, company branding & communication, etc.,) accuracy and credibility of reported impacts become rather very important. This stresses on the criticality of awareness of the decision maker on the uncertainties in reported impacts.

There are three key sources of uncertainty in LCA, namely:

Model uncertainty: This arises due to uncertainties that are inherent when modeling of fate of substances in the environment.

Data uncertainty: This is related to statistical variations in life cycle inventory data.

Scenario uncertainty: This covers statistical variations of measured impacts due to various assumptions made during building of the LCA models.

METHODS

Few approaches to handle model, data and scenario uncertainties have been proposed by this work. Approaches proposed to deal with data uncertainty are described below:

Approach 1: Probability based paired sampling:

In this approach, "paired sampling" Monte Carlo simulation is carried out for alternative products being compared. This may provide user with the probability of a product having lower impacts than its alternative. However this approach may not apply well when a steel product is being compared to a plastic product, since they are inherently based on very different value chains and hence may be considered to be from independent populations from statistical perspective. To overcome this issue, approach 2 has been proposed below:

Approach 2: Confidence interval based approach

In this approach, Monte Carlo based probability distributions of the measured impact are generated separately for both product alternatives.

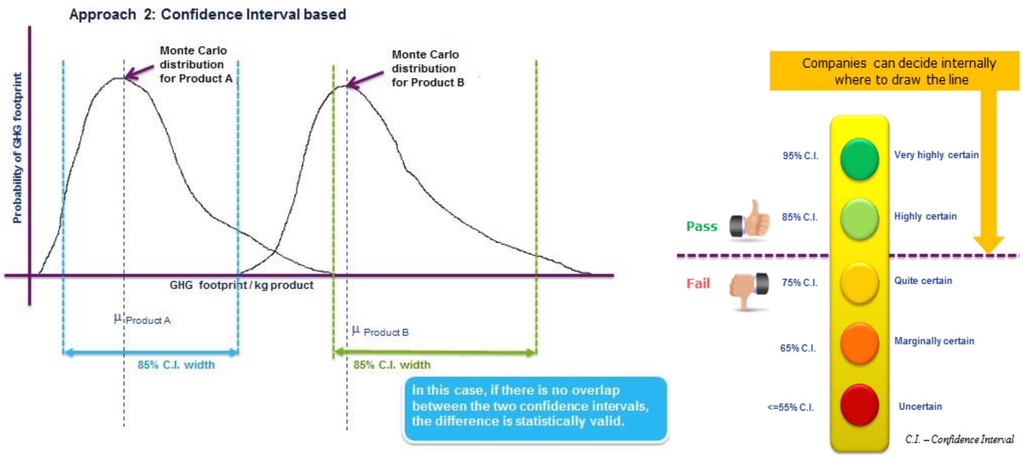


Figure 1: Monte Carlo based Confidence interval approach

By varying confidence interval of the probability distribution of both alternatives simultaneously from 95% down to 55% (in 5% decrements), user can look out for overlap of impact distribution of product alternatives. Overlap regions correspond to situations wherein the product alternatives may have comparable environmental performance. For instance, if the user observes overlap at 95% confidence level but no overlap at 90% then this is analogous to successful statistical hypothesis testing at 90% significance level. Such an approach can allow companies to set pass / fail criterion based on confidence intervals as shown in figure 1 above.

Approach 3: Parametric bootstrapping approach

Most environmental claims reported in public domain are based on deterministic or probabilistic mean of measured impacts. While this is a fair basis, it is also important for the target audience to be made aware of the likely range of variability of this reported value. To address this issue, approach 3 has been proposed.

Parametric bootstrapping technique can be used to generate detailed statistics on a population such as distribution of means, etc. This is a statistical sampling tool that carries out multiple resampling of the sample population so as to come up with a distribution of mean of the sampled population. This tool is available as part of Oracle Crystal Ball (add-on with Microsoft Excel). Process to be followed for performing parametric bootstrapping in Excel (using inputs from Monte Carlo simulation results) are not covered in this text. However the corresponding author can be contacted for further details.

Companies may resort to two different options for external communication based on outputs from Parametric Bootstrapping.

- *Option 1:* External communication on variability of mean of the estimated impacts. For instance, “mean carbon footprint for 1 kg of Product A may vary between 3.87 and 3.93 kgCO2 eq. For cases, wherein this variability is substantial, such communication can provide consumers with transparent information which in turn can enhance company branding.
- *Option 2:* Conservative approach for external communication on the product footprint. For instance, instead of claiming carbon footprint based on deterministic mean of 3.86 kgCO2 eq. for the product, company can claim a more conservative 3.88 kgCO2 eq. based on UCL mean (upper confidence interval mean). For cases where variability of mean may be higher, this can serve as a conservative estimate of the impact. This can ensure that environmental claims made by companies are both statistically sound and conservative.

RESULTS AND DISCUSSION

Another objective of this study was to conclude if a universal “difference threshold” can be set for making claims on a product’s superior environmental performance over its alternatives. The below graph (figure 2) is plotted on confidence interval (x-axis) against percentage difference of impact of the company’s product against its alternative (y-axis). For instance, if a company’s Product ‘A’ has 12% lower carbon footprint when compared to its alternative, then its Y-coordinate takes a value of 12. Each data point on the graph refers to the confidence level at which a product passes the confidence interval test (as described under approach 2 earlier in text). As can be inferred from the figure below, while some products that have lower carbon footprint difference of around 15-20% pass the statistical test at higher confidence levels (products 6 & 8), few others pass only at lower confidence levels (product 3 as in graph below). This would imply that setting difference thresholds may not be considered to be statistically valid all the time.

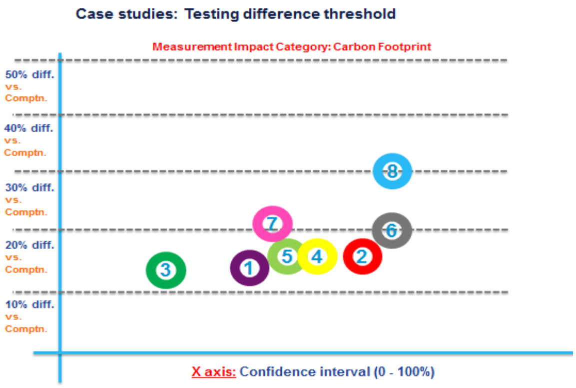


Figure 2: Testing difference threshold for claims

CONCLUSIONS

Based on the reviewed approaches, the following recommendations are made to approach data uncertainty in LCA:

Approach 1 proposed by this work (probability based approach) based on "paired sampling" may be used for comparison of product systems based of same or similar value chains. Approach 2 (confidence interval based) can be used as an effective statistical tool for external communication which allows for short-selection of product systems with superior environmental performance as compared to their alternatives. Based on this study, it can also be concluded that fixing a single universal threshold value of difference for external communication (for instance 10% difference on carbon footprint) is not a statistically valid approach. Approach 3 (robust means based on parametric bootstrapping) can be used for enhancing transparency and credibility in external communication by substantiation of variability of mean of reported environmental impacts. This can enable companies to set new standards for best practices. The proposed process for evaluation of data uncertainty (using approaches 2 or 3) can be easily built into a simple tool for LCA experts, the results of which can be converted into a standard template for use in business external communication.

REFERENCES

Hans-Jorg Althaus, Gabor Doka, Roberto Dones, Thomas Heck, Stefanie Hellweg, Roland Hischier, Thomas Nemecek, Gerald Rebitzer, Michael Spielmann, Gregor Wernet (2007). Overview and Methodology. In Rolf Frischknecht, Niels Jungbluth (Eds.), *Ecoinvent report No. 1 v2.0*.

Pederson, Weidema, Wesnaes (1996). Data quality management for life cycle inventories – an example of using data quality indicators. *Journal of Cleaner Production*, 4(3-4), 167-174.

Christoph Koffler, Martin Baltz, Annette Koehler (2012). Addressing uncertainty in LCI data with particular emphasis on variability in upstream supply chains. *PE International white paper* .

Shanon M. Lloyd, Robert Ries (2007). Characterizing, Propagating and Analyzing Uncertainty in Life Cycle Assessment, A Survey of Quantitative Approaches, *Journal of Industrial Ecology, 11(1),* 161-179.

Andreas Ciroth, Stephanie Muller, Bo Weidema, Pascal Lesage (2012). Refining the Pedigree matrix based approach in Ecoinvent: Towards empirical uncertainty factors. *LCA XII ACLCA Conference presentation.*

WEB BASED TOOLS FOR LIFE-CYCLE ENVIRONMENTAL ANALYSIS
SOME EXPERIENCES WITH PRIVATE COMPANIES AND BUSINESS ASSOCIATIONS

Luca Petruccelli[1], Gian Luca Baldo[1], Massimo Marino[1], Assunta Filareto[1]*
[1]Life Cycle Engineering

Via Livorno 60, Torino 10144, Italy

petruccelli@studiolce.it

Simplified tool; Life Cycle Management; EPD (Environmental Product Declaration); Ecodesign

ABSTRACT

Recently some companies and business/manufacturing associations have stimulated the development of innovative web based tools for the elaboration of ecoprofiles of products as well for CSR (company social responsibility) purposes when many plants participate to the direct data collection. TEA (Tool for Environmental Analysis) is a customized web based platform developed by Life Cycle Engineering to answer to these needs. The paper aims at illustrating two case studies of how LCA information has been used to support life-cycle-analysis and Environmental Product Declaration needs of a couple of associations operating at country level (CONAI, the Italian National Packaging Consortium) and at European level (BWA, Bitumen Water Proofing Association). The new web based tools have the purpose to support decision making at product and at plant level.

INTRODUCTION

In the last years environmental and sustainability issues are becoming important in the daily business practice. The increasing customers interest on environmental aspects of products and services has enhanced the use of EPDs as well as CSR. On the other hand the difficulties of companies and associations of managing sustainability related data are also grown up. Especially for associations the traditional LCA tools do not always fit needs from several actors. Moreover in some case the confidentiality issues could increase the difficulties of data collection. Indeed there is a gap between professional LCA software and customers needs of elaborating ecoprofile without spending excessive efforts in building internal system driving these processes.

The paper illustrates how TEA (Tool for Environmental Analysis), the customized web based platform developed by Life Cycle Engineering, has supported the life-cycle-analysis strategies of a national (CONAI) and European Associations (BWA), in which several participants have been involved in sustainability projects.

Eco Tool Conai

CONAI, promotes the adoption of an environmentally friendly oriented design for packaging solution at source by means of prevention incentives and leverage. The concept of prevention underlying CONAI's activities is also gathered to the general principles of sustainable development. The tool provides the possibility to benchmark the new versus and the existing packaging solution by means of a set of LCA indicators. CONAI associates have access to a wide database of materials and processes that are commonly used by this sector, including end of life scenarios that are monitored by CONAI on national scale.

The Eco Tool Conai is a web portal in which any producers and/or packaging fillers and seller can access to the system in order to assess the environmental potential benefits of ecodesign strategies applied on their packaging. The tool evaluate the overall packaging system starting from the unit retail to the tertiary packaging. The analysis is based on a streamlined LCA, commonly used in this field as decision making tool (*Varghese et al. 2010*), and the tool is able to elaborate three main indicators of potential impact that are, GWP (Global Warming Potential) Water Footprint and GER (Gross Energy Requirement). The selection of these indicator is twofold firstly they are able to identify impact on global aspect that are suitable in streamlined LCA, secondly they are easily understandable by a wide range of users. Ecodesign efficacy is elaborated as percentage delta between the previous and the new version of the same packaging solution. The aim is to evaluate if prevention actions, such as the increase of recycled material content or the change from a mono-use to a refill packaging, are able to reduce impact for all the indicators analyzed. The interfaces and the logical architecture were developed to ease users input data. The information required are the bill of material of the analyzed packaging, furthermore information on transport efficiency, logistic, direct processes consumption can easily added. Specific data such as electricity and thermal energy can be added. These features are included to allow also packaging producers to describe production process efficiency, even if the packaging characteristics are not changed.

The functional unit of LCA assessment is the quantity of product contained in the former packaging solution, therefore if the capacity of new version changes comparison is always consistent. The boundary are set as "cradle to grave" analysis and the open loop approach is set to elaborate *waste treatment* impact according to international EPD® system GRI (EPD 2008). This approach was also in line with the CONAI scope to promote the use of recycle materials. Significant efforts have been made to elaborate detailed Italian waste scenario for packaging. The waste scenario is not defined by users but automatically elaborated by the software basing on two variables which are the packaging typology and material. Since CONAI is the owner packaging waste management at national level, primary and comprehensive data were used to elaborate more than 100 dedicated scenarios e.g. PET Bottle are more recycled than a EPS tray for fruits and meats. As well as the tool is freely accessible for all Italian packaging fillers and seller as well for packaging producers, specific check on data entry have been developed in order to guarantee the consistency of data. LCA results are available to final users only after a CONAI verification to guarantee the reliability and the pertinence of the comparison.

BWA

The Bitumen Waterproofing Association (BWA) provides an authoritative voice for the Bitumen roofing and waterproofing membrane manufacturing industry across Europe and sustainable and environmental issues are, quite rightly, matters of great importance to the association. In this context, in the last 10 years several LCA exercises at European level have been developed by a direct and deep involvement of six clusters and about 40 plants at European level. The new 2012 web based LCA tool has been designed to collect typical LCI data from all European sites with the scope to provide the average European life-cycle environmental burden for EPD purposes as well as a robust tool for R&D to be used by each member company, with a stringent guarantee to respect confidentiality of single companies data. The tool supported the elaboration of the first EPD of an European producers association registered in the international EPD® system (BWA 2013).

The software architecture is based on a hierarchical structure of user in which data flows are illustrate in fig. 1. The Plant user the core of the system, has to provide production information in order to elaborate products eco-profile. The Cluster has the mandate to select plants which comply with the highest level of data quality (reliability and consistency) and to build the “cradle to roof” average. The admin collect data from clusters in order to start "cradle to gate" elaborations. Users from upper lever can ask for data checking and feedbacks to lower level.

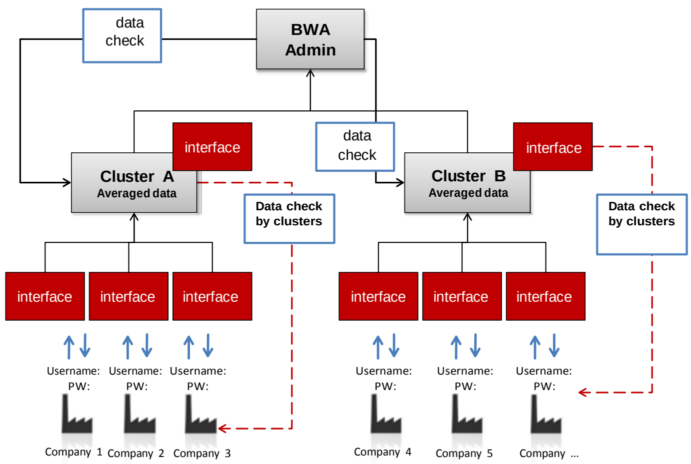


Fig.1 BWA architecture

Moreover, automatic checks were implemented in the tool itself and specific error messages were displayed to inform users in case of basic errors (e.g. insert text in place of a number to express an amount). To improve elaboration robustness, plant users are not allowed to delivery incomplete data to Cluster. The software calculates more than 32 LCA indicator and results are elaborated according to the UNI EN ISO 15804. The use of this software has also allowed to record in the DB thousands of LCI flow, assuring confidentiality among users, able to support the elaboration of several scenario analysis investigating strategy for environmental burden reduction. Moreover the tool is the basis to guarantee that all the producers, at European level have been elaborated and delivered data in the same configuration. Currently the development of the project is to understand the feasibility of the access of the main suppliers in tool. It should allow to increase robustness of results and to involve the supply chain the environmental strategy of the association.

DISCUSSION

The two case studies are briefly reported to highlights how the LCA can be approached in different fields and for different scopes by innovating the elaboration tool. The software developed were based on LCA data, as well as all professional software. The improvement was made in the design of the elaboration structure and in the simplify of data entry in order to fit the customer needs. The potential of these approach is to wider the potential customer interested in include LCA and sustainability information in the production process and supply chain as well in the decision making.

CONCLUSIONS

In both cases, TEA has played the role to make the use of the LCA approach easier and faster also for practitioners with a limited knowledge of LCA principles and at the same time has stimulated new relations with suppliers to improve the environmental management of the cradle to gate productions.

REFERENCES

BWA (2013) Environmental Declaration for Bitumen Roof Waterproofing Systems, Registration number S-EP-00414, available on http://gryphon.environdec.com/data/files/6/9113/epd414e_Bitumem_Waterproofing_Association_Rev1.1_.pdf

EN 15804:2012, Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products;

International EPD (29/02/2008) Cooperation; General Programme Instructions for Environmental Product Declaration; version 1;

International EPD (29/02/2008) Cooperation; Supporting annexes for Environmental Product Declaration; version 1 ;

Verghese K. L., Horne R, Carre A. (2010); PIQET: the design and development of an online 'streamlined' LCA tool for sustainable packaging design decision support, International Journal Life Cycle Assess, No. 15, pp. 608 620.

APPLICATION OF LIFE CYCLE APPROACH IN ENVIRONMENTAL POLICY

Monday, Aug 26: 3:30 pm - 5:00 pm

Session chairs: Eva Ahlner, Swedish EPA, Sweden
Pavel Misiga, European Commission, Belgium

ADDRESSING RESOURCE EFFICIENCY THROUGH THE ECODESIGN DIRECTIVE: A REVIEW OF OPPORTUNITIES AND BARRIERS

Carl Dalhammar, Lund University and Erika Machacek, University of Copenhagen.*

** IIIEE, Lund University, P.O. Box 196, 221 00 Lund, Sweden. Carl.Dalhammar@iiiee.lu.se*

Keywords: Ecodesign, resource efficiency, resource use, resource policies

ABSTRACT

The European Union has initiated a number of initiatives to improve resource efficiency in Europe. The Ecodesign Directive is one of the policy instruments that could aid the transition towards a more resource efficient economy. This paper examines the potential benefits and disadvantages in applying the Directive for this purpose, and reflects on the potential to apply certain types of standards. The research builds on literature studies and interviews. A main conclusion is that some types of legal requirements are more feasible than others, and that the type of product and user patterns are of high importance when legal requirements are assessed.

INTRODUCTION

Resource use considerations have come to the forefront of the sustainability agenda in the last couple of years. Both the European Union (EU) and various nations are currently developing strategies to identify critical resources, promote resource efficiency and address resource security. Apart from developing new policies, better enforcement of existing rules related to recycling is considered a key element in a strategy for resource efficiency.

While an effective response to the resource related concerns would involve a number of strategies at the international, European and national levels, most of the proposed policies – such as resource taxes – are difficult to implement due to political and legal reasons. The policy options are therefore limited. The Ecodesign Directive (Directive 2009/125/EC establishing a framework for the setting of ecodesign requirements for energy-related products) offers one of the few feasible ways to move forward. The Directive is already in place, and significant institutional learning is taking place on how to regulate the ecodesign characteristics of products, due to developments both under the Ecodesign Directive and other EU regulations; these include the WEEE Directive (Directive 2012/19/EU), the RoHS Directive (Directive 2002/95/EC), and the REACH Regulation (Regulation (EC) No 1907/2006).

At the time of its implementation, the Ecodesign Directive was considered to allow for the regulation of a wide range of life cycle aspects, but to-date most implementing measures set under the Directive so far primarily regulate energy efficiency during the use phase. This state of affairs has been criticized (van Rossem et al., 2009). Several current trends provide reasonable and interesting arguments for addressing resource related issues in the future. For instance, as the energy efficiency of products improves, the environmental impacts associated with other environmental life cycle impacts will become relatively more important. We also see shorter and shorter life spans of many product groups such as mobile phones and laptops (Öko-Institut/Fraunhofer, 2012). This means that the importance of energy in the use phase will lose some importance as compared to other aspects.

Recent reports and case studies have outlined different types of legal standards related to resource efficiency that may be set under the Ecodesign Directive in the future (DEFRA; Ardente and Mathieux, 2012). These include: durability requirements to increase life span; removing certain substances to aid future recycling practices; undertaking cost effective design measures to improve future recycling (e.g. by avoiding certain coatings or material mixes); providing information about certain critical materials and where they are placed in the product; other types of bill of material (BOM) requirements providing information about materials and substances; longer guarantee periods provided to consumers; maximum disassembly times; requirements to provide evidence that ecodesign was considered during the design process, and requirements on percentages of recycled content in the product.

OBJECTIVE AND METHODS

This paper provides the main findings from a research project. The main objectives of the research has been to a) examine the potential benefits and disadvantages of addressing resource use through the Ecodesign Directive, and b) to identify barriers that must be overcome in order to do so. The main methods used in the project are: vast literature review of relevant reports and other materials; semi-structured interviews with policymakers and industry representatives, and a case study on a product group (permanent magnet motors).

RESULTS

Addressing resource use issues through the Directive has a number of potential benefits:

- The Directive offers a way forward to address resources, whereas other policy options – such as an increased use of taxes – are less likely to be politically acceptable.
- Standards set through the Ecodesign Directive will – unlike taxes and charges – not necessarily put EU manufacturers at a competitive disadvantage because they apply equally to all products put on the EU market.
- There are even some expectations among stakeholders that the Ecodesign Directive could be “the pioneer instrument” for driving supply chain measures, paving the way for other instruments, e.g. by requiring material declarations or recycled content.
- More generally, the Ecodesign Directive can strengthen life cycle thinking and ecodesign practices, and potentially promote individual producer responsibility (IPR).
- Many actors view stringent energy efficiency standards as source of competitive advantage for EU industries; as they can trigger resource savings, and innovation.

Potential disadvantages associated with addressing resources under the Directive are:

- There are significant delays in the setting of standards for several product groups. More focus on non-energy related requirements could stall the process even further.
- By setting standards related to resources and materials, there is a risk of standards that limits innovation and/or increase costs. However, recent research seems to indicate that product and service regulation seems to be positively correlated with domestic industry

competitiveness (Blind 2012). Further, it is likely that barriers to innovation mainly occur if standards are poorly designed.

- The potential clash between different environmental aspects is a concern. It is likely that there are some inherent conflicts between different environmental objectives. Sometimes conflicts are possible to be solved technically, which reiterates the importance of involving experts in the policy process.

The main barriers towards a greater focus on resource efficiency and recycling under the Ecodesign Directive are likely to be:

- There is a need for better data, and measurement methods in relation to recycling and resources. Many actors are reluctant to set legal standards before these components are in place.
- The interpretation of legal rules can be an issue, most notably the interpretation of Article 15 in the Directive. It states that aspects should only be regulated if they represent a "*significant environmental impact within the Community*" and "*significant potential for improvement without entailing excessive costs*". It is not entirely clear how this wording should be interpreted, especially in relation to resource use issues. *One genuine problem concerns standards set now that could boost recycling in the future*. It is likely that some materials can be cost-efficiently recycled in the future as there are ongoing pilot projects to elaborate and test new recycling methods for commercialization, and prices of some resources are expected to rise. The costs of recycling practices however, will be influenced by the current design, when products are put on the market. However, *even if producers can make design alterations at a very low cost today to allow more cost-efficient recycling in the future, it is not clear if this is allowed under Article 15*.
- Chemicals in products are seen as barriers to recycling standards and requirements on recycled content; many actors do not want to spread toxics and therefore hesitate to promote more recycling until better control over chemicals is exercised.

Regarding the types of legal standards which are possible to be set under the Directive, input was provided by reports and interviews with representatives from industries. The main conclusions are:

- The types of requirements that can be put on products vary depending on product group, as characteristics such as technical solutions, use patterns, and type of business (e.g. B2B or C2C) are of importance.
- Among the potential requirements that was considered possible to apply by several of the interviewees were: durability requirements; removing certain substances from some product groups (to improve recycling); undertake cost effective design measures to improve future recycling (this could include the banning of certain types of design – such as plastic coating – if there is evidence that it is not necessary, and other designs do not lead to high additional costs); provide information about certain critical materials (e.g. individual rare earth element) and where they are placed in the product.
- Requirements in REACH/RoHS/US laws on conflict minerals have meant that there are formats that provide the foundation for more BOM type of requirements. However, keeping track of recycled material, or providing information about material composition is much more complex than providing information about chemicals.
- Among requirements not considered highly feasible and/or desirable are: longer guarantees provided to consumers; maximum disassembly times; requirements to provide

evidence that ecodesign was considered during the design process (since it is hard to monitor and show compliance for such requirements); requirements on percentages of recycled content in the product.

DISCUSSION

The research has provided a better understanding of several issues. For instance, user behavior and estimated life spans of products strongly influence whether durability requirements are feasible. If consumers switch products before there life span expires for reasons of seeking novelty and better functions, durability requirements will lead no over-engineering and thus to wasted resources. Further, methodological problems were discovered. One example concerns recycled content: if virgin material and recycled material are mixed among suppliers, it will be difficult to establish levels of recycled content in a product.

CONCLUSIONS

The overall conclusion is that there are convincing reasons to start working more coherently with resource efficiency requirements under the Ecodesign Directive, but that there is a need to develop further methodologies and extend existing ones to better handle such issues, and to better monitor the interaction between the Ecodesign Directive and other laws. Addressing resources is a "chicken-and-egg" situation: we can hardly expect perfect indicator systems and means of compliance until we have started to set requirements in the policy process. It is therefore worthwile to focus efforts on putting clear rules in place, as for instance, few companies will otherwise devote resources to set up costly supply chain initiatives.

REFERENCES

Commission. Joint Research Centre. Institute for Environment and Sustainability. Report n. 2 of the project "Integration of resource efficiency and waste management criteria in European product policies – Second phaseArdente, F. and Mathieux, F.(2012a) Application of the project's methods to three product groups. European". November 2012.

Blind, K. (2012). The influence of regulations on innovation: A quantitative assessment for OECD countries. Research Policy, 41, 391-400.

CSES/Oxford Research (2012). Evaluation of the Ecodesign Directive (2009/125/EC). Final Report to the European Commission. March 2012.

Global View Sustainability Services et al. (2011). Review of EuP preparatory study evidence: Does it support development of non energy related implementing measures? Report for DEFRA.

van Rossem, C., Dalhammar, C. and Toulouse, F. (2009). Designing Greener Electronic Products: Building Synergies between EU Product Policy Instruments or Simply Passing the Buck? Report: European Environmental Bureau (EEB), Brussels.

Öko-Institut e.V./ Fraunhofer IZM. (2012). Timely replacement of a notebook under consideration of environmental aspects. Report.

ACKNOWLEDGEMENTS

Funding for this research was provided by the Nordic Council of Ministers.

A LIFE CYCLE BASED CLIMATE INDICATOR IN SWEDISH ENVIRONMENTAL POLICY

*Anita Lundström, Eva Ahlner, *Hanna Brolinson Swedish Environment Protection Agency, Sweden. *Postal address: Swedish Environment Protection Agency, SE-106 48 STOCKHOLM, Sweden, email address: hanna.brolinson@naturvardsverket.se.*

Keywords: Consumption-based indicator, climate indicator, greenhouse gas emissions, environment policy.

ABSTRACT

The Swedish parliament has decided that Swedish environmental policy must not lead to increasing environmental and health problems outside of Sweden. By monitoring GHG emissions from consumption, policy-makers and businesses get a better basis for developing and implementing environment and climate policy instruments and measures that actually lead to a reduction on a global level. In order to follow GHG emissions in Sweden and in other countries, caused by Swedish consumption over time, a national consumption based climate indicator has been developed (Swedish EPA, 2013) and applied in the latest in-depth assessment of the Swedish environmental quality objectives. The indicator shows considerable increased emissions during the period 2000 to 2008, at the same time as the national emissions have decreased.

INTRODUCTION

Traditionally, statistics on domestic greenhouse gas (GHG) emissions is used for the following-up of climate performance on a national level. This statistics is reported to the EU and UNFCCC and is also used for national following-up of the climate target. However, this statistics only makes up one piece of the puzzle (Wijkman and Rockström, 2012) as emissions caused outside the Swedish borders are not taken into account. In Sweden, and in many other European countries, a large part of the GHG emissions from consumption (around 40 percent in average), is occurring beyond their borders (EEA, 2010). The global environmental life-cycle impact from consumption in the EU outside its borders therefore needs to be reduced (COM 710 final, 2012).

METHODS

The consumption-based indicator consists of two parts, emissions in Sweden and emissions abroad, both caused by Swedish consumption.

The underlying data source for the emissions in Sweden is the official statistics on emissions reported to UNFCCC, the UN's climate change convention. These emissions are broken down by industry and processed by Environmental Accounts at Statistics Sweden and used in an environmentally extended input-output analysis (Swedish EPA, 2010). The main difference between the domestic emissions caused by Swedish consumption and the domestic emissions reported to UNFCCC is that emissions caused when producing goods for exports are not a part of the emissions caused by consumption.

Emissions due to imported goods that are produced in other countries are estimated according to a model. The model for carbon dioxide emissions is based on how much - in economic terms - is imported from other countries (data from Statistics Sweden), emissions of carbon dioxide reported to Eurostat for EU countries and each country's emissions intensity in relation to GDP (data from World Resources Institute) for countries outside the EU. Emissions of methane and nitrous oxide in other countries are calculated as if they occurred in Sweden.

RESULTS

An indicator for emissions of greenhouse gases caused by Swedish consumption, in order to follow the negative environmental impact in other countries over time has been developed.

The indicator shows the total greenhouse gas emissions caused by Swedish consumption, consisting of emissions in Sweden and emissions in other countries.

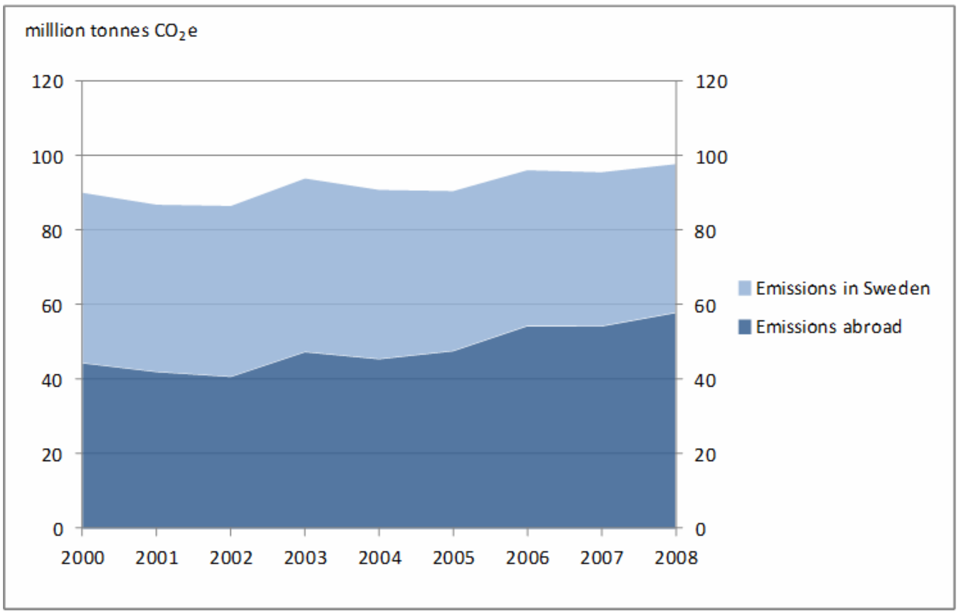


Figure 1. Model calculated emissions of greenhouse gases caused by Swedish consumption, in millions of tonnes of carbon dioxide equivalents (carbon dioxide, methane and nitrous oxide weighted together) 2000 to 2008.

The indicator shows that total emissions caused by Swedish consumption increased from 90 million tonnes carbon dioxide equivalents in 2000 to 98 million tonnes carbon dioxide equivalents in 2008. This implies an increase of 9 percent during the period.

The increase shown by the indicator of the total emissions is caused by an increase in emissions abroad and can be explained in the model by increased consumption met by increasing imports.

DISCUSSION

At the same time as the domestic emissions reported to UNFCCC, the UN’s climate change convention, and to the EU have decreased, the consumption based indicator shows increasing emissions. The increase shown by the indicator of the total emissions is caused by an increase in emissions abroad and can be explained in the model by increased consumption met by increasing imports. An increase can also be the result if the composition of consumption changes, i.e. if other types of products are imported, product types that cause higher emissions, or if the production of imported goods takes place where higher emissions are caused in producing the same type of goods. Nearly half of the increase can be explained by the population growth during the period. To find out more about the driving forces behind the increased emissions, supplementary studies must be performed.

The consumption and life cycle based perspective on emissions require development of new methodologies and statistics to follow up and assess environmental impacts from Swedish consumption along the whole life-cycle. It could also be relevant for Sweden in taking part in work aiming to streamline the methods and data sources used internationally to assess consumptions based emissions.

CONCLUSIONS

The consumption and life cycle based climate indicator shows increasing emissions over time. The increase of the total level is explained by increasing emissions in other countries. The indicator gives a supplementary picture of the overall Swedish GHG emissions. The indicator can be used by policy-makers and businesses to get a better basis for developing and implementing environment and climate policy instruments and measures that actually lead to a reduction on a global level.

REFERENCES

COM (2012) 710 final Subject: Proposal for a decision of the European Parliament and of the Council on the General Union Environment Action Programme to the 2020 “Living well, within the limits of our planet”

European Environmental Agency (EEA) (2010). The European Environment State and Outlook – Consumption and the Environment.

Swedish Environmental Protection Agency (2010). Methods to assess global environmental impacts from Swedish consumption. Report 6395.

Swedish Environmental Protection Agency (2013). Consumption-based indicators in Swedish environmental policy. Report 6508. Wijkman, A., Rockström, J. (2012). Bankrupting nature - Denying our planetary boundaries

ASSESSMENT OF MAJOR ELECTRICITY GENERATION TECHNOLOGIES BASED ON DIFFERENT ENERGY INDICATORS – THE EFFECT OF SYSTEM BOUNDARIES

Ingunn Saur Modahl (Ostfold Research, Norway), Hanne Lerche Raadal (Ostfold Research, Norway), Luc Gagnon (Energy and Climate Change consultant, Canada) and Tor Haakon Bakken (SINTEF Energy Research, Norway)*

** Gamle Beddingvei 2b, 1671 Kråkerøy, Norway. E-mail: ism@ostfoldforskning.no, phone: +47 4112 3551*

Keywords: energy indicators; EPR; CED; system boundaries; electricity

ABSTRACT

The aim of this paper is to improve the basis for the comparison of energy products. The paper is based on results for hydropower, wind power and electricity from biomass, gas and coal, and discusses how system boundaries affect the results of the various energy indicators.

The internal ranking of cases within one electricity generation technology is dependent on the choice of energy indicator. These variations do not, however, alter the general ranking of the major technologies studied.

Future assessments are suggested to focus on a smaller set of energy indicators. CED should be included as it is the most universal indicator.

INTRODUCTION

A wide range of indicators have been designed to impart information about the life-cycle energy performance of energy products. This paper aims to describe the most common energy indicators and define their purpose and system boundaries in order to propose methods to improve the consistency of results. Inconsistencies with regard to energy performance assessment methods have been documented by Davidsson et al. (2012) and Modahl et al. (2012), showing that there is a need for an increased effort in work on standardising energy performance calculations methods.

METHODS

Energy indicators can basically be divided into two categories according to their purpose and system boundaries: 1. Tracking all the energy required by an option. This process requires the inclusion of all upstream and embedded energy. 2. Assess the payback of energy options. A selection of activities is included, without including the embedded energy.

Figure 1 and table 1 present some of the energy indicators used, together with their calculation method and system boundaries.

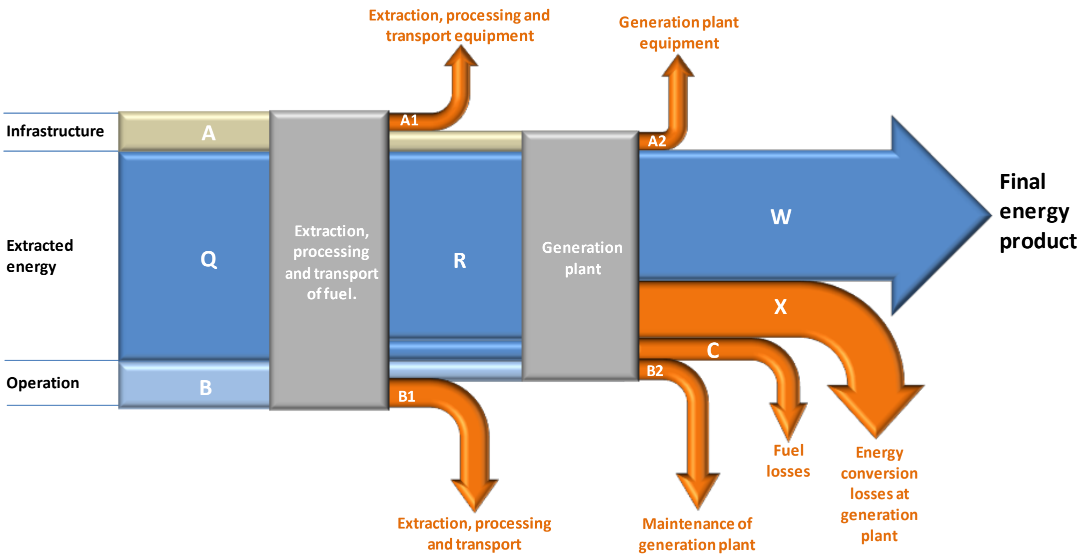


Figure 1 Life-cycle chain of energy products.

Table 1 Energy indicators.

System boundaries	Indicator/ calculation	Description
Embedded energy included.	CED = Cumulative Energy Demand = (A+B+Q)/W	All primary energy required to build, maintain and supply the system, divided by the final energy product generated during a system lifespan.
	NER = Net Energy Ratio = W/(A+B+Q)	Final energy product generated during a system lifespan, divided by the *fossil* energy required to build, maintain and supply the system.
Embedded energy not included as invested energy (the denominator). Based on W/(A+B).	EPR = Energy Payback Ratio = W/(A+B)	Final energy product generated during a system's lifespan, divided by the primary energy required to build, maintain and supply the system.
	Net Energy Payback	Identical to EPR.
	Energy budget	
	Energy ratio	
	EROEI = Energy Return on Energy Investment	
	External Energy Ratio = $W/(A+B)_{fossil}$	Electricity delivered to the grid divided by (fossil fuel energy consumed within the system, minus the energy contained in the fuel fed to the power plant).

RESULTS

Because CED and EPR are the most general indicators in each category, these two were chosen to represent the two different purposes for using energy indicators. These indicators have been compared for all the 44 investigated studies, representing five different electricity production technologies; hydropower, wind power and electricity from biomass, gas and coal (Askham 2007; Vold et al. 1998; Kyläkorpi and Setterwall 2011; Bureau Veritas Certification 2010 and 2011; Ecoinvent Centre 2010; Raadal and Vold 2012; Lenzen and Munksgaard 2002; Burger and Bauer 2007; Schleisner 2000; Voorspools et al. 2000, Crawford 2009; Bauer et al. 2008 and Vold et al. 2012). The study shows that hydropower achieves the best performance, wind power comes second, and the thermal power generation technologies (biomass, natural gas and coal) have the lowest performance. These results are achieved both by CED and EPR.

When looking more closely at the figures, however, the internal ranking between specific cases within one technology is dependent on the choice of indicator.

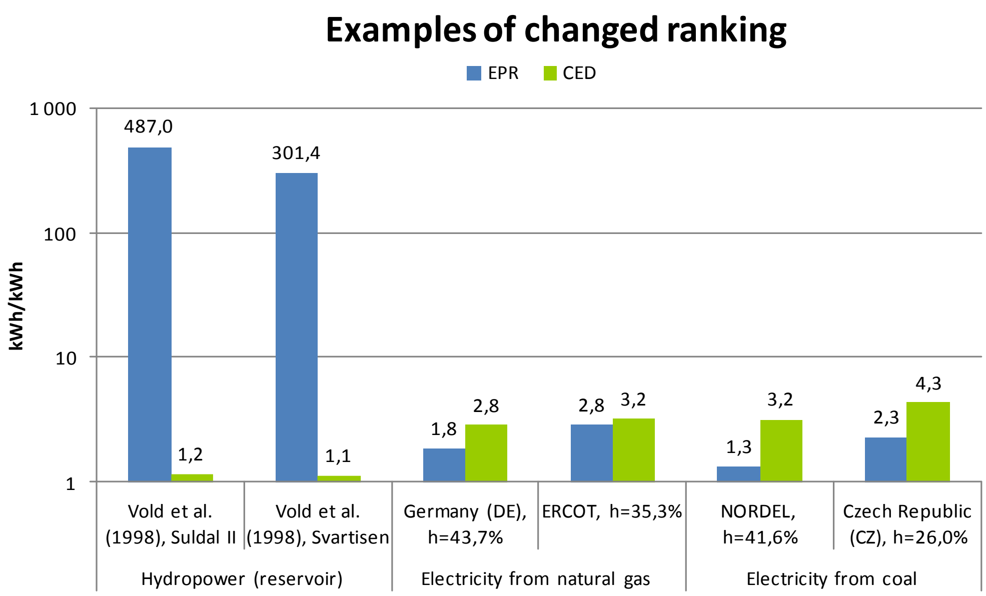


Figure 2 Examples of changed ranking. h = plant efficiency. The higher the EPR, and the lower the CED, the more efficient the performance.

DISCUSSION

As EPR ranks technologies based on “supporting energy”, thus excluding the electricity conversion loss in the invested energy, small differences in supporting energy (compared to the total delivered electricity amount) creates large differences in EPR. In contrast, the CED includes embedded energy as invested energy, showing the energy efficiency throughout the total value chain.

This fundamental difference in system boundaries can lead to the result that a number-one thermal plant according to EPR could be ranked as average, or even the worst case, according to CED, and vice versa.

CONCLUSIONS

It is unlikely that methodological issues would change the overall ranking. However, the internal ranking within each technology is dependent on the choice of indicator, due to the differences in system boundaries of the energy indicators.

Considering the many different energy indicators, it is suggested that future assessments focus on a smaller set of indicators. CED should be included as it is the most universal indicator. In addition, it can be split into the different energy sources and life cycle stages, hence CED can give added information compared to most other indicators.

REFERENCES

Askham, C. (2007): “EPD: Hydroelectricity from Trollheim Power Station”. EPD - Environmental Declaration ISO 14025 NEPD 010E. EPD-Norge/Ostfold Research. http://www.epd-norge.no/getfile.php/PDF/EPD/Energi/NEPD010ETrollheim.pdf.

Bauer, C., C. Dones, T. Heck, and S. Hirschberg (2008): “Environmentalassessment of Current and Future Swisselectricity Supply Options.” In Interlaken, Switzerland.

Bureau Veritas Certification, Sweden (2010): “EPD: Electricity from Wildegg-Brugg Run-of-river Power Plant”. EPD - Environmental Declaration ISO 14025 S-P-00205. Axpo AG. http://www.environdec.com/en/Detail/?Epd=7569#.ULYJsmej-70.

Bureau Veritas Certification, Sweden (2011): “EPD: Au-Schönenberg Small-scale Hydro Plant”. EPD - Environmental Declaration ISO 14025 S-P-00262. Elaqua AG/Axpo AG. http://www.environdec.com/en/Detail/?Epd=7789#.ULYJS2ej-71.

Burger, B., and C. Bauer (2007): “Windkraft. In Final Report Ecoinvent: Sachbilanzen von Energiesystemen: Grundlagen Für Den Ökologischen Vergleich von Energiesystemen Und Den Einbezug von Energiesystemen in Ökobilanzen Für Die Schweiz (ed. Dones R.)”. Final report ecoinvent data v2.0, No. 6. Dübendorf, Switzerland: Swiss Centre for Life Cycle Inventories.

Crawford, R.H. (2009): “Life Cycle Energy and Greenhouse Emissions Analysis of Wind Turbines and the Effect of Size on Energy Yield.” Renewable and Sustainable Energy Reviews 13 (9) (December): 2653–2660. doi:10.1016/j.rser.2009.07.008.

Davidsson, S., M. Höök, and G. Wall (2012): “A Review of Life Cycle Assessments on Wind Energy Systems.” The International Journal of Life Cycle Assessment 17 (6) (July 1): 729–742. doi:10.1007/s11367-012-0397-8.

Ecoinvent Centre (2010): The Ecoinvent Database (version 2.2). St-Gallen: Ecoinvent Centre, Swiss Centre for Life Cycle Inventories. http://www.ecoinvent.ch/.

Kyläkorpi, L., and C. Setterwall (2011): “EPD: Electricity from Vattenfalls Nordic Hydropower”. EPD - Environmental Declaration ISO 14025 S-P 00088. Environdec/Vattenfall. http://www.environdec.com/en/Detail/?Epd=7468#.ULTOr2ej-70.

Lenzen, M., and J. Munksgaard (2002): “Energy and CO2 Life-cycle Analyses of Wind Turbines—review and Applications.” Renewable Energy 26 (3): 339–362. doi:10.1016/S0960-1481(01)00145-8.

Modahl, I.S., K.-A. Lyng, H.L. Raadal, and C. Askham (2012): “Cumulative Energy Demand - How Valid and Comprehensive Are Our CED Practice Today?” In Berlin: SETAC. http://berlin.setac.eu/?contentid=404.

Raadal, H.L., and B.I. Vold (2012): “GHG Emissions and Energy Performance of Wind Power - LCA of Two Existing Onshore Wind Power Farms and Six Offshore Wind Power Conceptual Designs”. OR 24.12. Fredrikstad, Norway: Ostfold Research.

Schleisner, L. (2000): “Life Cycle Assessment of a Wind Farm and Related Externalities.” Renewable Energy 20 (3) (July 1): 279–288. doi:10.1016/S0960-1481(99)00123-8.

Vold, B.I., A. Brekke, and K.-A. Lyng (2012): “Energibruk og konverteringstap ved bioenergiproduksjon (Editor: Sidelnikova)”. Oppdragsrapport A 10-2011. NVE (Norges vassdrags- og energidirektorat). http://webby.nve.no/publikasjoner/oppdragsrapportA/2011/oppdragsrapportA2011_10.pdf.

Vold, M., C. Askham, and C.-H. Borchsenius (1998): “Inventory of Life Cycle Data for Hydroelectricity Produced and Distributed in Norway”. Comissioned report OR 58.98. Fredrikstad, Norway: Ostfold Research Foundation (now Ostfold Research).

Voorspools, K.R., E.A. Brouwers, and W.D. D’haeseleer (2000): “Energy Content and Indirect Greenhouse Gas Emissions Embedded in `emission-free’ Power Plants: Results for the Low Countries.” Applied Energy 67 (3): 307–330.

CONSEQUENTIAL LIFE CYCLE ASSESSMENT OF END-OF-LIFE WOOD PARTICLEBOARDS MANAGEMENT SYSTEM FOR PUBLIC POLICY-MAKING SUPPORT

Mélanie GUITON[1], Daryna PANASIUK[1], Enrico BENETTO[1], Edouard CARTERON[2], Sébastien ZINCK[2]*
[1*] *Public Research Centre Henri Tudor (CRPHT)/Resource Centre for Environmental Technologies (CRTE), 6A Avenue des Hauts-Fourneaux, L-4362, Esch-sur-Alzette, Luxembourg* . Corresponding author: melanie.guiton@tudor.lu
[2] Steelcase International WorkLab

Keywords: Consequential LCA; Policy-making; Wood resources; End of life management

ABSTRACT

At the European level an important stock of particleboards (PB) from end-of-life furniture is currently managed without considering its potential as secondary resource. In France the Grenelle 2 policy recently introduced the principle of "extended producer responsibility", which fostered public policy to reorganize management of end-of-life PB. The ADEME (French EPA) has commissioned a study to assess the current management system and to propose alternatives. In order to assess these alternatives from an environmental point of view, a Consequential Life Cycle Assessment (cLCA) of several prospective scenarios was carried out. Results demonstrated the added-value of assessing the environmental impacts of a global management system in the associated macro-economic environment, and the importance of a precise definition of the policy context.

INTRODUCTION

An increasing demand for wood resources is observed on the market worldwide, inducing a global rise of the extracted volume of wood. The increased demand results from local incentives for GreenHouse Gas (GHG) emissions reduction and from the development of biomass energy including wood. The increased demand for wooden based products such as household and professional furniture, due to societal factors (e.g. shorter replacement cycles before the existing furniture is worn out, increasing demand for a wider variety of products than in the past) is an important driver as well (International Trade Centre UNCTAD/WTO and International Tropical Timber Organization, 2005). Due to this pressure, the availability of wood resources for furniture industry is a subject of debate because of the competition with the energy sector. In parallel, an important stock of particleboards (PB) from end-of-life furniture is currently managed without considering its potential as secondary resource. As of 2012, in France the Grenelle 2 policy introduced the principle of "extended producer responsibility" (REP) for the furniture industry, which fostered public policy to reorganize and improve the chains of collection, valorization and treatment of end-of-life PB. The ADEME (French EPA) has commissioned a study to a consortium of scientists and industrial practitioners aimed to assess the current French PB management system and to propose environmentally-sound alternatives. In order to support the policy-making process steering the strategic evolution of the PB management system, Steelcase, leader in eco-designed professional furniture, and CRP Henri Tudor have carried out a consequential LCA (cLCA) of several prospective policy scenarios, in combination with an attributional LCA (aLCA) of the system at status-quo conditions.

MATERIALS AND METHODS

The study addressed two questions. The first one is related to the assessment of potential environmental impacts generated by the average operation of the PB management system, before and after the changes occurring from the implementation of the "extended producer responsibility" principle. The year 2009 was considered as reference, reflecting the existing system operation at status-quo conditions, mainly because of the availability of inventory data regarding the PB stock, collection, valorization and treatment (Lescop et al, 2010). The year 2020 has been chosen as the year reflecting system operation after changes occurred, because of the related political objectives set at the national and European level (e.g. energy and climate "20-20-20" objectives). Status quo situations at the two time horizons were evaluated through aLCA approach (Figure 1). The second question aims at evaluating the environmental consequences generated by the "extended producer responsibility" principle implementation, through a consequential LCA (cLCA) approach (Figure 1).

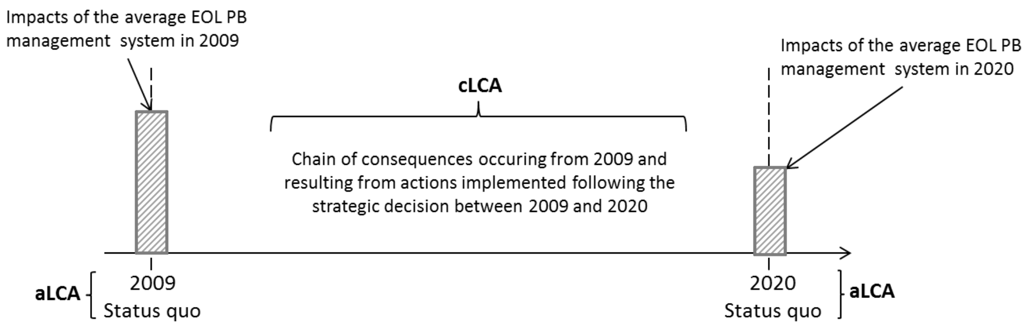


Figure 1: Combination of aLCA and cLCA .

Three prospective scenarios representing different (economic) drivers were considered. The first one (Scenario 1) is based on the EU and French legislation objectives, promoting the recycling of end-of-life PB and reserving the raw wood to the wood energy sector. The second prospective scenario (Scenario 2) takes into account the use of raw wood for PB production and the use of end-of-life PB for energy production. This scenario ultimately depends on the flexibility of regulations regarding waste wood incineration. The last scenario (Scenario 3) is in between the two others, assuming a realistic technical capacity to integrate end-of-life PB in the different treatment technologies considered, based on interviews with experts in the field. For each scenario, the flows of end-of-life PB and treatment technologies – i.e. municipal incineration, energy production in industrial boiler, recycling in PB production, reuse, recycling in cement production and in steel production – were calculated based on accurate analysis of present and prospective regulatory, market, and technical issues. For most of the consequence chains, the scope of cLCA was limited to the direct (first level) consequences from the implementation of the three scenarios, because of the limited constrains and co-product effects in the foreground life cycle inventory system.

RESULTS

Life cycle impact assessment (LCIA) results for both the attributional and consequential LCA approaches are illustrated in Figure 2.

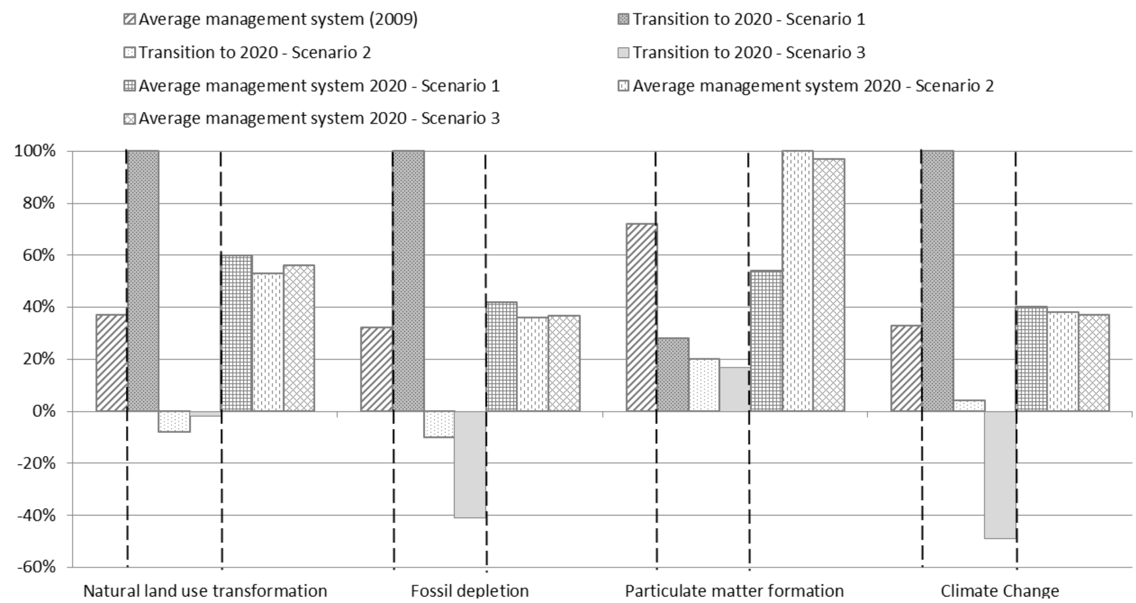


Figure 2: Life Cycle Impact Assessment (LCIA) results

Regarding natural land transformation, assessed using the ReCiPe methodology (Goedkoop et al, 2009), the consequences following scenario 1 are more important than for scenarios 2 and 3. This is due to the higher PB recycling rate of scenario 1 which leads to the replacement of raw wood for PB production and the corresponding avoided impact of natural land transformation. As a consequence, the demand for raw wood from the energy production processes increases (as well as the demand for fossil fuel, supplied by natural gas), in order to substitute the part of PB originally sent to municipal incineration and valorization in industrial boiler. This indirect effect generates an additional impact on natural land transformation. In the case of scenarios 2 and 3, the effect is less important since the demand for raw wood for novel PB production process is not significant compared to the additional demand for energy production processes observed in scenario 1. Regarding the impacts on fossil depletion, using EDIP2003 (Hauschild et al, 1998) and ReCipE, scenarios 2 and 3 show an evident advantage because of valorization of end-of-life PB in energy production processes, replacing fossil fuels. Scenarios 2 and 3 present a larger contribution to particulate matter formation (using ReCiPe) than in Scenario 1, due to the larger amount of PB incinerated in order to produce energy.

Concerning Climate Change, the additional combustion of natural gas in scenario 1 generates a higher impact score than scenarios 2 and 3, which show a significant avoided impact due to the substitution of petroleum coke and natural gas in cement plant. In scenario 3, the valorization of 4% end-of-life PB in steel electric furnace production, replacing anthracite and pulverized coal, represents an additional significant avoided impact. In order to account for the carbon storage in the PB recycled and reused against the carbon release through PB incineration, the Time Adjusted Warming Potential (TAWP; Kendall, 2012) was used. Time series were considered in order to account for the cumulated biogenic carbon emissions over an observation period 2009-2104, representing the period during which a fraction of end-of-life PB stock from 2009 is kept into the system. The results showed a much more important delay of carbon recirculation in the case of transition scenario 1. The comparison of the environmental impacts from the average operation of end-of-life PB management system following the three 2020-scenarios show the same trends, except for particulate matter formation.

DISCUSSION

Results for Scenario 1 are hampered by the LCA methodological shortcomings regarding the accounting of wood extraction impacts and the regionalised assessment of land transformation. Consequential models for scenarios 2 and 3 should be refined in order to include emissions from the combustion of PB in industrial processes. Also, additional indirect impacts in the chain of consequences should be better investigated, and the geographical area beyond the French boundaries should be extended, in order to account for import/export of raw wood and end-of-life PB. Results have demonstrated the particular interest of transition scenario 1 regarding the recirculation of biogenic carbon stored in PB, and for the amount of raw wood made available for energy production. Transition scenarios 2 and 3 present clear advantages due to the substitution of fossil resources by PB and to the flexibility of energy production processes as compared to recycling, for which infrastructures exist only in a few regions of France. Also, the added-value of assessing the environmental impacts of a global management system in the associated macro-economic environment, beyond the analysis of specific technical barriers, was demonstrated, requiring an accurate definition of the policy context and the involvement of decision-makers.

CONCLUSIONS

The final recommendation is to promote PB recycling, based on the actual capacity of PB manufacturers to use end-of-life PB in the production processes, and to set realistic recycling percentages objectives for 2020, which would not require substantial investments. The potential of PB valorization in cement and steel production should also be explored further although these sectors, especially steel, does not seem to be ready for this transition.

REFERENCES

Goedkoop M., et al. (January 2009). ReCiPe 2008. A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. *First edition. Report I: Characterisation*.

Hauschild M. et al. (1998). Environmental Assessment of Product. Volume 2: Scientific background. *Chapman & Hall, London. ISBN 0 412 80810 2.*

International Trade Centre UNCTAD/WTO and International Tropical Timber Organization. (2005). International wooden furniture markets, a review. *ISBN 92-9137-284-6*

Kendall A. (2012). Time-adjusted global warming potentials for LCA and carbon footprints. *Int. J of LCA. DOI 10.1007/s11367-012-0436-5*

Lescop J-B., Mugnier E., Paupart C., Servantie A., April M. (Novembre 2010). Dimensionnement et cadrage de filières pour la gestion des mobiliers ménagers et professionnels usagés. *Rapport Final. Ernst & Young, ADEME.*

DETERMINATION OF THE PUBLIC TRANSPORT POLICIES FOR ESKISEHIR CITY THROUGH LIFE CYCLE ASSESSMENT

Müfide Banar[1] Alp Özdemir[2] Zerrin Çokaygil[1] Aysun Özkan[1]*

[1]Anadolu University, Faculty of Engineering, Department of Environmental Engineering, Iki Eylul Campus, 26555, Eskisehir / Turkey mbanar@anadolu.edu.tr
[2] Anadolu University, Institute of Transportation Science, Eskisehir/Turkey

Keywords: Eskisehir; LCA; Public transport.

ABSTRACT

In this study, it was aimed to make an environmental assessment of current public transport system and alternative systems by using LCA method in order to support decision makers. To realize this aim, three new public transport systems were developed as an alternative to current public transport system in accordance with the further policies of Eskisehir Greater City Municipality. The public transport options in current system (in the year of 2012) and alternative scenarios for the years of 2014, 2020 and 2023 are given as S_1, S_2, S_3, S_4, respectively. In LCA, scenarios were compared using CML 2 baseline 2000 method for the selected impact categories. According to the total results, human ecotoxicity, fresh water aquatic ecotoxicity and terrestrial ecotoxicity would be reduced by almost 1.8, 1.6, 1.4 times by S_4 scenario compared to S_1 scenario. Also, S_4 scenario has been detected the lowest environmental impact in these impact categories.

INTRODUCTION

In literature, several studies were carried out by using life cycle assessment for transportation systems. In order to effectively reduce environmental impacts from transportation modes, life cycle environmental performance should be considered to operate the vehicles. Chester, Horvath and Madanat (2010) were performed a LCA for existing transit modes in three different large metropolitan areas of the United States; New York City, Chicago and Los Angeles. Oua, Zhang, and Chang (2010) were examined the life cycle GHG emissions and energy use for several alternative fuel buses including several different fuel technologies in China from a well to wheels (WTW) approaches. Ally and Pryor (2007) were conducted a study for the Sustainable Transport Energy Program for the government of Australia focusing on life cycle impacts of diesel, natural gas and hydrogen fuel cell buses. The other studies (Bartolozzi, Rizzi, & Frey, 2013; Chester et al., 2012) by using life cycle assessment were performed to evaluate the environmental performance of urban/public transportation model including vehicle, infrastructure and fuel inventories.

In this study, it was aimed that to realize an environmental assessment of current public transport system and alternative systems for Eskisehir city by using LCA method in order to support decision makers. For this aim, LCA analysis was carried out at three stages; goal and scope, life cycle inventory and life cycle impact assessment. In the first step, the system boundaries and functional units were determined. In the second step, materials and energy components with releases of pollutants were formed on the basis of functional unit. In the last part of the study, the environmental impacts of compartments (vehicles, infrastructure and energy) of public transport scenarios have been calculated based on CML baseline 2000 method for selected impact categories by using licensed SimaPro 7.3.3 PhD version.

METHODOLOGY

In this study, the daily percentile distribution of public transport options in current system (in the year of 2012) and alternative scenarios for the years of 2014, 2020 and 2023 are given as follow: S_1 (2012): (37.5% tram + 37.5% bus + 25% minibus), S_2 (2014): (75% tram + 20% bus + 5 % minibus), S_3 (2020): (75% tram + 12.5% hybrid electric bus + 12.5% bus) and S_4 (2023): (75% tram + 25% hybrid electric bus). In **S_1 scenario**, daily 240,000 passengers are carried by 23 trams, 200 buses and 211 minibuses. The total length of tramline is 16 km (double line) and total main road's length is about 200 km. In **S_2 scenario,** daily 250,000 passengers would be carried by 33 trams, 100 buses and 65 minibuses. The total length of tramline is planned to be extended along 34 km (double line) in 2014 whereas there is no extension plan for main road's length (200 km). In **S_3 scenario,** it is expected to transport daily 272,000 passengers by 33 trams, 68 buses and 25 electric hybrid buses. For **S_4 scenario**, daily 282,000 passengers are expected to be carried by 33 trams and 50 electric hybrid buses. It was assumed that the total length of tramline and road's length in S_2, S_3 and S_4 scenarios were the same. These data were obtained by Eskisehir Greater City Municipality personnel.

In the case of public transport, summary of the system boundaries are given in Fig.1. Daily passenger number has changed with the population, vehicle types and simultaneously road types have changed with the technology and the economical capability of the municipality, electricity production mix has changed with the government policies. For these reasons, in this study, *functional unit* was distinguished into three parts: daily public transport in Eskisehir was considered as "operational functional unit"; number of vehicles to transport was taken into account as "vehicle functional unit" and the total length of tram rail and road were considered as "infrastructure functional unit."

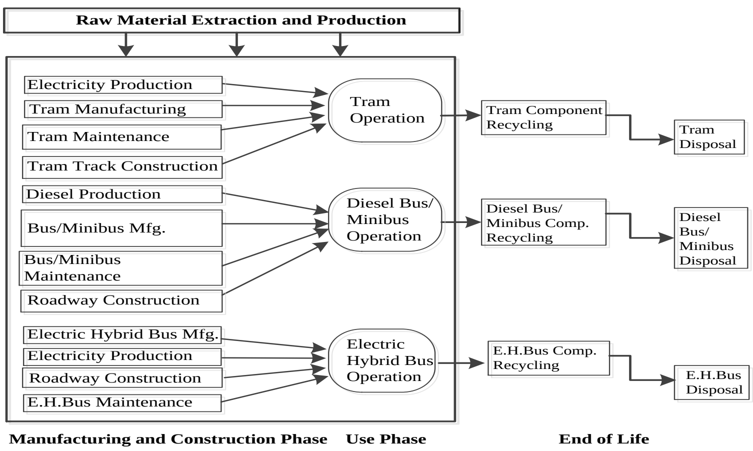


Figure 1. System boundaries of the study

Life cycle inventory (LCI)

The data regarding to tram and bus were obtained from the Ecoinvent databases in SimaPro 7.3.3 software. The data related to other vehicles were calculated based on the literature EEA (2007) and adapted from Ecoinvent database. Infrastructure data for tram line and roadway were obtained from Ecoinvent database. Energy production data were obtained from Spielmann, Bauer, Dones, & Tuchschmid (2007) and Banar, Özdemir, Çokaygil, & Özkan (2013).

Manufacturing of vehicles (bus, minibus and hybrid electric bus) processes related to energy, materials and emissions data were gathered from Ecoinvent database and it was adapted to Eskisehir public transportation system. In operation of vehicles processes, fuel/energy consumption of vehicles was calculated as kg fuel or kWh per kilometers. According to these calculations; bus, minibus, tram and hybrid electric bus consume 0.139 kg diesel, 0.916 kg diesel, 1.75 kWh electricity and 0.05 kWh electricity per kilometer, respectively. The emissions and other pollutants sourced from bus and minibus operation process were calculated based on the EEA (2007); Spielmann et al. (2007) emissions inventories and the other vehicles (tram and electric hybrid bus) operation emissions data were calculated based on Ecoinvent database.

Energy, materials and emissions data regarding to construction and maintenance of roadway and tram line was obtained from the literature (Spielmann et al., 2007). It was considered that the tram line consists of double line that each has 6.5 m and the roadways lines have three layers consisting of gravel, concrete and bitumen.

Turkey electricity mix for the years of 2012, 2014, 2020 and 2023 were estimated according to “Electricity Energy Marketing and Security of Supply Strategy Paper” (2009) and Banar et al. (2013).

RESULTS

The LCA calculations were carried out by using licensed SimaPro 7.3.3 PhD version. In the impact assessment step, the CML2 2000 baseline method was applied. According to the percentiles of normalized impact rates (calculated from normalization results) impact categories (abiotic depletion, acidification, eutrophication, global warming, human toxicity, freshwater aquatic ecotoxicity and terrestrial ecotoxicity) with impact rates equal and over than 4% have been selected for further investigations. Additionally, the radar graphs of four different scenarios were plotted in Fig.2. According to Fig. 2, environmental impacts resulted from vehicles and infrastructures have the almost same effect for S_1. On the other hand, the effect of vehicles decrease while the effect of infrastructure increased from 2014 (S_2) through 2023 (S_4) scenario.

CONCLUSIONS

According to results, generally it was observed that manufacturing of vehicles, electricity or fuel consumption and infrastructure are components of the public transportation system that would affect the results. The results show that all impact category values of S_2 (75% tram +

20% bus + 5% minibus) show an increase with respect to the S_1 (37.5% tram + 37.5% bus + 25% minibus) excluding the values of total toxicity. It was thought that these increases resulted from the increasing number of trams and tram line extension while the buses and minibuses were still in operation. Although there was a reduction on the number of buses and minibuses, this reduction had no considerable effect in the whole scenario. Human ecotoxicity, fresh water aquatic ecotoxicity and terrestrial ecotoxicity would be reduced by almost 1.8, 1.6 and 1.4 times, respectively, by S_4 scenario compared to S_1 scenario due to the reduction on the number of total vehicles and electricity production from renewable resources in 2023. As a conclusion, although the S_4 scenario (75% tram + 25% hybrid electric bus) seems to the best scenario, future study that would be focus on economic, social and technical effects should be carried out by application of Multi Criteria Decision Making (MCDM) to give a certain decision for the public transport system.

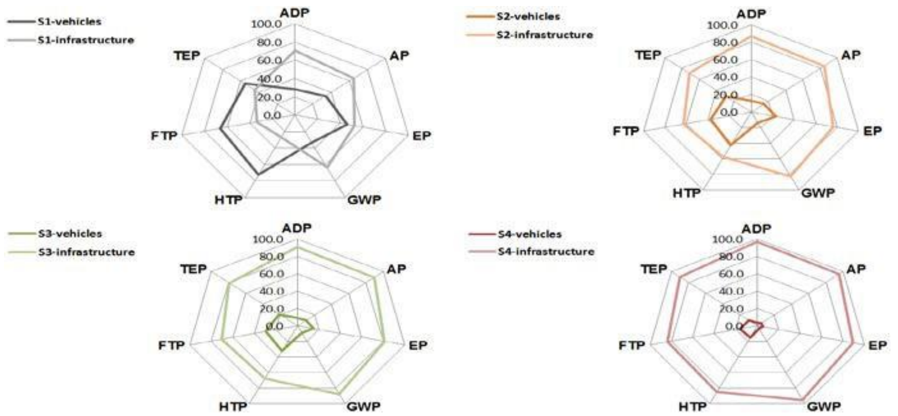


Figure 2. Life cycle impact assessment of different scenarios

REFERENCES

Ally, J., & Pryor, T. (2007). Life-cycle assessment of diesel, natural gas and hydrogen fuel cell bus transportation systems. *Journal of Power Sources, 170*(2), 401-411. doi: 10.1016/j.jpowsour.2007.04.036

Banar, M., Özdemir, A., Çokaygil, Z., & Özkan, A. (2013). *Life Cycle Assessment Based Comparison of Electricity Power Generation Alternatives in Turkey*. Paper presented at the 3rd International Exergy, Life Cycle Assessment, and Sustainability Workshop & Symposium (ELCAS-3), Nysros, Greece.

Bartolozzi, I., Rizzi, F., & Frey, M. (2013). Comparison between hydrogen and electric vehicles by life cycle assessment: A case study in Tuscany, Italy. *Applied Energy, 101*, 103-111. doi: 10.1016/j.apenergy.2012.03.021

Chester, M., Eisenstein, W., Pincetl, S., Elizabeth, Z., Matute, J., & Bunje, P. (2012). Environmental Life-cycle Assessment of Los Angeles Metro's Orange Bus Rapid Transit and Gold Light Rail Transit Lines.

Chester, M., Horvath, A., & Madanat, S. (2010). Parking infrastructure: energy, emissions, and automobile life-cycle environmental accounting. *Environmental Research Letters*, *5*(3), 034001. doi: 10.1088/1748-9326/5/3/034001

EEA. (2007). Emission Inventory Guidebook- Group 7: Road Transport Retrieved 07.04.2013, from http://www.eea.europa.eu/publications/EMEPCORINAIR4/page016.html

Oua, X., Zhang, X., & Chang, S. (2010). Alternative fuel buses currently in use in China:Life-cycle fossil energy use, GHG emissions and policy recommendations. *Energy Policiy, 38*, 406-418. doi: 10.1016/j.enpol.2009.09.031

Spielmann, M., Bauer, C., Dones, R., & Tuchschmid, M. (2007). Transport Services Data v2.0. Dübendorf: Swiss Centre for Life Cycle Inventories.

ENVIRONMENTAL IMPACTS OF FOOD CONSUMPTION AND ITS REDUCTION POTENTIALS

Niels Jungbluth[1,*], *Karin Flury,* [1] *Geneviève Doublet*[1]

ESU-services Ltd., CH-8050 Zürich, www.esu-services.ch/projects/lifestyle/

Corresponding author. E-mail: jungbluth@esu-services.ch

Keywords: food consumption, reduction potential, environmentally friendly diet, sustainable life style

ABSTRACT

Nutrition accounts for 30% of environmental impacts caused by the final consumption of Swiss households. It is the most important activity from an environmental point of view. We investigated possibilities to reduce the environmental impacts of food consumption, energy use and mobility in a systematic approach for different behavioral options of consumers. Most important improvements for nutrition can be expected on the level of diets and especially in the reduction of meat consumption. The approach has also been applied in the consumption sectors mobility and energy use of households. It allows for a systematic comparison of the reduction potential of environmental impacts due to different changes in consumer behavior.

GOAL AND SCOPE

Nutrition accounts for about 30 % of environmental impacts caused by the final consumption of Swiss households (Jungbluth, Nathani, Stucki, & Leuenberger, 2011). It is the most important consumption sector from an environmental point of view. Therefore, it is necessary to investigate and understand the environmental impacts of food consumption and possibilities for the reduction of these environmental impacts.

We investigated possibilities to reduce the environmental impacts of food consumption in several LCA case studies during the past 15 years. Several options of reducing environmental impacts have now been compared within a general framework. Besides the consumption of food products also reduction potentials for impacts due to energy use in households and private mobility have been investigated (Jungbluth, Itten, & Stucki, 2012). The assessment has been made for average consumption patterns in Switzerland and the city of Zurich (Jungbluth & Itten, 2012).

METHOD

The method follows a stepwise approach (Jungbluth, et al., 2012). In a first step, the total environmental impact of Swiss consumption was calculated. Then the share of the environmental impacts related to food consumption was assessed. Based on a more detailed analysis of this consumption sector, it was investigated by what percentage environmental impacts can be reduced by a certain change in the consumer behavior. Finally, this estimation is used to evaluate the potential reduction of the total environmental impacts. For the impact assessment the ecological scarcity method was used as a key indicator (Frischknecht, Steiner, & Jungbluth, 2009), but the results were also computed for greenhouse gas emissions and cumulative energy demand.

RESULTS

Share of food consumption

The investigation of the share of the environmental impacts shows that nutrition causes about 12% of total energy demand and 18% of greenhouse gas emissions of the total Swiss consumption. If all types of environmental impacts are included in the analysis this share rises to about 30% (Jungbluth, et al., 2011). The main part of the environmental impact arises from the agricultural production of meat.

Changes in consumer behaviour

Consumers can aim to reduce the environmental impacts by decisions on different levels(Jungbluth, Tietje, & Scholz, 2000). These range from the choice of packages for a product, preferences for certain labels, choices on ingredients for a meal, vegetarian or other diets to general considerations such as e.g. concerning household budgets. In this short paper we present and compare the reduction potential in the total environmental impacts, if all consumers:

- Buy locally (no air-transported products)
- Buy seasonally (no fruits and vegetables from heated greenhouses)
- Vegetarian diet
- Buy organic food
- Resign on luxury food (chocolate, wine, coffee etc.)
- No food wastes in households
- Reduce obesity to normal weight
- Combine different changes towards a healthy and environmentally friendly diet

Example for modelling a vegetarian diet

A vegetarian diet is one approach to reduce the environmental impact. The comparison of meat products with vegetarian alternatives however is complicated because vegetables or other vegetarian products cannot always one-to-one substitute meat. In order to overcome this obstacle, we assessed the environmental impact of 10 different meat based and vegetarian canteen meals. The meat-based meals have an average environmental impact of 6622 ecopoints per meal and the vegetarian meals account for 2085 ecopoints (Leuenberger & Jungbluth, 2009) which equals a reduction potential of more than 50%.

Reduction potentials

The most promising single change in behavior is a vegetarian diet. The next best option is the resign on luxury products such as alcohol, coffee and chocolate. A further important option is the reduction of food waste. A regional or seasonal choice of products only does however not show such a high potential for reducing environmental impacts. Different such measures can be combined in order to achieve an even higher reduction potential: For the modeling of the "healthy and environmentally friendly diet", it is assumed that meat consumption is reduced to two portions a week instead of six. Furthermore, air-transported products are not bought anymore and fruits and vegetables are purchased seasonally. With this combination of measures it would be possible to reduce the environmental impacts of total household consumption by more than 12% (and cut the impacts of the nutrition by 40%).

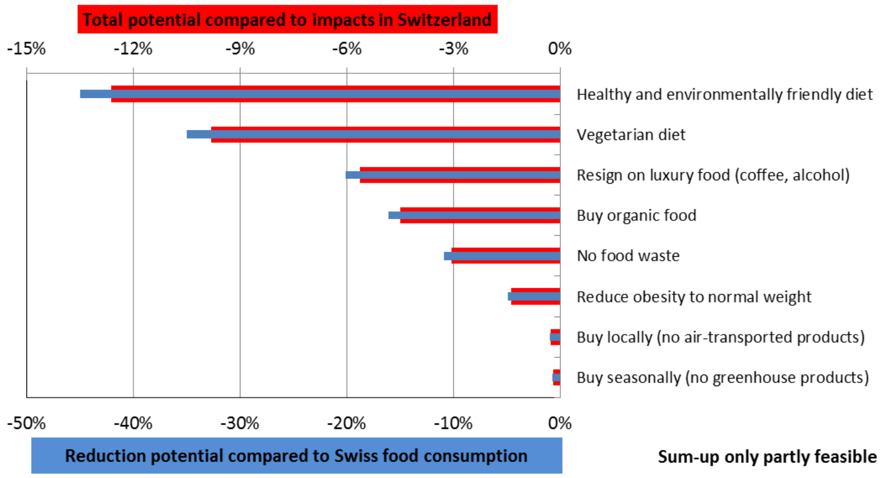


Fig. 1: Reduction potentials for total environmental impacts (ecological scarcity method 2006) due to behavioral changes in food consumption

CONCLUSIONS & OUTLOOK

With this research, it has been shown that, the reduction of meat and animal products is the most important issue from an environmental point of view. Also important is the reduction of luxury food and food wastes. The same methodological approach has also been applied on the consumption sectors energy and mobility and thus allows a consistent framework for the comparison of different changes in consumer behavior.

REFERENCES

Frischknecht, R., Steiner, R., & Jungbluth, N. (2009). The Ecological Scarcity Method - Eco-Factors 2006: A method for impact assessment in LCA. Zürich und Bern: Federal Office for the Environment FOEN.

Jungbluth, N., & Itten, R. (2012). Umweltbelastungen des Konsums in der Schweiz und in der Stadt Zürich: Grundlagendaten und Reduktionspotenziale. Zürich: ESU-services GmbH im Auftrag der Stadt Zürich.

Jungbluth, N., Itten, R., & Stucki, M. (2012). Umweltbelastungen des privaten Konsums und Reduktionspotenziale. Uster, CH: ESU-services Ltd. im Auftrag des BAFU.

Jungbluth, N., Nathani, C., Stucki, M., & Leuenberger, M. (2011). Environmental impacts of Swiss consumption and production: a combination of input-output analysis with life cycle assessment (pp. 171). Bern, CH: ESU-services Ltd. & Rütter+Partner, commissioned by the Swiss Federal Office for the Environment (FOEN).

Jungbluth, N., Tietje, O., & Scholz, R. (2000). Food Purchases: Impacts from the Consumers' Point of View Investigated with a Modular LCA. *Int J LCA*, *5*(3), 134-142.

Leuenberger, M., & Jungbluth, N. (2009). Ökoprofil von vegetarischen und fleischhaltigen Grossküchenmahlzeiten. Uster, CH: ESU-services GmbH im Auftrag des WWF Schweiz.

IMPLEMENTATION OF THE ECOLOGICAL SCARCITY METHOD FOR THE RUSSIAN FEDERATION AND GERMANY

Marina Grinberg, Robert Ackermann, Matthias Finkbeiner, Technische Universität Berlin, Berlin, Germany*

Address: Technische Universität Berlin, Institut für Technischen Umweltschutz, Sekretariat Z1, Strasse des 17. Juni 135, 10623, Berlin, Germany

E-mail: marina.grinberg@mailbox.tu-berlin.de

Keywords: life cycle impact assessment; ecological scarcity; transformation rule, chemical oxygen demand.

ABSTRACT

The ecological scarcity method refers to Life Cycle Impact Assessment (LCIA) methods. The intent of the method is to evaluate different kinds of the environmental impact in the same units, eco-points. To do this it is necessary to have database of eco-factors (EF) values for the pollutant or resource consumption. Transformation rules advance the eco-factor calculation for different countries in the case if data for the direct calculation are missed. The paper provides results for definition of transformation rules between Switzerland, Japan, Germany and the Russian Federation, based on the example of chemical oxygen demand (COD).

INTRODUCTION

The Ecological Scarcity Method is one of the methods for impact assessment in LCA. It enables to express different environmental impacts in single score units, eco-points. Such results are handy for decision-makers in policy or enterprises to improve environmental management.

The main advantages of the method are ease of use, transparency and direct derivation from political targets (Frischknecht et al., 2010).

Another advantage of the Ecological Scarcity method is that the concept can be used to establish an ecological scarcity method valid for other nations or political entities. The Ecological Scarcity Method was developed in Switzerland. The first version was published in 1990. It has spread to several European countries in the 1990s, but the most widespread dissemination has been in Japan. First, was developed JEPIX (Environmental Policy Priorities Index for Japan) Method (Miyazaki et al., 2004) and later Ecological Scarcity Japan (Büssel et al., 2012).

The ecological scarcity method for Russia and Germany has been implemented by adaptation of the latest available version of Swiss eco-factor 2006 (Frischknecht et.al., 2009).

METHODS: THE ECOLOGICAL SCARCITY

The formula representation

In 2006 the main formula was updated in accordance to ISO 14044: Environmental management -- Life cycle assessment -- Requirements and guidelines (Finkbeiner et al., 2006).

The formula is used in the Ecological Scarcity Method– Eco-Factors 2006 (Frischknecht et.al., 2009):

$$Eco-factor = K \cdot \frac{1 \cdot EP}{F_n} \cdot \left(\frac{F}{F_k}\right)^2 \cdot c$$

K: Characterization factor
F: Current flow
c : Constant (10^{12}/a)

Fn: Normalization flow
Fk: Critical flow
EP: Eco-point

Critical and current flows are the key parts of the formula for eco-factors calculation. For each country the critical and actual flow are individual and stipulate national conditions.

Transformation rule concept

The transformation rule (TR) should advance the determination of the eco-factor for different nations if the direct calculation is not possible for some reason. Direct calculation is feasible if critical and actual flows are explicitly identified. TR can be obtained as a coefficient between known eco-factor for Switzerland or Japan, for example, and the one that needs to be calculated. In general, transformation rule should reflect the difference between the countries.

Swiss Eco-factors 2006 includes information on more than 600 substances for different impact categories. In some cases, these eco-factors can be directly applied for countries with similar environmental policy (Jungbluth et al., 2011), for example Germany. But it doesn't work with countries like the Russian Federation that has different driving forces for setting environmental goals and targets and level of social awareness. It is possible to get the trend between eco-factors for the same substance, but for diverse countries, by having data sets at least for several categories.

EXAMPLE OF DEFINING TR: COD

Chemical oxygen demand (COD) expresses the amount of oxygen necessary for oxidizing organic compounds in surface water or waste water. It makes COD a useful indicator of water quality.

The data regarding eco-factors for COD in Switzerland, Japan and Germany presented in the table below.

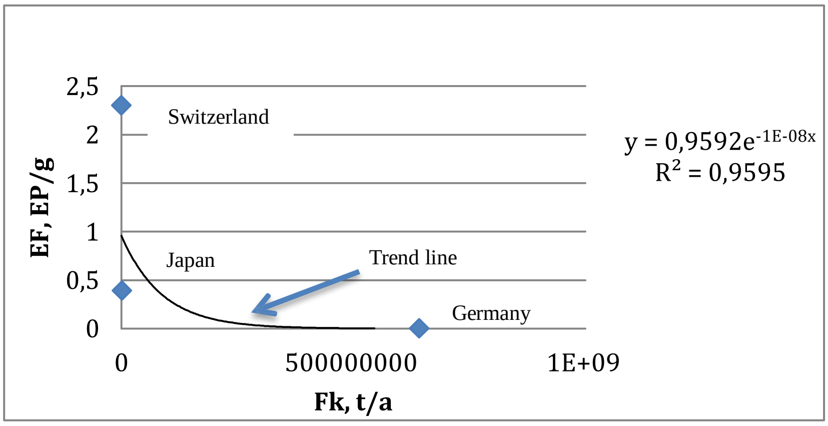
Table 1. Eco-factor for COD

Country	Actual flow, t/a	Critical flow, t/a	Weighting factor	Eco-factor, EP/g COD	Source
Switzerland	47,700	144,000	0.11	2.3	The Ecological Scarcity Method - Eco-Factors 2006 (Frischknecht et.al., 2009)
Germany	239,764,000	642,225,000	0.14	0.00058	own calculation
Japan	1,350,000	1,854,550	0.53	0.39	Ecological Scarcity Japan (Büssel et al., 2012)

For Russia it is possible to define critical flow for COD from the limitation according to the State Sanitary and Epidemiological Regulation of the Russian Federation. The critical flow is 3,339,000 t per year. Unfortunately, environmental statistical data doesn't give clear information that can lead to actual flow estimation. Thus, organic matter in surface water is addressed as substance with applicable political target. Nevertheless, calculation of Eco-factor seems to be impossible without actual flow.

Having the correlation between critical flow and eco-factors for Switzerland, Japan and Germany , eco-factor for Russia could be roughly estimated.

Figure 1. Correlation between critical flow (Fk) and eco-factor (EF).



The trend line helps to define the missing eco-factor. In case of the Russian Federation, it is 0.93 EP/g COD. Using the main formula of EcoScarcity, the actual flow and weighting can be estimated as well.

DISCUSSION

The estimation of eco-factors with the transformation rule is only one possibility in case of data gap. It should be seen as an intermediate solution. The available data must be carefully analyzed and all assumptions should be clearly described, to make the TR transparent and understandable. The LCA case studies carried out with the “artificial” eco-factors should be interpreted correctly and do not lead to wrong conclusion.

In general, transformation rule should reflect the difference between the countries for example, geographical difference, population and economical grows, time frame, social aspects, etc.

CONCLUSIONS

Ecological Scarcity is policy oriented method and gives the feedback to the policy-makers for the future actions in the field of environmental regulation and monitoring. They should put the attention to the substance and substance categories for which part of the data are missing.

The application Ecological Scarcity for the Russian Federation aims to implement the LCIA method that is based on publicly available data for Russia and enforce the wider use of LCA tool as a step toward sustainable development.

For nations with high environmental standards and similar to Switzerland environmental policy, such as Germany, calculation of own eco-factors can be considered a regionalization and adjusts the EcoScarcity method widely using.

REFERENCES

Büsser S., Frischknecht R., Hayashi K. and Kono J. (2012). Ecological Scarcity Japan. Report. *Uster, July 2012.*

Finkbeiner M., Inaba A., Tan R. B.H. et al. The new International Standards for Life Cycle Assessment: ISO 14040 and ISO 14044. *Int J LCA, 2006, 11(2), pp.80-85.*

Frischknecht R., Steiner R., Jungbluth N. (2009). The Ecological Scarcity Method – Eco-Factors 2006. A method for impact assessment in LCA. *Environmental studies no. 0906. Federal Office for the Environment, Bern: 188 pp.* http://www.environment-switzerland.ch/uw-0906-e

Frischknecht R., Buesser S., Hayashi K. and Uchida S. (2010). Development of Ecological Scarcity Japan. *Proceedings of EcoBalance2010, Tokyo, Japan. A1-1610, pp.34-37.*

ISO 14044: Environmental Management - Life Cycle Assessment - Requirements and Guidelines. *International Organization for Standardization (ISO), 2006.*

Jungbluth N., Büsser S., Frischknecht R., Flury K. and Stucki M. (2011). Feasibility of environmental product information based on life cycle thinking and recommendations for Switzerland. *Journal of Cleaner Production 28(2012),pp.187-197. doi:10.1016/j.jclepro.2011.07.016*

Miyazaki N., Siegenthaler C., Schoenbaum T. and Azuma K. (2004). Japan Environmental Policy Priorities Index (JEPIX) - Calculation of Ecofactors for Japan: Method for Environmental Accounting based on the EcoScarcity Principle. *7. International Christian University Social Science Research Institute, Tokyo.*

State Sanitary and Epidemiological Regulation of the Russian Federation. 2.1.5. Water disposed in populated areas. Sanitary protection of water bodies. Guidelines MU 2.1.5.1183-03 (in Russian). *Russian Ministry of Health, Moscow*

LCA IN BIOFUEL REGULATIONS: COMPARING THE US & EU APPROACHES

Richardson, C[1,], Bernard F[2], Boreux S[2], Nissing C[1], Soleille S[3] and Girault N[1]*

*[1] TOTAL New Energies, Paris, France, [2] TOTAL Refining & Chemicals, Harfleur, France, [3] TOTAL Marketing & Services, Paris, France, * Tour MICHELET, 24 cours Michelet 92069 Paris La Défense Cedex. christine-joy.richardson@total.com*

Keywords: LCA; biofuels; RED; RFS; LCFS.

ABSTRACT

This study compares the use of LCA in the rapidly evolving regulations governing biofuels in the US and EU. It focuses specifically on the European Commission Renewable Energy Directive, the US Renewable Fuel Standard II, and the Californian Low Carbon Fuel Standard, with emphasis on the respective LCA methodologies described. All three regulations use Life Cycle Assessment (LCA) to quantify the variation in GHG emissions relative to a fossil baseline fuel. Different definitions for system boundaries and life cycle phases make results difficult to disaggregate and one-to-one comparison of the models difficult. Overall, *co-product allocation*, *N_2O emissions* and *land use change* (LUC) are identified as the major methodological differences. These differences can result in significantly different outcomes when assessing identical pathways.

INTRODUCTION

Policy plays a key role in the biofuels market with the development of several national or regional regulations for biofuels and other renewable energies. Such regulations provide sustainability criteria, compliance rules and greenhouse gases (GHG) emission reduction targets among other requirements for fuel producers or importers.

The scope of this study covers the regulations governing biofuels in the US and Europe, focusing on the following documents:

- European Commission Renewable Energy Directive (RED) (EC, 2009)
- US Renewable Fuel Standard, version 2 of 2010 (RFS2) (EPA, 2010)
- California Low Carbon Fuel Standard (LCFS) (CARB, 2009a)

In all three regulations Life Cycle Assessment (LCA) is used to quantify the net reduction in lifecycle GHG emissions reduction relative to a fossil baseline fuel. However, examination of the values provided by the respective regulations frequently shows vastly different results for the same fuel, produced from the same feedstock. Some of these differences can be explained by differences in geographical location, transport logistics or variation in the fuel production process. Differences in agricultural or process yields and input data also play a role. However, the methodological differences between the three regulations mean that even if an identical pathway were assessed, the results can be different. This paper thus aims to provide an overview and broad understanding of the LCA methodology and calculation approaches taken by the three regulations and to identify key differences.

METHODS

To address the objectives, information was taken from the relevant legislative documents themselves, as well as key documents from the public domain in the form of comments or summaries of the legislation and existing comparative studies. The effect of these methodological differences was then further investigated through case studies for sugarcane ethanol and soybean biodiesel.

RESULTS AND DISCUSSION

While each of the three regulations examined in this report requires the calculation of life cycle GHG emissions of fuels, the structure of the modeling approach, specific tools used and inclusion or exclusion of aspects such as land use change (LUC) exist as obvious differences between the LCA modeling approaches taken. An overview of these and other key methodological differences is given in Table 1. Of particular interest are the GHG emission factors for CH_4 and N_2O, and fossil fuel references which are different in all three regulations.

Table 1: Comparison of LCA methodology in the RED, RFS II and LCFS

Issue	RED	RFS II	LCFS
Unit/metric	gCO_{2eq}/MJ GHG reduction (%) vs fossil reference	$gCO_{2eq}/mmBTU$ GHG reduction (%) vs fossil reference	Carbon intensity (CI) in gCO_{2eq}/MJ, adjusted according to an Energy Economy Ratio (EER)
LCA steps considered	Direct LUC - Biomass production - Biofuel production Biomass + fuel transport -	Domestic LUC International LUC Domestic agriculture International agriculture Biofuel production Biomass + fuel transport Tailpipe emission	LUC (total) - Biomass production - Biofuel production Biomass + fuel transport Tailpipe emission
Reference fossil fuel values	83.8 gCO_{2eq}/MJ	92.9 gCO_{2eq}/MJ	95.85g CO_{2eq}/MJ (gasoline) 94.71g CO_{2eq}/MJ (diesel)
GHG emission factors	CO_2: 1; CH_4: 23 ; N_2O: 296 (IPCC 2001)	CO_2: 1; CH_4: 21; N_2O: 310 (NRC 2010)	CO_2: 1; CH_4: 25; N_2O: 298 (IPCC 2007) Volatile organic compounds (VOCs): 3.1; CO 1.6
GHG emissions from combustion	Zero rating for any GHG	Zero rating for CO_2. CH_4 and N_2O included	Zero rating for CO_2. CH_4, N_2O, CO & VOCs included
Biofuel-use vehicle efficiency	If evidence provided for difference	Not included	Yes, using EER relative to a reference fuel
Modelling tools	Not defined	FASOM, FAPRI-CARD, GREET	CA-GREET – adapted to Californian conditions
Time horizon [i]	20 years	30 years	30 years

i. The length of time during which all emissions are accounted for and attributed to the biofuel, allocated over the volume of fuel produced in that time period (Life Cycle Associates, 2012)

Table 2. Key methodological differences between the LCA modelling approaches

	RED	RFS II	LCFS
Co-product allocation	Allocation by energy content except for heat and excess electricity	System expansion → Displacement method	Varies for different pathways (Displacement, substitution, mass based allocation)
Direct land-use emissions	Default option: No Reference land use in January 2008 or 20 years before raw material was obtained	Yes, using FAPRI-CARD and FASOM models for domestic and international LUC respectively	Yes, using Global Trade Analysis Project (GTAP) model – no split between direct/indirect or domestic/international LUC
Indirect land-use emissions	Not yet included (under review)		
N_2O emissions	IPCC methodology, tier 1 as default, tier 2 or 3 if available	DAYCENT for domestic N_2O emissions, adapted IPCC factors for international N_2O emissions	IPCC and GREET emission factors, crop residues not always accounted for

Overall however, *co-product allocation*, *agricultural N_2O emissions* and *LUC* are identified as the major methodological differences, resulting in different outcomes when assessing identical pathways. The different approaches taken by the three regulations on these aspects are summarised in Table 2.

These differences have been identified both internally and in publically available review studies (Khatiwada, Seabra, Silveira, & Walter, 2012; Life Cycle Associates, 2011, 2012). There is little scientific consensus on these issues. It was found that the overall results are highly sensitive to these methodological choices, and that notably different modelling approaches are taken in the three regulations. The effect of these methodological differences is illustrated in Table 3 through case studies for sugarcane ethanol and soybean biodiesel.

Table 3: Comparison between results of different regulations for Brazilian sugarcane ethanol (gCO_{2eq}/MJ)

	Sugarcane Ethanol			Soybean Biodiesel		
Life cycle step	**RED**	**RFS II**	**LCFS**	**RED**	**RFS II**	**LCFS**
Agriculture	14	38	19	19	-9	5,4
Processing	1	-11	-4,9	26	13	8,7
Transport & distribution	9	5	5,5	13	3	2,7
Tailpipe emissions	0	1	0,8	0	1	4,5
Total WtW	**24**	**33**	**20,4**	**58**	**8**	**21,3**
Land use change	0	5	46	0	34	62
Total WtW + LUC	**24**	**38**	**66,4**	**58,0**	**42**	**83,3**
Fossil benchmark	83,8	92,9	95,85	83,8	92,9	94,71
GHG emissions saving	**71%**	**59%**	**31%**	**31%**	**55%**	**12%**
GHG reduction target	60%	50%	>0%*	60%	50%	>0%*

* LCFS uses a credit based system relative to the fossil benchmark

For sugarcane ethanol, the highest emissions savings are achieved using the RED methodology, despite having the lowest fossil benchmark. Agriculture is particularly significant in the RFS II case due to the method by which emissions from crop residues are considered. Allocation of co product electricity credit is especially significant for sugarcane ethanol as the two US regulations both consider the displacement of marginal electricity from natural gas rather than the average mix, while the RED does not give credit for excess electricity.

For soybean biodiesel, the RED deviates from the default IPCC tier 1 methodology and uses emissions as reported by the JEC (2007) for the calculation of N_2O emissions. This is the main cause of the elevated emissions from agriculture. The RFS value for agriculture is negative due to several indirect impacts, not considered by the other two regulations. Co product methodology then causes significant deviation between the three regulations. The RED allocates by energy content and the LCFS by mass, resulting in 66% and 80% allocation to the soy meal co product respectively.

It must be noted that while it is mandated by the RED to calculate dLUC if land use change occurs for a specific feedstock, the RED default values assume that there is no dLUC for either pathway. If dLUC was taken into account, this could increase or decrease the overall result depending on the assumptions taken. While LUC is calculated in both the RFS and LCFS, different results are reported due to the use of different agro-economic equilibrium models. LUC is extremely dominant for both LCFS biofuel pathways, as calculated using the GTAP model. As a result, the lowest emissions savings are found for LCFS results.

It is interesting to note that for sugarcane ethanol, despite varied results, all values result in qualification as a biofuel/low carbon fuel according to the rules set by their respective regulations. They are thus all eligible to contribute towards the overall regional blending and GHG reduction targets set by their respective regulation.

CONCLUSIONS

This study has outlined the current status and understanding of the overview LCA methodology and calculation approaches taken by the three regulations. *Co-product allocation, agricultural N_2O emissions* and *LUC* are identified as key methodological differences. The nature of the regulations is that of evolution and change. It thus is essential to continue to follow further developments in this field.

REFERENCES

CARB. (2009a). Proposed Regulation to Implement the Low Carbon Fuel Standard. Volume 1. Staff Report: Initial Statement of Reasons. Sacramento, California.

European Commission - DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, Official Journal of the European Union, Brussels, (2009).

EPA. (2010). Renewable Fuel Standard Program (RFS2): Regulatory Impact Analysis. In Assessment and Standards Division. Office of Transportation and Air Quality (Ed.).

JEC. (2007). Joint Research Centre-EUCAR-CONCAWE collaboration - Well-to-Tank Appendix 1 Version 3c

Khatiwada, D., Seabra, J., Silveira, S., & Walter, A. (2012). Accounting greenhouse gas emissions in the lifecycle of Brazilian sugarcane bioethanol: Methodological references in European and American regulations. *Energy Policy, 47*, 384-397.

Life Cycle Associates. (2011). Review of transportation fuel life cycle analysis. Alpharetta: CRC.

Life Cycle Associates. (2012). Transportation fuel life cycle analysis: A Review of Indirect Land Use Change and Agricultural N2O Emissions. Alpharetta: CRC.

METHODOLOGICAL FRAMEWORK FOR ASSESSING THE ENVIRONMENTAL IMPACTS OF PHOTOVOLTAICS SYSTEMS USING THE LCA METHOD

Bastien Evon[1,], Jérôme Payet[1], Isabelle Blanc[2], Didier Beloin-Saint-Pierre[2], Eric Raison[3], Nadine Adra[3], Yvonnick Durand[4]*

[1]*Cycleco,* [2]*ARMINES/MINES ParisTech,* [3]*Transenergie,* [4]*ADEME*

**Cycleco, 1011 avenue Léon Blum, 01500 Ambérieu-en-Bugey, FRANCE. bastien.evon@cycleco.eu; +33 (0)4 37 86 07 12*

Keywords: guidelines; harmonised methodology; Life Cycle Assessment; photovoltaic system

ABSTRACT

This paper presents the guidelines for environmental assessment of photovoltaic systems in France by considering the total life cycle. It aims at helping designers of photovoltaic systems to evaluate the environmental impacts of producing electricity using the rules set out in the methodological framew ork. A specific common framework is created to conduct LCA (functional unit, system boundaries and product categories). A reference database of impact factors is developed allow ing analysts to perform LCA in a simple manner. Some of the default impact factors are intentionally conservative. This choice is made to encourage manufacturers of photovoltaic system components to replace them w ith their ow n value to better match their systems impacts. This framework is availab le since the beginning of 2013.

INTRODUCTION

The increasing demand for photovoltaic (PV) systems in France and the grow ing interests for environmental issues have encouraged the French government to better consider the environmental aspects of the PV sector. To support the development of photovoltaic installat ions, new French regulations are now heading to take into account an assessment of the environmental footprint of energy production systems over their entire life cycle by introducing LCA results in call for tenders as a significant criterion. Recognizing that a w ide variability in assumptions that can affect the valid ity and reliability of the results from PV LCAs, the French Environment and Energy Management Agency (ADEME) has set a methodological framew ork to help installers and designers of PV systems to undertake these LCAs w ith common and coherent rules to meet these new requirements (Payet et al., 2013).

METHODS

This methodological framew ork, mainly based on ISO standard 14040 and 14044 (ISO, 2006) and provisions of the ILCD handbook (European Commission, 2010) takes into account the technical and geographic characteristics of a PV system. An impact factors database has been specifically designed to build default values to allow the user to calculate the environmental assessment of a series of PV categories .

Product category

The environmental assessment set out in this framew ork applies to the product categories defined in Table 1. Three main product categories are proposed in accordance w ith the technical systems characterization.

Table 1. Product categories covered by the framework

Product categories	Power P_{max}	Voltage range	Description of PV system installation
Category 1	Above 0 kVA and under 36 kVA	Low Voltage single phase or three phases	System integrated into or connected to building or installed on roof
Category 2.a	Strictly above 36 kVA and under 250 kVA	Low Voltage three phases	System integrated into or connected to building or installed on roof
Category 2.b			System installed on ground
Category 3.a	Strictly above 250 kVA	Medium Voltage	System integrated into or connected to building or installed on roof
Category 3.b			System installed on ground

The methodological framew ork is a general method that can be applied to all PV systems installed in France except for concentration PV systems (CPV). Single-crystal silicon and thin-layer technologies are singled out in the framew ork. It applies exclusively for grid- connected PV installations.

Def inition of the scope of LCA study

The basic function of the PV installations analys ed using the methodological framework is electricity production. The functional unit of the LCA should be determined in conjunction w ith the function of the system observed and should serve as a basis of comparison for analyzing the results of the different PV systems producing electricity . Consequently, functional unit of the assessment is defined as one kWh produced by a photovoltaic system during its lifespan and either injected into the distribution or transport network or consumed.

The system boundaries are defined: it includes extraction and production of PV system components, installation, use and maintenance, dismantling and end-of-life processing (recycling, incineration and/or landfill of materials composing the PV system).

For assessing the environmental impacts, the methodological framew ork sets a number of environmental impact indicators and energy flow indicators. The used impact indicators and the methods are in accordance w ith the recommendations set out by the European Commission's Joint Research Centre (European Commission, 2011). The energy flow indicators describe consumption of fossil, nuclear and renew able energy sources throughout a PV system's life cycle. The Cumulative Energy Demand method is applied to quantify consumption of both renew able primary energy (i.e. geothermal hydraulic, solar, w ind and biomass) and non-renew able primary energy (i.e. fossil and nuclear) (Frischknecht et al., 2007). Some of the methodological framew ork's impact categories are obligatory – i.e. users are obliged to calculate impacts for these impact categories, w hile others are optional – i.e. users can enter them if they choose (Table 2).

Environmental impact / energy flow	Calculation of life cycle impact values in the framework
Climate change	Obligatory
Respiratory inorganics	Obligatory
Resource depletion, water	Obligatory
Primary energy consumption, renewable	Obligatory
Primary energy consumption, non-renew able	Obligatory
Ozone depletion	Optional
Human toxicity, cancer effects	Optional
Human toxicity, non-cancer effects	Optional
Ionizing radiation, human health	Optional
Ionising radiation, ecosystems	Optional
Photochemical ozone formation	Optional
Acidification	Optional
Eutrophication, terrestrial	Optional
Eutrophication, freshwater	Optional
Eutrophication, marine	Optional
Ecotoxicity, freshwater	Optional
Land use	Optional
Resource depletion, mineral, fossil and renewable	Optional

Table 2. Environmental impact indicators and energy flow s indicators

Calculating the environmental impacts of PV systems

LCAs studies are time demanding and can make heavy demand on the resources on LCA practitioners, mainly on the Life Cycle Inventory (LCI) phase. The quality of a LCI directly influences the overall quality of an LCA (Mongelli et al., 2005). To ease such demanding step, the methodological framew ork provides three steps to calculate the PV system's impact factors.

Step 1 – Identific ation of the produc t c ategory: The user of the methodological framew ork identifies the product category.

Step 2 – Calc ulation of the impac t fac tors per proc ess : For each product category considered, the user calculates the impact factor for each PV system process. Default values are provided in the methodological framework. Some of the default values proposed to users of this methodological framew ork are intentionally conservative. This choice of conservative values is devised to encourage manufacturers of photovoltaic system components to substitute these conservative values w ith their own value to better match the actual environmental conditions of the PV system's components. The impact factors proposed in the methodological framew ork are either conservative (marked *FI*) or not conservative (marked *fi*). This distinction w as established when the methodological framew ork w as draw n up and is based on identifying the significant or insignificant proportion that each of these processes contributes to the entire PV system's environmental impact. Processes that strongly influence the LCA are characterized by *FI*, w hile processes that have a relatively low influence on the results are c haracterized by *f i*. This distinction has been derived from feedback on environmental analyses of PV systems.

Step 3 – Calc ulation of the PV system's impact factors : Depending on the decomposition of the PV system, the impacts of each process are calculated to obtain the impacts corresponding to each PV sub-system. The PV system's impacts are finally obtained by adding the impacts of each PV sub-system.

RESULTS AND CONCLUSIONS

This guide is available since early 2013. The methodological framew ork should be used for environmental assessments when making public policy decisions regarding the implementation of photovoltaic systems. This methodological framework w as developed after consulting a w orking group representing professionals from the French PV industry (i.e. industrials, professional trade unions, engineering consultancy firms, project developers, PV system designers and operators, ministerial representatives, research and certification bodies).

ACKNOWLEDGEMENTS

The authors would like to acknow ledge ADEME for its financial supports to this project and bringing together different French specialists from the PV industry and LCA fields.

REFERENCES

European Commission – Joint Rese arch Cent er – Inst it ut e of Environment and Sust ainabilit y . (2010). *International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessm ent – Detailed guidance* (1st ed.). Luxembourg: P ublicat ions Office of t he European Union . doi: 10.2788/94987

European Commission – Joint Rese arch Cent er – Inst it ut e of Environment and Sust ainabilit y . (2011). *International Reference Life Cycle Data System (ILCD) Handbook - Recomm endations for life cycle im pact assessm ent in the european context - based on existing environm ental im pact assessm ent m odels and factors* (1st ed.). Luxembourg: P ublicat ions Office of t he European Union , Luxembourg. doi: 10.278/33030

Frischknecht , R., Alt haus, H. J., Dones, R., Hischier, R., J ungbl ut h, N., Nemecek, T ., ... & Wernet , G. (2007, December). Rene wabl e Energy Assessment wit hin t he Cumulat ive Energy Demand Concept : Chal lenges and Sol ut ions. In *proceedings from : SETAC Europe 14th LCA case study sym posium : Energy in LCA -LCA of Energy* (pp. 3-4).

Int ernat ional Organizat ion for St andardizat ion (ISO). (2006). *Environm ental Managem ent – Life Cycle Assessm ent – Principles and fram ework* (2nd ed.), Geneva.

Mongelli, I., Suh, S., & H uppes, G. (2005). A St ruct ure Comparison of t wo Approaches t o LCA Invent ory Dat a, Base d on t he MIET and ET H Dat abases (10 pp). *The International Journal of Life Cycle Asse ssm ent*, *10*(5), 317-324. doi: 10.1065/lca20 04.12.198

P ayet , J ., Evon, B., Sie, M., Blanc, I., Beloin Saint -P ierre, D., Guermont , C., Adra, N., Rai son, E., P uech, C., & Durand, Y. (2013). Référent iel d'évaluat ion des impact s environnement aux des syst èmes phot ovolt aïques par la mét hode d'Analyse du Cycle de Vie. Ret rieved from ht t p://www.ademe.fr/

SCOPING OF LIFE CYCLE ASSESSMENT STUDIES: A MISSED OPPORTUNITY?

S.J. McLaren, Massey University and New Zealand Life Cycle Management Centre*

**IAE, Massey University, Private Bag 11222, Palmerston North 4442, New Zealand*
s.mclaren@massey.ac.nz

Keywords: Life Cycle Assessment; Goal and Scope Definition; procedure

ABSTRACT

A distinction is commonly made between analytical and procedural tools when evaluating LCA against other environmental assessment approaches, and LCA is described as an analytical tool. However, this distinction is somewhat blurred. In this paper, it is argued that the procedural aspects to LCA should given more attention in LCA guidelines and standards. In particular, more guidance should be given regarding the procedures for defining system boundaries, choice of quantitative versus qualitative LCA, subjective modelling decisions, and choice of impact assessment method. This will increase the relevance and usefulness of LCA in different decision situations.

INTRODUCTION

In the literature evaluating LCA against other environmental assessment approaches, a distinction is commonly made between analytical and procedural tools. Analytical tools focus on the quantitative assessment of the studied object, and procedural tools focus on the process for undertaking a study (e.g. Baumann and Cowell, 1999; Wrisberg et al., 2002; Finnveden and Moberg, 2005). LCA is generally described as an analytical tool whereas approaches such as Environmental Impact Assessment are described as procedural tools.

However, the distinction between analytical and procedural tools is somewhat blurred. In this paper, it is argued that there are procedural aspects to LCA and that they should given more attention in LCA guidelines and standards. It follows from work by Cowell (1998) who suggested that one way of emphasising the importance of the procedure in LCA is to describe LCA as a **process** rather than as a **tool** in environmental management. Cowell et al. (1997, p.7) defined a tool as “a means of combining information in a form which can be used in decision-making processes,” and a process as “a way of using and integrating different tools with stakeholder expectations and other decision parameters to meet one or more of the requirements for a decision.”

LCA AS A TOOL OR PROCESS?

Perhaps the most tangible expression of recognition of the procedural aspects of LCA can be found in the ILCD Handbook, the first authoritative guide to LCA methodology to provide detailed guidance on how an LCA study should be shaped by its decision context. It defines four types of LCA study according to the decision situation: micro-level decision support

(Situation A), meso/macro-level decision support (Situation B), accounting including interactions with other systems (Situation C1), and accounting without interactions with other systems (Situation C2). The ILCD Handbook goes on to provide guidance about use of attributional versus consequential modelling, and short- and long-term marginal processes, depending upon which situation is under analysis (European Commission, 2010a, p.36-48).

However, as well as decisions about choice of attributional versus consequential modelling, and use of marginal processes, a number of other decisions are made during the execution of an LCA study that may significantly affect the final results – and where the procedures for making those decisions have yet to be defined in detail. These include: system boundary definition, quantitative versus qualitative modelling, subjective modelling decisions, and choice of impact assessment method. The importance (or not) of defining a procedure for making each of these decisions in an LCA study is discussed below.

System boundary definition

There is relatively little guidance in the LCA standards and guidebooks on how to define the appropriate system boundary for a study. The ISO 14040 standard states that the system boundary should be defined by “the goal and scope definition of the study, its intended application and audience, the assumptions made, data and cost constraints, and cut-off criteria” (ISO, 2006, Section 5.2.3). It further states that, “The criteria used in setting the system boundary are important for the degree of confidence in the results of a study and the possibility of reaching its goal” (ISO, 2006, Section 5.2.3).

However, the flexibility in defining the scope of an LCA study may result in identification of limited options for improvement by a company. Coelho and McLaren (2013) discuss the process of undertaking LCA studies with six manufacturing firms as part of a Life Cycle Management project in New Zealand. For three of the companies, the system boundaries for the LCA studies were expanded during the process of undertaking the LCA studies and this led to identification of quite different improvement options for the company products. They concluded that, “the process of defining an LCA study’s scope in cooperation with the commissioners of that study deserves further consideration in future research” (Coelho and McLaren, 2013, p.880).

There is a tension, then, between the role of LCA in highlighting the (un)expected hotspots in product life cycles by expanding the system boundary, and the potential usefulness of such information in a decision situation. A procedure for defining the system boundary in relation to different decision situations would clarify this aspect.

Quantitative versus qualitative LCA

In some decision situations, particularly in product design where decisions have to be made on short timescales, more qualitative forms of LCA may be used to support decisions. And the importance of applying the concept of life cycle thinking – as opposed to using Life Cycle Assessment in its analytical tool “mode” – has been asserted by Heiskanen (2002). She discusses the use of life cycle thinking and LCA in two Finnish companies, suggesting that formal LCA had a relatively marginal role in their decision-making. However, the life cycle concept provided a way for employees in the companies to legitimise their concerns - and rationale for taking action - regarding environmental impacts in the upstream and downstream supply chain associated with the companies’ products.

This issue has been highlighted recently by Baitz et al. (2013) who suggest that, prior to undertaking an LCA in industry, questions should be asked about when the results are needed, to whom the results are to be communicated, and whether all the information is available internally or needs to be sourced with external support. This information should then guide the execution of the LCA study in order to provide results that are timely and relevant whilst providing "as much precision as needed to get good answers while avoiding irrelevant complexity" (Baitz et al., 2013, p.13).

Of course, there is a tension here because "you don't know what you don't know." For this reason, it would be helpful to provide more guidance on the procedure for defining the level of detail required in an LCA study.

Subjective modelling decisions

It is recognised that LCA frames problem situations based on a positivist (or "rational") worldview (e.g. Bras-Klapwijk, 1998; Tukker, 2000), and that its methodology omits consideration of some environmental aspects such as assessment of environmental risks, ability to manage environmental impacts, and unknown impacts (e.g. Hofstetter, 2000; Tukker, 2000). If these aspects are not consciously articulated in a decision-making process that involves use of LCA-based information, the LCA results may bias the processes because "the apparent objectivity gives LCAs too much authority and neglects that they are based on a specific frame and specific environmental goals" (Bras-Klapwijk, 1998, p.340).

Therefore a procedure for making the underlying assumptions in LCA more explicit when LCA studies are used to support decision-making, and arguably adapting LCAs to be more responsive to different decision contexts, may increase the credibility of LCA to support decision-making.

Impact assessment method

The choices to be made in an LCA study related to Impact Assessment, and within the framework of the ISO 14040 and 14044 standards, include: number of impact categories to be addressed, assessment method (which may be at midpoint or endpoint level in the cause-effect chain), and inclusion or exclusion of normalisation and weighting steps.

The ILCD Handbook (European Commission, 2010a, p.109) provides a default series of impact assessment categories. It also provides a set of criteria and a procedure for the evaluation of different characterisation models addressing midpoint and endpoint levels (European Commission, 2010b). The aim is to identify the best practice among existing characterisation models for each impact category; however, it does not address the question of how to choose between alternative models that may meet all these criteria. Also, detailed guidance on normalisation and weighting is not included in the ILCD Handbook (European Commission, 2010a, p.113).

Given the importance of impact assessment methods in defining the results of LCA studies, it may be advisable to extend the guidance provided in the ILCD Handbook to cover procedures for managing (at least) these choices at Impact Assessment.

DISCUSSION AND CONCLUSIONS

All of the choices outlined in this paper are choices that are made during the Goal Definition and Scoping phase of an LCA study (albeit that they are revisited in an iterative way throughout the study). This suggests that more attention should be given to the procedure for making such choices at Goal and Scope Definition, and in particular to how the choices are related to different decision contexts. Definition of appropriate procedures has the potential to increase the usefulness and relevance of LCA studies.

REFERENCES

Baitz, M., Albrecht, S., Brauner, El, Broadbent, C., Castellan, G., Conrath, P., … Tikana, L. (2013). LCA's theory and practice: like ebony and ivory living in perfect harmony? *International Journal of Life Cycle Assessment, 18,* 5-13.

Baumann, H., & Cowell, S.J. (1999). An evaluative framework for environmental management approaches. *Greener Management International*, 26, 109-122.

Bras-Klapwijk, R.M.. (1998). Are life cycle assessments a threat to sound public policy making. *International Journal of Life Cycle Assessment,* 3(6): 333-342.

Coelho, C.R.V., & McLaren, S.J. (2013). Rethinking a product and its function using LCA - experiences of New Zealand manufacturing companies. *International Journal of Life Cycle Assessment*, *18*(4), 872-880.

Cowell, S.J. (1998). *Environmental Life Cycle Assessment of agricultural systems: integration into decision-making* (Unpublished doctoral dissertation). University of Surrey, Guildford, UK.

Cowell, S.J., S. Hogan and R. Clift. (1997). Positioning and Applications of LCA. In H.A. Udo de Haes and N. Wrisberg (eds.), *Life Cycle Assessment: State-of-the-Art and Research Priorities. LCA Documents*, Volume 1 (pp.33-57). Bayreuth, Germany: Eco-Informa Press.

European Commission. (2010a). *ILCD Handbook. General guide for Life Cycle Assessment – Detailed Guidance.* Ispra, Italy: European Commission Joint Research Centre and Institute for Environment and Sustainability.

European Commission. (2010b). *ILCD Handbook. Framework and requirements for Life Cycle Impact Assessment models and indicators.* Ispra, Italy: European Commission Joint Research Centre and Institute for Environment and Sustainability.

Finnveden, G., & Moberg, Å. (2005). Environmental systems analysis tools – an overview. *Journal of Cleaner Production, 13,* 1165-1173.

Heiskanen, E. (2002). The institutional logic of life cycle thinking. *Journal of Cleaner Production 10,* 427-437.

Hofstetter, P.. (2000). Modelling the valuesphere and the ecosphere: Integrating the decision makers' perspectives into LCA. *International Journal of Life Cycle Assessment, 5*(3): 161-175.

ISO. (2006). *ISO 14040 Environmental management – Life Cycle Assessment – Principles and Framework.* Geneva, Switzerland: ISO.

Tukker, A. (2000). Philosophy of science, policy sciences and the basis of decision support with LCA: Based on the toxicity controversy in Sweden and the Netherland. *International Journal of Life Cycle Assessment, 5*(3): 177-186.

Wrisberg, N., Udo de Haes, H.A., Triebswetter, U., Eder, P., & Clift, R. (2002). Analytical tools for environmental design and management in a systems perspective. In A. Tukker (ed.), *Eco-efficiency in industry and science.* Dordrecht, Netherlands: Kluwer Academic Publishers.

USING LCA AS A TOOL TO REGULATE BIOFUELS – A CONSIDERATION OF UNCERTAINTIES IN CULTIVATION

Serina Ahlgren (Swedish University of Agricultural Sciences) and Elin Röös (Swedish University of Agricultural Sciences). *Department of Energy and Technology, PO Box 7032, 750 07 Uppsala, Sweden, serina.ahlgren@slu.se.* *Keywords: EU; biofuels; GHG; sustainability criteria; uncertainty*

ABSTRACT

According to the EU Renewable Energy Directive, biofuels must reduce GHG emissions with at least 35% compared to fossil fuel. Cultivation of raw material represents a large proportion of biofuels´ GHG emissions, however these emissions are associated with major uncertainties. The aim of this paper is to study the uncertainty in GHG emissions for ethanol, considering measuring uncertainty and variability in data for wheat cultivation in Sweden. The results show that uncertainty in emissions from cultivation is large, but when using bioenergy as a process fuel in the ethanol production, the risk of exceeding the savings threshold is small. However, there are many uncertainties to be considered; the Directive does for example presently not include indirect land use change.

INTRODUCTION

In 2009, EU adopted the Renewable Energy Directive (Directive 2009/28/EC). The Directive mandates that all Member States shall have 10% biofuels in the transport sector by 2020. In order for a biofuel to be accounted within the national reporting, and to receive financial supports such as tax exemption, it must meet a number of sustainability criteria. One of the sustainability criteria is that the use of a biofuel must reduce GHG emissions with at least 35% compared with the use of a reference fossil fuel, increasing to 50% and 60% over time. For these calculations, the Directive mandates LCA methodology to be used.

Further, cultivation of raw material represents a large proportion of biofuels´ GHG emissions. However, emissions from cultivation are associated with major uncertainties e.g. quantification of N_2O emissions from fields and variability in yields between different regions and years. The question arise, are the uncertainties so large that we risk using biofuels in fact not meeting the GHG sustainability criteria?

Generally speaking, there are three levels of uncertainty in GHG calculations: (1) technical uncertainties connected to quality and appropriateness of data; (2) methodological uncertainties connected to model layout and structure; and (3) epistemological uncertainties connected to lack of knowledge of system behavior (Björklund, 2002; Spielmann et al., 2005).

Epistemological uncertainties are difficult to diminish; a reduction of epistemological uncertainties implies making known what one does not know. The EU Renewable Energy

Directive help reduce methodological uncertainties to some extent, since the Directive gives guidelines on methods and choice of data. However, the technical uncertainties remain. Two types of technical uncertainties can be distinguished; measuring uncertainty and variability. Variability is an inherent property of a system and, unlike measuring uncertainty, it cannot be reduced by more accurate measurement (Björklund, 2002; Johnson et al., 2011). In LCA of agricultural products, variability arises for example due to variations in yield between different regions and years, but also within regions in a particular year.

The aim of this paper is to study the uncertainty in GHG emissions for ethanol calculated according to the EU Renewable Energy Directive, considering measuring uncertainty and variability in data at farm level for wheat cultivation in Sweden.

MATERIALS AND METHODS

The calculations of the GHG emissions from biofuel production was based on the EU renewable energy Directive 2009/28/EC (Annex V), which is based on an attributional LCA approach. In short, the methodology requires allocation based on lower heating value, straw and manure are not allocated any emissions. Changes in soil carbon are not accounted for unless there is a land use change (e.g. from forest to agriculture). Land use change was not relevant for Swedish wheat cultivation why emissions from land use change was not included in the uncertainty evaluation.

The uncertainty analysis included both measuring uncertainty, which describes the precision with which the parameters can be collected on a real-life farm, as well as variation which describes the variation between farms due to differing farming systems, technical solutions and energy efficiencies. The uncertainty was quantified using Monte Carlo simulation in which parameters are described by a probability distribution. The calculation of GHG emissions are repeated a number of times (here 10,000), each time randomly drawing a parameter value from the probability distribution describing the input data. The result gives an indication of the probability of different results from the GHG emissions calculation.

The farm level parameters used in the simulations are presented in Table 1. All other input parameters for the farm LCA calculations (e.g. production of potassium and phosphorus fertilisers) were kept constant, as they in other studies have shown to have little impact on the results.

Table 1: Variables used in the calculation of GHG emissions from wheat cultivation for ethanol production. Variation and uncertainty expressed as the geometric standard deviation for a lognormal distribution (approximate percentage value corresponding to 95% conf. interval) unless otherwise stated. For full explanation and references to chosen data, see (Ahlgren et al., 2012).

	Variation	**Measuring uncertainty**
Yield	Data collected from real farms	1.01 (± 2%)
Amount of mineral N	Data collected from real farms	1.05 (± 10%)
Amount of organic N	Data collected from real farms	1.05 (± 10%)
Field N_2O emissions	0.01 kg N_2O-N per kg added N, uncertainty range 0.003-0.03 (lognormal distribution)	
Emissions from the production of mineral fertilisers	Discrete distribution: 3.1 kg CO_2e/kgN – 60% (Yara) 8.1 kg CO_2e/kgN – 24% (Russia) 7.8 kg CO_2e/kgN – 16% (EU)	1.1 (± 20%)
Amount of fuel for field operations	1.30 (± 60%) (25-108 l/ha)	1.05 (± 10%)
Emissions from grain drying	Discrete distribution: 16 g CO_2e/kg grain – 25% (central drying) 21 g CO_2e/kg grain – 63% (hot air farm drying) 11 g CO_2e/kg grain – 12% (cold air farm drying)	1.25 (± 50%) for central drying, 1.1 (± 20%) for hot on-farm drying 1.2 (± 35%) for cold on-farm drying

RESULTS

In Figure 1, the GHG emissions per MJ ethanol is presented for two cases; in the first case with bioenergy as process fuel in the ethanol production and in the second with natural gas as process fuel. The data for process emissions and transports is taken from the Directive. The cultivation data is from the modeling, the green blocks represent the mean value for cultivation of winter wheat in the county of Uppsala in Sweden. The variation and measuring uncertainty that was simulated in the model is shown as black bars (2.5-97.5 percentiles). The GHG reduction thresholds as given in the Directive (35, 50 and 60% reduction) are also plotted. As can be seen, the ethanol produced with bioenergy process fuel is well below the 60% savings threshold, however using natural gas risks missing the 50% target.

The variability in yields between farms was a major cause for the uncertainty. The reason for the variability is difficult to establish. In general, there is a direct positive correlation between amount of nitrogen applied and yield level. However, yield is often influenced by many other factors such as weather conditions during the growing season, soil texture, weed pressure, soil phosphate level and disease pressure.

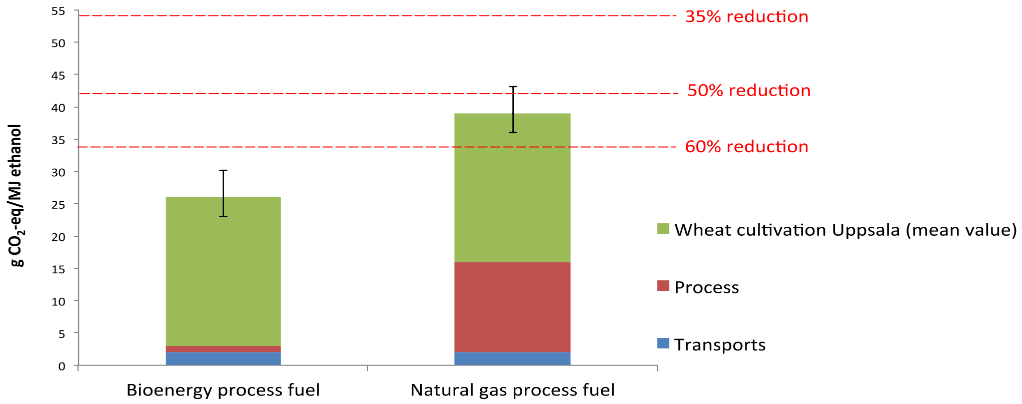


Figure 1. GHG emissions from ethanol production using bioenergy or natural gas as process fuel, calculated according to methodology in EU Renewable Energy Directive. Savings compared to fossil reference (35, 50 and 60%) and uncertainty bars (2.5-97.5 percentiles) for emissions from cultivation of winter wheat in Uppsala, Sweden, are plotted.

DISCUSSION

In addition to uncertainty connected to data described in this study, a further problem with the current EU regulation of the GHG emissions of biofuels is the exclusion of indirect effects. Indirect effects can be market induced, for example an increased production of bioenergy affects the price of agricultural products, which in turn will affect the way farmers use their land. Indirect effects are difficult to quantify and tend to be very uncertain, but can potentially be large enough to change the GHG balance. In the EU it is widely recognized that indirect land-use change (ILUC) GHG emissions need to be accounted for in the assessment of the carbon balance of biofuels and the European Commission is currently working on ways to including ILUC in the Directive sustainability certification system.

CONCLUSIONS

The results show that uncertainty in emissions from cultivation is large, but when using bioenergy as process fuel in the ethanol production the risk of exceeding the savings threshold is small. We also conclude that should ILUC be included in the EU regulation, a new type of uncertainty would be introduced. We suggest that work on the direct GHG emissions of biofuels should progress in parallel with work on the indirect GHG emissions.

REFERENCES

Ahlgren, S., Röös, E., Di Lucia, L., Sundberg, C., Hansson, P.-A. 2012. EU sustainability criteria for biofuels: uncertainties in GHG emissions from cultivation. *Biofuels*, **3**(4), 399-411.

Björklund, A. 2002. Survey of approaches to improve reliability in lca. *The International Journal of Life Cycle Assessment*, **7**(2), 64-72.

Johnson, D.R., Willis, H.H., Curtright, A.E., Samaras, C., Skone, T. 2011. Incorporating uncertainty analysis into life cycle estimates of greenhouse gas emissions from biomass production. *Biomass and Bioenergy*, **35**(7), 2619-2626.

Spielmann, M., Scholz, R., Tietje, O., Haan, P. 2005. Scenario Modelling in Prospective LCA of Transport Systems. Application of Formative Scenario Analysis (11 pp). *The International Journal of Life Cycle Assessment*, **10**(5), 325-335.

CHEMICAL ASSESSMENT

Monday, Aug 26: 3:30 pm - 5:00 pm

Session chairs: Sverker Molander, Chalmers University of Technology, Sweden
Peter R. Saling, BASF SE, Germany

BIOCIDE TREATED ARTICLES – ASSESSING KNOWLEDGE LEVELS

Helena Strehlenert, Jenny Westerdahl, Hanna Ljungkvist and Eliana Alvarez.*
IVL Swedish Environmental Research Institute

**IVL Swedish Environmental Research Institute, Box 53021*
400 14 Gothenburg, hanna.ljungkvist@ivl.se

Keywords: biocides; consumer products; knowledge

ABSTRACT

The study assessed the level of knowledge regarding biocides in consumer products within three stakeholder groups; importing companies, municipalities and consumers. Importer representatives of five product categories were interviewed. Questionnaires were sent to the environment and consumer advice offices of Swedish municipalities and to representatives from two consumer organisations. Twelve out of thirty companies reported not to import biocide treated products, and most of them considered this an informed, conscious decision. In municipalities, the environment respondents were generally aware about biocides in consumer products and associated risks, while consumer advisers had less knowledge. Both groups stated that little effort was directed to the issue in their municipalities. Consumer organisation respondents were more knowledgeable, and worked to educate consumers about biocides.

INTRODUCTION

Biocides are substances used to prevent damage to humans, products, animals or the environment caused by harmful microorganisms, animals or plants. Today, everyday products are increasingly being treated with biocides, which is not only positive. The active substances in biocides may however pose a risk to humans and the environment, and also influence the development of bacteria resistance to biocides used as disinfectants and preservatives.
In September 2013, the new EU Biocidal Products Regulation (No 528/2012) enters into force, placing large responsibilities on manufacturers and importers. In brief, articles that are treated with biocides may only be placed on the market if the active substances contained have been approved in accordance with biocide legislation. This will apply also to articles imported from outside the EU. If an article is claimed to have biocidal properties, e.g. antibacterial, it shall also be labeled with information about this claim and about the active substance(s) contained. Furthermore, the claimed biocidal property of the treatment will have to be substantiated.

The present study aimed to find out the level of knowledge about biocides in consumer articles among the stakeholder groups of companies, municipalities and consumers, providing a basis for further work and preparations for the new regulation (KemI 2012).

METHODS

Telephone interviews were conducted with selected representatives from importing companies representing five product groups (see Figure 1) with a substantial net inflow of products to Sweden. Apart from background information about the company, the questions covered six different aspects of the survey topic: (1) Biocides and biocide treatment of consumer articles, (2) Aim, need and efficiency of biocide treatment, (3) Risks associated with biocide treatment, (4) Alternatives to biocide treatment, (5) Information in the supply chain and (6) Laws and regulations. The interviews were adapted to whether or not the informant responded that they do import biocide treated articles. If a company did not import such goods, a shorter version of the interview was conducted, covering only topics (1), (5) and (6). After completion of the interview, the respondents were offered additional information on the Biocidal Products Regulation from the Swedish Chemicals Agency. In total, 30 interviews (five to seven interviews for each product category) were conducted. Electronic questionnaires were sent to offices for land use planning and/or environment as well as to offices for consumer advice in all municipalities in Sweden. The questions were developed in cooperation with the Swedish Chemicals Agency and comprised both open-ended and closed-ended questions. A similar electronic questionnaire was sent to representatives of the Swedish Society for Nature Conservation and the Swedish Consumers' Association. An e-mail with a short presentation of the survey, the aim and a link to an electronic questionnaire was sent to all the e-mail addresses provided. A reminder was sent after 13 days and after another seven day the questionnaire was closed. The data was then compiled and analysed according to basic principles of thematic content analysis (Weber, 1990), i.e. classified into content based categories, enabling the search for patterns regarding knowledge about biocides and the companies’ views on these issues.

RESULTS

Importing companies

Ten out of the total 30 companies stated that they do import biocide treated products, hence they were asked the full set of questions. Twelve informants said that their company had chosen not to import biocide treated goods. Eight informants did not know whether articles in their product range are treated with biocides or not.

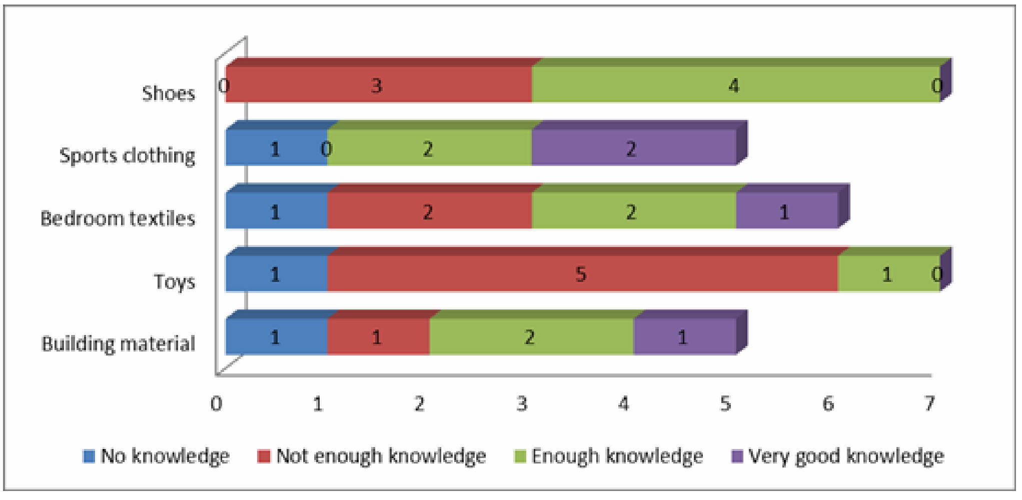


Figure 1 Answers to the interview question "What is your level of knowledge about biocides?" (Number of informants)

As shown in the table below, the informants that did not know whether their company imports biocide treated products rated their knowledge about biocides as being insufficient. Companies that do not import biocide treated products generally reported having sufficient knowledge. Most of these respondents also reported the exclusion of treated products to be an informed decision. Such decisions were reported from all product categories, except building material.

Table 1 Combined answers regarding level of knowledge and import of biocide treated products: "Is your level of knowledge about biocides sufficient?"

Product category	**Import**	**No import**	**Unsure of import**
Shoes	No	Yes	Not available
Sports clothing	Yes	Yes	No
Bedroom textiles	Not available	Yes/No	No
Toys	No	Yes	No
Building material	Yes	Not available	No

The new requirements for treated articles in the upcoming Biocidal Products Regulation were recognised by 12 of the 30 interviewed companies. The informants were also asked to rate their level of knowledge about chemicals in products in general. In this case, the results indicate that companies claim to have better knowledge than about biocides. Throughout the interviews, it was however apparent that informants mixed the topic of biocide treated articles with the more general topic of chemicals in products.

Municipal functions for environment and consumer advice

Questionnaires were sent to municipal offices for planning/environment and consumer advice. Only planning/environment respondents were asked to rate their level of knowledge concerning biocides in consumer articles. The majority of them, 83 percent, reported having no or insufficient knowledge, while 16 percent said that they had enough or very good knowledge. Despite this low rating of knowledge, a majority of both groups answered "yes" when asked whether they knew of any types of consumer articles that may be treated with biocides. 77 percent of the planning/environment respondents and 46 percent of the consumer advice respondents could give examples of such articles. The most frequently mentioned categories included clothing, hygiene products and domestic detergents.

Only a small portion of the municipality respondents thought that biocide treated consumer articles were perceived as a problem in their municipality, with a greater level of uncertainty in the consumer guidance group. A clear majority in both groups (93 percent of the planning/environment respondents and 94 percent of the adviser respondents) reported that they very rarely or never get questions about biocide treated consumer articles, and pointed out that very little attention is paid to these issues by the public and the media in general.

Consumer organisations

The respondents from consumer organisations had a higher level of knowledge than the municipality representatives, and also considered biocides in consumer articles to be a problem to a greater extent. Both respondents worked to spread knowledge among consumers, and they were aware of the upcoming Biocidal Products Regulation.

DISCUSSION

The company respondents' ratings of their biocide knowledge are distributed over the entire scale, also within most of the product categories. Due to this, and to the limited number of respondents, it is difficult to point out a specific product category where knowledge level stands out in positive or negative direction. There seems to be a higher estimated knowledge level among the respondents who do not import biocide treated products, which is consistent with the finding that most of these report the exclusion to be an informed and conscious choice. Such decisions were reported from most of the product categories. However, there are representatives from all product categories, except shoes, who claim to have no knowledge at all about biocides.

The results from the municipal planning/environment and consumer adviser questionnaires show that environment respondents generally have some knowledge about biocides in products and awareness about the associated risks while consumer advisers are less familiar with the issue. Both groups estimate that biocide treated consumer articles are perceived as a problem by the public only to a small extent and report that little activity and effort is directed to these issues in their municipality. This is quite different from the consumer organisations, which perceive the issue as a problem and put considerable efforts into informing the public.

CONCLUSIONS

The main conclusions relating to knowledge levels concerning biocides and treated articles among importing companies, municipalities and the general public can be summarised as follows:

- The topic of biocides in consumer products is generally conceived as important, within importing companies as well as consumer organisations and municipalities.
- Importing companies and consumer organisations work more actively with this issue than the municipalities.
- The new requirements for treated articles in the Biocidal Products Regulation are recognised by 40 percent of companies, 25 percent of environment officers and 11 percent of consumer advisers.

REFERENCES

KemI (Kemikalieinspektionen) 2012. Biocide treated articles- assessing knowledge. PM10/12.

Regulation (EU) No 528/2012 concerning the making available on the market and use of biocidal products Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:167:0001:0123:EN:PDF

Weber, R.P. (1990). Basic Content Analysis. 2nd ed. CA: Newbury Park.

GRAVE-TO-GATE LCA OF POROUS MATERIALS MADE FROM BLACK LIQUOR: COMPARISON OF TWO SCENARIOS INCLUDING VEGETABLE OIL OR PETROCHEMICAL

Amandine Foulet[* (1)]*, Guido W. Sonnemann*[(1)]*, Hervé Deleuze*[(1)] *and Philippe Garrigues*[(1)]
(1) Université Bordeaux 1, ISM-UMR CNRS 5255

Univ. Bordeaux, ISM, UMR 5255, F-33400 Talence, France.
CNRS, ISM, UMR5255, F-33400 Talence, France.
E-mail: a.foulet@ism.u-bordeaux1.fr

Keywords: black liquor; castor oil; petrochemical; porous polymer; life cycle assessment

ABSTRACT

The Kraft black liquor is an aqueous solution allowing to prepare oil-in-water emulsions with a hydrophilic surfactant. Emulsion-templated porous monoliths based on castor oil-in-black liquor and on dichloroethane-in-black liquor emulsions were obtained by using two different techniques including recycling phases. In both cases the inputs and the outputs were collected in order to conduct a grave-to-gate life cycle assessment at laboratory scale. The early results showed that using a vegetable oil leads to a low potential impact on climate change but is less advantageous than using a petrochemical in most other environmental indicators studied.

INTRODUCTION

The preparation of biobased materials aims for the development a new generation of materials that are ecofriendly and biodegradable. In the worldwide Kraft pulping process, the dissolved wood together with the spent pulping chemicals forms a liquid stream called weak black liquor containing organic matter such as degraded lignin. Everyday tons of Kraft black liquor are produced and merely used for energy production whereas it could be a source of biopolymers. Kraft lignin valorization has been investigated in our research group (Forgacz, 2013). This consists in using Kraft black liquor (KBL) and castor oil (CO) for the preparation of microcellular materials through polymerization of a Medium Internal Phase Emulsion (MIPE). Combining a vegetable oil with an industrial waste to prepare polyMIPEs seems to be in line with the green chemistry principles (Anastas and Warner, 1998). In this paper, the validity of this assumption is being determined by a comparative life cycle assessment (LCA) like it was previously done for soybean-based lubricants (Miller, 2007). To draw up a comparison, CO has been replaced by a petrochemical, the 1,2-dichloroethane (DCA).The resulting preparation technique allows to establish the recycling of all solvents used in the process including DCA, unlike CO. Experimental data along with existing databases are incorporated within the analysis and allow to conduct a grave-to-gate LCA.

EXPERIMENTAL

Materials

The as-received KBL comes as a thick, black liquid (Smurfit Kappa Cellulose du

Pin, Facture, France). density ρ = 1.3 g.cm^{-3}; dry matter amount =50 wt.%. castor oil (CO), Kolliphor® EL, epichlorhydrin (≥99%) and 1,2-dichloroethane (ACS reagent, ≥99%) were obtained from Sigma-Aldrich and were used as received.

Formulation of stable CO-in-black liquor MIPE

This synthesis has been previously described by our research group (Forgacz, 2013). Briefly, a mixture of KBL (25g), epichlorhydrin (2.77g), CO (23.67g) and Kolliphor® EL (1.1g) was placed into a double syringe-pump device. Backwards and forwards movements of the pistons are induced by a specific engine for 80 min (E=0.111 kWh).

Formulation of stable dichloroethane-in-black liquor MIPE

A mixture of KBL (82.5g), epichlorhydrin (8.8g) and Kolliphor® EL (18.7g) was placed into a batch stirred reactor equipped with an overhead agitation impeller and 1,2-dichloroethane (129g) was slowly added to the former mixture for 2h (E=0.440 kWh).

Preparation and characterization of the monoliths

The obtained emulsions were placed in PTFE cylindrical moulds and crosslinked for 24h at 60°C in an oven (E=2.57 kWh). The CO contained in the resulting monoliths was extracted by refluxing with ethanol (48h) in a Soxhlet apparatus (E=14.375 kWh). The monoliths were finally dried under hood and ethanol was recovered by a rotary evaporator (E=0.122 kWh) and then reused as it is. A solid waste was also collected and characterized. As for the dichloroethane monoliths the solvent extraction was carried with 1-propanol (48h) and the monoliths were dried in a vacuum oven at 60°C to constant weight (E=4.23 kWh). Propanol and dichloroethane were then distilled by a spinning band distillation (E=7.31 kWh) and then reused as it is.

The porosity and the connection size distribution of each sample were determined by mercury intrusion porosimetry using a Micrometrics Autopore IV 9500 porosimeter. The morphology was observed by scanning electron microscopy (SEM) in a Hitachi TM-1000 microscope.

LCA METHODOLOGY

Goal and Scope

The goal of this study is to compare the use of a vegetable oil with a petrochemical for the production of activated carbons-to-be porous monoliths from black liquor, as a waste that becomes a resource. The use and end of life of the monoliths were not taken into account. Therefore, this paper presents a grave-to-gate LCA conducted on a laboratory-scale process for the production of porous monoliths mainly made from black liquor directly recovered as a waste stream in the production of Kraft paper. The life cycle of black liquor being common to the two scenarios, not taking it into account wouldn’t change the results. As functional unit, we chose to compare 1 kg of porous monoliths preceded by a medium internal phase emulsion (MIPE) presenting a volume fraction of 0.54.

For the preliminary investigation, all the environmental impact categories are taken into account and compared for both scenarios. Life cycle impact assessment was done following the ReCiPe Midpoint (Hierarchist) V1.06 method (Goedkoop, 2012).

Inventory analysis

All life cycle inventory calculations were performed using SimaPro 7.3.3. The inventory analysis is based on the flow chart reported in Figure 1. Since the waste stream of black liquor was used as the “original” resource entering into the system of a grave-to-gate LCA, its inputs and outputs were not taken into account. DCA, 1-propanol and ethanol were found in EcoInvent database. We managed to found a study on LCA of biodiesel made from CO led by the Industrial University of Santander (Castro Orduz, 2009) and the synthetic pathways of epichlorhydrin and Kollipohor® EL were also available (Bell, 2008; BASF, 2008).

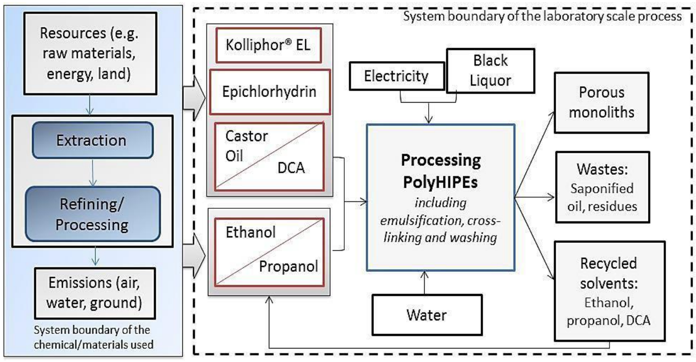


Figure 1: The system boundary of the preparation of porous monoliths from black liquor via laboratory scale process

The consumption of electricity for all included laboratory equipment has been measured directly using a power meter providing an accuracy of 0.5%. According to the geolocation, Brazilian and French electricity productions were used from the EcoInvent database for energy calculations of CO (Latin America) production and laboratory process (France), respectively. We acknowledge that using Brazilian electricity data for the geolocation in Latin America is just an approximation. Transport stages between the manufacturing plants and the laboratory have been ignored due to uncertainties regarding modes of transport and distances travelled.

RESULTS & DISCUSSION

Monoliths characterization

The analysis of the solid waste obtained in the CO based process presents typical fatty acids signals especially ricinoleic acid signals among many unidentified signals. The supposed saponification of CO doesn't allow yet to recycle it. In contrast the use of DCA enables to establish a recycling process by taking into account the boiling points of different solvents and the absence of possible azeotropes, resulting in using 1-propanol as the washing solvent. The morphology of the different samples were observed using SEM in order to estimate the size and size distribution of the voids. In both cases the average voids size values are around 12 μm. The size distribution is more regular when using DCA than CO.

Life Cycle Impacts Assessment & Interpretation

Figure 2 presents the LCA results according to the ReCiPe Midpoint (Hierarchist). This provides us with the environmental profile of the two studied scenarios. It seems that using CO would be better for the climate change but otherwise more impactful than using DCA for the preparation of porous monoliths. In order to understand that fact, it is necessary to look at each step of the two processes by complementary characterization calculations on SimaPro. For both monoliths

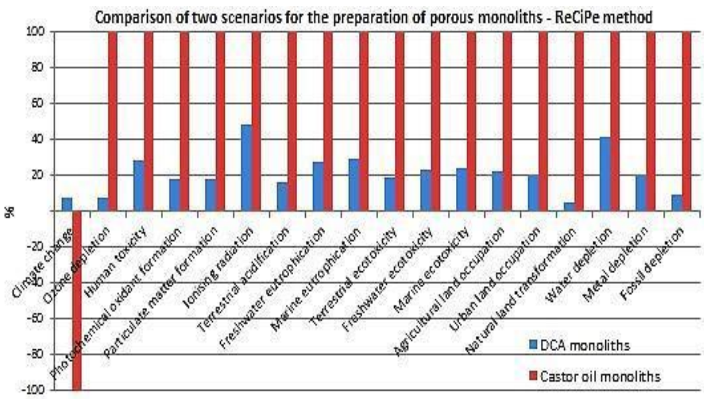


Figure 2: Comparison of the environmental impacts of both scenarios

preparation, two steps are highly responsible for the presented potential impacts: emulsification and drying.

Emulsification implies the use of electricity and raw materials. The electricity used for this step is below 0.5 kWh and thus negligible. In contrast, as all the raw materials, except for the dispersed phase (DCA and CO), are common to the two emulsifications, it means that the choice of the dispersed phase is substantial. The extraction method, the farming constraints and the non-recyclability (in the studied process) of CO are the criteria to be found the most impactful in most environmental impact categories. To dry the monolith, it requires heat, stirring and ethanol for the CO case and stirring and propanol for the DCA case. The choice of these solvents is certainly addressed by the LCA results but the biggest difference between the two drying scenarios comes from energy. Indeed, the required energy to totally remove CO from monolith matrix is up to 14.38 kWh whereas for DCA removal it only takes 4.23 kWh.

The recycling of DCA and propanol within the process has a positive influence on the LCA results as it allows to significantly decrease the potential impacts values except for a few categories (ionizing radiation, terrestrial ecotoxicity, and water depletion). As for the castor-oil-based process, the recycling of ethanol also helps to moderate the potential impacts values but not enough to compete with DCA recycling. With regard to climate change CO is more advantageous considering the photosynthesis implication during the growth of plants. Eventually this gives a negative value (-35.13 $kgCO_2/eq$ for 1 kg of porous monoliths) for Global Warming Potentials (GWP) compare to DCA monoliths GWP (2.81 $kgCO_2/eq$).

CONCLUSIONS

The use of castor oil for the production of activated-carbon-to-be materials seemed to be a judicious choice in green chemistry and it has allowed to obtain the desired polyMIPE structure. However castor oil was degraded by the alkali media and is thus non reusable. Judicious choice of a petroleum substitute such as dichloroethane allows the recycling of all raw materials. According to LCA results, environmental impacts are higher when using castor oil instead of dichloroethane as the dispersed phase for emulsions preparation. It appears that the production of castor oil and the technique to prepare its resulting monoliths are responsible for that latter fact. Considering that among the studied impact categories, climate change shows the advantage of using castor oil further research needs to strive towards good GWP results while avoiding the transfer of environmental pressure to other impact categories.

REFERENCES

ANASTAS P., WARNER J., (1998), Green Chemistry: Theory and Practice, Oxford University Press: New York

BASF technical data sheet on Kolliphor EL, EMP 030711e-05/06/2008

BELL, B. M., et al. (2008). *Clean Journal*, 36(8), 657 – 661. DOI: 10.1002/clen.200800067

CASTRO ORDUZ (2009). Evaluation of the life cycle assessment for the production of biodiesel from castor oil at Eja Cafetero, Chem. Engineering Thesis, Industrial University of Satander, 74p.

FORGACZ, C. et al. (2013). Synthesis of Porous Emulsion-Templated Monoliths from a Pulp Mill By-Product, *J. Appl. Polym. Sci*., DOI: 10.1002/APP.38981

GOEDKOOP, M. et al. (2012, July). ReCiPe 2008. A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. First edition (revised). Report I: Characterisation

MILLER, S.A. et al. (2007). A Comparative Life Cycle Assessment of Petroleum and Soybean-based Lubricants, *Environ. Sci. Technolog*., 41,4143-4149

HOW THE CHEMICAL AND MATERIAL MANAGEMENT IN THE AUTOMOTIVE INDUSTRY BECAME A QUALITY IMPROVER FOR LCA STUDIES IN THE VOLVO GROUP

Lisbeth Dahllöf, Volvo Group Trucks Technology, Advanced Technology and Research, BF 40820, M1:4, SE-405 08 Gothenburg lisbeth.dahllof@volvo.com

Keywords: Chemical Lists; IMDS; LCA, Design for Environment

ABSTRACT

The complex nature of the automotive industry has forced it to develop chemical and substance lists and to harmonize these to a common list, the Global Automotive Declarable Substance List (GADSL). The International Material Data System (IMDS) includes this and other lists from REACH and the End-of-Life (ELV) Directive. It also includes the weight of different materials and substances. This turns IMDS into a source for LCA studies. The time saved for the Life Cycle Inventory (LCI) is at about 90 %. The quality of LCA studies is also increased. Although there are secrecy aspects to take into account for Material Data Sheets (MDSs), there is now a foundation for improved DfE, remanufacturing and recycling.

INTRODUCTION

It is a difficult task to guarantee chemical substance safety in the automotive industry; there are many different parts and chemical substances, and the supply chains are complex. Therefore, the Volvo Group has worked for a long time with risk minimization by using the Volvo issued black and grey chemical lists for prohibited and declarable substances in articles (Bruhn et al [1996], Hall Jennifer [2000], STD 100-0002, STD 100-0003). Current legislation is the basis for the most part, but Volvo also puts a lot of effort into foreseeing future legislation that will affect the automotive industry, and this is mirrored in the lists. Nowadays, these lists are complemented by the Global Automotive Declarable Substance List (GADSL) which is a common automotive industry list for automotive parts. Weight, material and substance data for the parts are collected through the common automotive International Material Data System (IMDS) where these data are checked against various lists such as the GADSL, the REACH and the End-of-Life (ELV) Directive's metals lists. Volvo started to work actively with IMDS in 2009 and now many but not all parts have Material Data Sheets (MDS) in IMDS. MDSs for Volvo parts are uploaded to a database at Volvo that can be regarded as a gatekeeper for chemical substances. Here, a check is made against the black and grey lists as a complement to the other lists checks. The background for the IMDS system is mainly the ELV Directive, which currently stipulates 80 % reuse or recycling rate, with a total recovery of 85% and prohibition of certain heavy metals (lead, mercury, cadmium and hexavalent chromium). Today, the Volvo black and grey lists are used for chemicals in the production processes and for parts where there is a risk that employees will enter into physical contact.

To complete the picture of chemical substance management, it is worth mentioning that, to secure chemical products used in the Volvo Group, the complete recipe is given by the supplier under a strict confidentiality agreement for assessment at Volvo. This is done outside of IMDS.

The Volvo Group has a long tradition of analysing the whole life cycle of vehicles in order to minimize the environmental impact. Therefore, LCA studies are made when new technology and vehicles are developed (Kantz, 2000).

A bonus effect of all this effort of keeping track of chemical substances and materials is that LCA studies at the Volvo Group can now be performed much faster and with better quality, as described below.

METHODS

As a rule, LCA studies on vehicles are extremely time-consuming due to the inventory phase. Without Material Data Sheets (MDS) from the IMDS, the LCA practitioners have to do manual work such as searching for part numbers in the product data management system where the data are often imprecise. The data series usually contain gaps, why the LCA practitioner has to consult the original designer or purchaser to obtain information. Data for the small amounts of, e.g., additives or trace metals are often not mentioned.

Inspired by Koffler et al, 2008, the Volvo Group now uses the IMDS database for LCA studies. The Volvo “gatekeeper” database can create Bill of Materials (BOMs) by connecting to the product data management and prototype systems. By using these connections, material data for the parts are uploaded for a specified vehicle. Since the data are very specific − there are hundreds of materials and even more material names, but the amount of LCI data for the production of materials is limited −, Volvo uses a module for translating material names to names that have LCI data in the LCA software. Sometimes, the material name matches exactly a material for which we have LCI data for material production, while other times an approximation has to be made. Translation is done once for each material name; thus, if the material occurs repeatedly, the translation is done for all instances. Manufacturing data for parts will also be added to this module.

LCA calculations are also simplified by using the DfX extension to the GaBi software since the structure for the BOM is ready-made in the computer software.

RESULTS

In such cases where all parts are reported in the IMDS, which is the goal, the Volvo Group has managed to speed up the LCA studies by about 90 %. To a large extent, data quality is also improved. This enables Volvo to increase the number of LCA studies so as to assess the achievements in environmental improvements and to guide, internally within Volvo, Design for Environment.

A complementary result is that we now, thanks to the IMDS, can sum up the number of different elements and chemical substances in vehicles and also to know the weights. Technically we can, of course, trace everything back to the individual parts, but we must be careful not to misuse data and especially not to communicate them to the purchasing departments or others who are working with business cases. However, there may be opportunities to initiate collaboration with suppliers in order to minimize the use of scarce elements, to increase remanufacturing opportunities and to contribute to more efficient recycling.

DISCUSSION

IMDS output data cannot be better than the input data, and there are of course issues in data quality, e.g. for electronics. But still, IMDS is a big step forward both for substance assessment and the LCA.

CONCLUSIONS

IMDS has opened the door to more efficient and quality-assured LCA studies in the automotive sector. There is now a basis for more environmentally conscious design, more remanufacturing and better recycling.

REFERENCES

Bruhn R., Lidholm P., Wass U. (1996). Chemicals to be phased out – the black and grey Volvo lists. *25th International Congress on Occupational Health*, p. 87. ISBN 91-7045-381-0.

Hall, Jennifer (2000). Product Design to Reduce Restricted Substances: experience with brominated flame retardants in vehicle design. *Swedish National Chemicals Inspectorate 7/00,* 66−67. ISSN 0284-1185.

Kantz, Orley (2000). Volvo's holistic approach to environmental strategy, *Corporate Environmental Strategy, Vol. 7, issue 2*, 156−169.

Koffler, C., Krinke, S., Schebek, L. and Buchgeister, J. (2008). Volkswagen slimLCI: a procedure for streamlined inventory modelling within life cycle assessment of vehicles, *Int. J. Vehicle Design, Vol. 46, no. 2,* 172–188

STD 100-0002. Chemical substances which must not be present in processes or products within the Volvo Group, Volvo's black list. Retrieved on May 24, 2013, from http://www.tech.volvo.com/std/docs/100-0002

STD 100-0003, Chemical substances which should not be present in processes or products within the Volvo Group, Volvo's grey list. Retrieved on May 24, 2013, from http://www.tech.volvo.com/std/docs/100-0003

ACKNOWLEDGMENT

PE International is acknowledged for developing the translation module for DfX in collaboration with the Volvo Group.

IMPROVED CHARACTERIZATION OF DETERGENT (ECO)TOXICITY IN LCIA USING REACH EXPERIENCE

Elorri Igos, Ruth Moeller, Enrico Benetto, Arno Biwer, Mélanie Guiton (Public Research Centre Henri Tudor), Philippe Dieumegard (Chemolux / McBride Group)*

* *Public Research Centre Henri Tudor, 6A avenue des Hauts-Fourneaux, L4362 Esch sur Alzette, Luxembourg. elorri.igos@tudor.lu*

Keywords: toxicity, LCA, REACH, detergent, dishwasher, USETox

ABSTRACT

Life Cycle Assessments of three detergents products from Chemolux-McBride group are analysed in order to evaluate the environmental improvements provided by the novel formulations. Detailed discussion of the characterization factors (CFs) developed within the USEtox model for freshwater ecotoxicity and human toxicity is provided. In particular, the publically available data collected under REACH were used for the development of the CFs. The results demonstrate the benefit of removing phosphate ingredients. Several limitations in the CF development process were found: for example the endpoints required by the REACH regulation are different from the ones required by USEtox. Nevertheless, the two approaches can be used to obtain harmonized and complementary results.

INTRODUCTION

The composition of dishwasher detergents is highly regulated and the European Union Member States agreed to ban phosphorous as ingredient due to the eutrophication potential. According to the literature review, several studies focused on laundry detergent products, evaluating the environmental performances of different formulations using the Life Cycle Assessment (LCA) methodology (ISO 1040 and 14044, 2006). These studies had a special focus on freshwater ecotoxicity potential of the effluent from dishwasher. However, the chemicals included in the effluent, mainly coning from the detergents composition, are hardly characterized by the current Life Cycle Impact Assessment (LCIA) methods and therefore new characterization factors need to be developed, for example using the USEtox model (Rosenbaum et al., 2008), as in Van Hoof et al. (2011).

In this paper, the LCIA results of three detergents products from Chemolux-McBride group are analysed in order to evaluate the environmental improvements provided by the recent novel formulations. Detailed discussion of the characterization factors (CFs) developed within the USEtox model for freshwater ecotoxicity and human toxicity is provided. In particular, the publically available data collected under REACH (European Commission, 2006) were used for the development of the CFs, taking profit from the links between REACH and LCA (Askham, 2012). Comparison with existing results from literature as well as sensitivity analysis have been performed to highlight the robustness and limitations of the results.

MATERIALS AND METHODS

A phosphate-based tablet (PB), an eco-labelled tablet (EL) and a phosphate-free soluble bag (PF) were analysed. For each detergent product, the life cycle inventory is based on the use of the detergent product, using formulation data from the producer and removal performances of wastewater treatment plant (treating the effluent) from literature. Freshwater ecotoxicity and human toxicity have been characterized for the effluent after one washing cycle and a partial removal in the wastewater treatment plant. Regarding the three detergents, only four ingredients in total were already characterized by USEtox. New CFs have been developed for the other substances, assuming a cut-off of 1%, in order to focus on the main substances. Polymer compounds were modelled considering acrylic acid as a proxy due to the general lack of data on polymers. Nine other substances were specifically characterized: alcohols C11 ethoxylated propoxylated (AE C11), alcohols C8-C10 ethoxylated (AE C8-10), disodium carbonate compound with hydrogen peroxide (Na-percarbonate), N,N'-ethylenebis[N-acetylacetamide] (TAED), pentasodium triphosphate (STP), polyethylene glycol (PEG), silicic acid sodium salt (Na-silicate), sodium carbonate (Na-carbonate) and tetrasodium (1-hydroxyethylidene) bisphosphonate (4Na HEDP).

The USEtox model describes the cause-effect chain of a chemical emitted into the environment: fate, exposure and effect. The CF is obtained by multiplying these three factors. For freshwater ecotoxicity, the unit is $PAF.m^2.day.kg^{-1}$ (PAF for Potentially Affected Fraction of species), while human toxicity is expressed in $cases.kg^{-1}$. New CFs can be calculated using an Excel sheet provided by the USEtox developers.

In USETox, the fate of the substances in the environment is based on a multimedia model, requiring twelve physicochemical parameters which can be reduced to eight in case of organic substances under specific assumptions. For the four inorganic substances contained in the studied detergents, (Na-percarbonate, STP, Na-carbonate and Na-silicate), the same eight parameters were also considered by default, due to a lack of data. The specific parameters proper to each substance were retrieved from EPI Suite™ model (2013) if no experimental data were available in the HERA reports (2013). No data were available for Na-percarbonate: properties similar than the ones of Na-carbonate and Na-silicate were assumed and no degradation potential (as in Van Hoof et al., 2011). Environmental exposure is calculated through the dissolved fraction in freshwater, while human exposure is evaluated via the potential transfer pathways (water drinking, air inhalation, food ingestion, etc.).

The effect of the pollutant is assessed through: i) its ecotoxicity potential, based on the geometric mean of chronic EC50s, i.e. the effect concentration at which 50% of the tested population are affected; and ii) its toxicity potential, based on chronic ED50, i.e. the effect dose which affects 50% of the tested population. These toxicity endpoints were mainly collected from the ECHA portal (2013) as data are up-to-date and presumably complete. In case of missing data, other databases were used (OECD eChem, PAN Database, ChemID or ECOSAR from EPI Suite™). In some cases, extrapolation factors defined in USEtox were applied in order to account for different time of exposure (e.g. factor of 2 between acute and chronic EC50s), interspecies differences (e.g. factor of 4.1 between rat and human ED50s) or endpoint differences (e.g. factor of 9 between NOAEL and ED50).Furthermore there is no indication that the assessed substances are carcinogenic and only non-carcinogenic effects to humans were therefore evaluated.

RESULTS

CFs for freshwater ecotoxicity were calculated for the nine substances while only four CFs could be developed for human toxicity (AE C8-10, TAED, Na-silicate and 4Na HEDP) due to lack of repeated doses tests in the toxicity databases. After integration of these newly calculated values, the USEtox results for the effluents from the three detergents are presented in Figure 1. More than 95% of the effluent composition is characterized for freshwater toxicity whereas only less than 40% is represented for human toxicity. Regarding the three detergents, the main contributing substances are Na-carbonate, Na-percarbonate, acrylic acid (proxy for all polymers), Na-silicate and STP. The large contribution of STP in the PB product highlights the benefit of its removal into the new formulations (EL and PF). When assessing the freshwater ecotoxicity of the overall lifecycle of the detergents, the effluent contribution varies from 60% to 80% of the whole lifecycle impact. This result emphasizes the importance of the characterisation of the effluent composition.

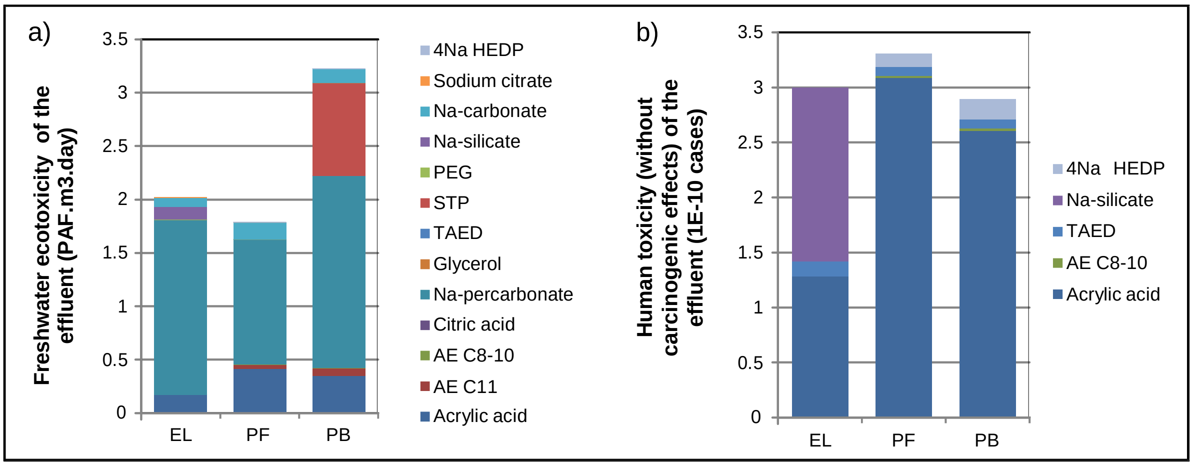


Figure 1: Comparison of a) freshwater ecotoxicity and b) human toxicity (without carcinogenic effects) of the effluent from EL, PF and PB detergents.

DISCUSSION

A comparison between the developed CFs and the ones of Van Hoof et al. (2011) was carried out for eight substances which were in common. The resulting variation of CFs is acceptable (same order or one order of magnitude difference). The differences show, however, the sensitivity of the USEtox model with respect to the data source and to the practitioner choices. Sensitivity analysis was also carried out on each parameter of the model. The ecotoxicity effect was found to be the most influencing one. Results for fate properties were only sensitive to the degradation rate in water, in accordance to Birkved and Heijungs (2011).

The development of CFs within USEtox model implies several limitations. First, the fate model is hardly applicable to inorganic compounds. In order to improve their assessment, the potential organic dissociation products could be studied. Evaluating the impact of the mother compound can lead to overestimations because only part of the dissociation products could be toxic. Secondly, the effect assessment suffers from a lack of available data, in particular if the chemical has not yet been registered under REACH. Even in the case of a registered substance, the chronic EC50 and ED50 endpoints required by USEtox are rarely reported because other endpoints are used in the regulatory assessment and partially or no reliable data are provided in the registration. The lack of availability and/or reliability of data can lead to the use of extrapolation factors increasing the uncertainty of the assessment.

CONCLUSIONS

The results confirmed the environmental benefits of removing phosphate ingredients from the composition of dishwasher detergents. The importance of characterizing new substances was proven by the high contribution of the effluent to the overall ecotoxicity of the detergents lifecycle. For a more consistent comparison of the products, other environmental categories should also be considered. The present work focused on the development of CFs within USEtox to characterize only the (eco)toxicity of the detergent ingredients. The comparison with previous studies showed that the model was quite stable. The most sensitive parameter is the effect factor, which requires therefore special attention by the practitioners. The endpoints have been selected using data collected under the REACH regulation. Although the two frameworks are fundamentally different, they can benefit from each other to increase data availability and reliability, as well as provide harmonized results to the industry.

REFERENCES

Askham, C. (2012). REACH and LCA – methodological approaches and challenges. *Int J LCA 17, 43-57.*

Birkved, M. & Heijungs, R. (2011). Simplified fate modeling in respect to ecotoxicological and human toxicological characterisation of emissions of chemical compounds. *Int J LCA 16(8), 739-747.*

ECHA (2013). European Chemicals Agency portal, available at http://www.echa.europa.eu/

EPI Suite™ (2013). Estimation Programs Interface Suite™ model by the U.S. EPA Office of Pollution Prevention and Toxics and SRC, downloaded at http://www.epa.gov/oppt/exposure/pubs/episuite.htm.

European Commission (2006). Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission

HERA (2013). Human and Environmental Risk Assessment reports on ingredients of household cleaning products, downloaded at http://www.heraproject.com/RiskAssessment.cfm.

ISO-International Organisation for Standardisation (2006). Environmental Management – Life Cycle Assessment ISO 14040 Principles and Framework ISO 14044 Requirements and Guidelines, Geneva.

Rosenbaum, R.K., Bachmann, T.M., Gold, L.S., Huijbregts, M.A.J., Jolliet, O., Juraske, R., Koehler, A., Larsen, H.F., MacLeod, M., Margni, M., McKone, T.E., Payet, J., Schuhmacher, M., van de Meent, D., & Hauschild, M.Z. (2008). USEtox-the UNEP-SETAC toxicity model: recommended characterization factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment. *Int J LCA 13, 532-546.*

Van Hoof, G., Schowanek, D., Franceschini, H., Muñoz, I. (2011). Ecotoxicity impact assessment of laundry products: a comparison of USEtox and critical dilution volume approaches. *Int J lCA 16, 803-818.*

SUSTAINABLE INNOVATION OF CHEMICALS: USING LCA AS A METRICS IN ADVANCING AND SCALING UP GREEN CHEMISTRY RESEARCH

Guido W. Sonnemann, Amandine Foulet and Philippe Garrigues*

Univ. Bordeaux, ISM, UMR 5255, F-33400 Talence, France.
CNRS, ISM, UMR5255, F-33400 Talence, France.
The Life Cycle Group CyVi
Email: g.sonnemann@ism.u-bordeaux1.fr

Keywords: Sustainable innovation, chemicals, LCA metrics, green chemistry

ABSTRACT

The concept of Green Chemistry was coined in the 1990s and can be briefly defined as applying the pollution prevention approach to chemistry. LCA is a technique to assess environmental impacts associated with all the stages of a product's life from-cradle-to-grave. If this method is applied in the form of a gate-to-gate LCA it provides the environmental profile, or footprint, of a chemical or material composed of multiple chemicals. A criticism to the 12 green chemistry principles as a tool is their qualitative nature. Using two examples, this paper shows how LCA can help evaluating the 12 principles in concrete cases of advancing green chemistry research towards the sustainable innovation of chemicals. Emphasis is made to show the potential for using LCA as a metrics in scaling up this research.

INTRODUCTION – GREEN CHEMISTRY (GC)

The concept of Green Chemistry (GC) was coined by US EPA in the 1990s and can be briefly defined as applying the pollution prevention approach to chemistry (Anastas and Werner, 1998). Overall the concept has a strong focus on reducing and eliminating the use and generation of hazardous substances. In order to make this concept operational, the USEPA developed the Twelve Principles of Green Chemistry; see Figure 1.

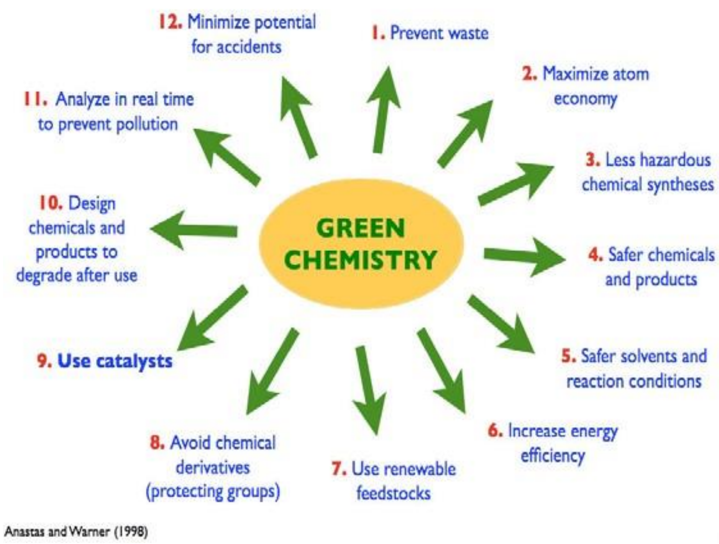


Figure 1. The Twelve Principles of Green Chemistry

These principles constitute the backbone of GC and a universal code of practice for the eco-design of chemicals and chemical processes (Clark and Macquarrie, 2002). A criticism to the 12 principles of Green Chemistry as a tool is that some of them have qualitative nature, which can lead to difficulties when the progress made by introducing GC practices has to be measured, or when trade-offs between principles arise (Muñoz, 2012).

METHODS – LIFE CYCLE ASSESSMENT (LCA)

The scientific community noticed this limitation of Green Chemistry, and several methods for environmental assessment in GC have been proposed. Life Cycle Assessment has been highlighted as a suitable tool in this context by several authors such as Anastas and Lankey (2000), Domenech et al (2002), Gustafsson and Börjesson (2007) and Muñoz (2012).

According to the ISO 14040 series Life Cycle Assessment is a technique to assess environmental impacts associated with all the stages of a product's life from-cradle-to-grave. It allows accounting for the resource consumption and emissions at each step of the product life cycle. If this method is applied in the form of a gate-to-gate LCA it provides the environmental profile, or footprint, of a chemical or material composed of multiple chemicals.

RESULTS – USING LCA AS A METRICS FOR TWO GC EXAMPLES

Life Cycle Assessment is applied in two cases to demonstrate how it can be used as a metrics to quantify the results achieved on the basis of the green chemistry principles. One example is the case of two chemical reactions to produce maleic anhydride and the other is the production of hydrogen from fossil fuels or from vegetable oils.

Maleic anhydride

Domenech et al (2002) present an example with two routes of obtaining maleic anhydride that are compared using LCA, to ascertain which one is the environmentally more sustainable one. A possible way to produce maleic anhydride is the oxidation of benzene with oxygen gas over a V_2O_5 catalyst, at 3 to 5 bar of pressure and at a temperature of 350 to 450 °C. The use of butene as feedstock is an alternative way of obtaining produce maleic. Figure 2 presents chemical reactions, the thermodynamic conditions and the Atom Economy (AE) of the two reactions. Table 1 explains which Green Chemistry principles have been applied.

Figure 3 presents the Life Cycle Impact Assessment results from the LCA for the comparison of these two routes of obtaining maleic anhydride. The results clearly demonstrate how LCA allows communicating with quantitative sustainability information the application of the qualitative Green Chemistry principles.

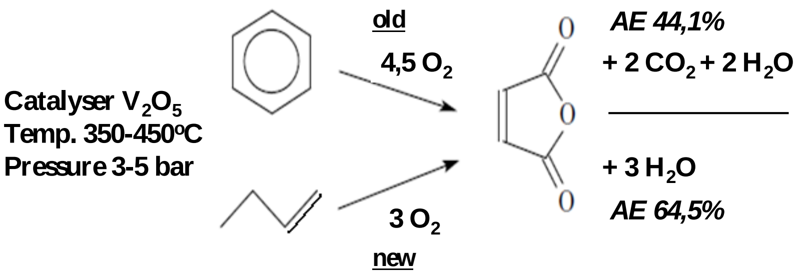


Figure 2. Two routes of obtaining maleic anhydride (AE – Atom Economy)

Green Chemistry Principle	Industrial Motivation
Atom Economy	Δ AE 20,4%
Simple and safe process	Easy recovery and separation due to reduced by-products
Less waste and emission	Emissions of CO_2 avoided
Minimisation of toxicity	Toxicity of benzene avoided

Cavani et al (2009)

Table 1. The application of the Green Chemistry principles and the industrial motivation

System	GWP g CO_2	AP. g SO_x	EP. g PO_4^{3-}	ODP g C_2H_2	Solid waste g	Energy Cons. MJ
Production of 1 mole maleic anhydride from benzene						
Benzene prod.	42	0.60	0.069	0.26	0.76	5.8
Oxygen prod.	31	0.33	0.008	N	N	0.28
Waste Treat.	88	0,0012	N	N	0.36	0.06
Energy prod.	-67	-0.31	N	N	N	-0.49
TOTAL	**94**	**0.63**	**0.077**	**0.26**	**1.1**	**5.65**
Production of 1 mole maleic anhydride from butylene						
Benzene prod.	28	0.41	0.044	0.16	0.46	3.8
Oxygen prod.	20	0.22	0.006	N	N	0.19
Waste Treat.	0,0010	0.018	0.001	N	0.54	0.09
Energy prod.	-40.5	-0.19	N	N	N	-0.30
TOTAL	**7.5**	**0.46**	**0.051**	**0.16**	**1.0**	**3.78**

GWP – Global Warming Potential
AP – Acidification Potential
EP- Eutrophication Potential
ODP – Ozone Depletion Potential
Cons. – Consumption
Prod. - Production

Domenech et al (2002)

Figure 3. Life Cycle Impact Assessment results for the routes of producing maleic anhydride

Hydrogen

Following the GC principle to use renewable feedstock Marquevich et al (2002) studied pathways to produce hydrogen from vegetable oils. A life cycle inventory was prepared to assess the CO_2 (fossil) emissions and then to calculate the Global Warming Potential (GWP), associated to the production of hydrogen by the steam reforming of hydrocarbon feedstocks (methane and naphtha) and vegetable oils (rapeseed oil, soybean oil and palm oil).

Results show that the GWPs associated with the production of hydrogen by steam reforming in a 100 years time frame are 9.71 and 9.46 kg CO_2-equivalent/kg H_2 for natural gas and naphtha, respectively. For vegetable oils, the GWP decreases to 6.42 kg CO2-equivalent/kg H_2 for rapeseed oil, 4.32 for palm oil and 3.30 for soybean oil. A dominance analysis determined that the part of the process that has the largest effect on the GWP for vegetable oil-based systems is harvesting and oil production. The quantitative information provided by LCA allows choosing the vegetable oil with the lowest carbon footprint. Applying only the GC principle does not provide this level of detail to orientate further research.

DISCUSSION – ADVANCING AND SCALING UP GC RESERACH

The two simple examples put into evidence that using LCA is useful to advance Green Chemistry research since it facilitates the choice of the most environmentally sustainable path forward and provides a consistent basis for a professional communication about relevant sustainability characteristics like carbon footprint. Applying the Green Chemistry principles and quantifying the progress in sustainable innovation of chemicals made by LCA offer a decent framework for moving towards a sustainable chemistry.

LCA is of particular interest when getting out of the chemistry lab into an industrial scale. Then resource efficiency and cost consideration become the crucial criteria for moving ahead in the innovation process or discarding an originally promising new chemical reaction or process. However, precaution needs to be applied in interpreting LCA results from lab experimentation. It does not mean that the idea for a novel technology is not good; it just means it is not resource-efficient yet but with maturation the production processes may still get through a continuous learning period to an unexpected level of efficiency.

CONCLUSIONS AND PERSPECTIVES

A criticism to the 12 principles of Green Chemistry as a tool is their qualitative nature, which can lead to difficulties when the progress made by introducing GC practices has to be measured, or when trade-offs between principles arise. The scientific community noticed this limitation, and several methods for environmental assessment in GC have been proposed. LCA has been highlighted as a suitable tool in this context by many authors.

Using only two literature examples, this paper shows how LCA can help evaluating the 12 GC principles in concrete cases of advancing green chemistry research towards the sustainable innovation of chemicals. A particular strength of LCA is the role it can place as a metrics in insuring resource efficiency when scaling up Green Chemistry research. Evidently, precautions should be taken in interpreting LCA results from lab-scale chemical experiments.

Further work foreseen implies to integrate the existing GC metrics like effective mass yield and atom economy in an indicator framework with Life Cycle Impact Assessment and to apply LCA to green synthesis pathways like use of microwave, ultrasound or ionic liquids.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial support of the Institute of Molecular Sciences (ISM) and the Region of Aquitaine, France, for allowing the corresponding author and his colleagues to carry out this research and to present our work at the conference.

REFERENCES

Anastas P.T., Warner J.C. (1998) Green Chemistry: Theory and Practice, Oxford University Press, New York

Clark J.H. and Macquarrie D.J. (eds, 2002) Handbook of Green Chemistry and Technology, Blackwell Science, Oxford, UK

Muñoz I. (2012) LCA in Green Chemistry: a new subject area and call for papers, Int J Life Cycle Assess 17:517–519

Anastas, P.T. , Lankey R.L. (2006) Life-Cycle Assessment and Green Chemistry: The Yin and Yang of Industrial Ecology. Green Chem. 6: 289-295

Gustafsson L.M., Börjesson P. (2007) Life Cycle Assessment in Green Chemistry - A comparison of various industrial wood surface coatings, Int J Life Cycle Assess 12:151–159

Domenech X., Ayllon J.A., Peral J., Rieradeval J. (2002) How Green Is a Chemical Reaction? Application of LCA to Green Chemistry, Environ. Sci. Technol. 36: 5517-5520,

Cavani F., Centi G., Perathoner S., Trifiro F. (2009) Sustainable Industrial Processes, WILEY-VCH Verlag, Weinheim, Germany

Marquevich M., Sonnemann G. Castells F., Montané D. (2002) Life cycle inventory analysis of hydrogen production by the steam-reforming process: comparison between vegetable oils and fossil fuels as feedstock, Green Chemistry 4: 414–423

PREPARING FOR RIGHT PRICES

Monday, Aug 26: 3:30 pm - 5:00 pm

Session chairs: Bengt Steen, Chalmers University of Technology, Sweden
Philipp Preiss, Universität Stuttgart , Germany

A NEW SET OF VALUATION FACTORS FOR LCA AND LCC BASED ON DAMAGE COSTS – ECOVALUE 2012

*Göran Finnveden KTH Royal Institute of Technology, Division of Environmental *Strategies Research. Drottning Kristinas väg 30. 100 44 Stockholm. goran.finnveden@abe.kth.se*

Cecilia Håkansson KTH Royal Institute of Technology, Division of Environmental Strategies Research.

Maria Noring KTH Royal Institute of Technology, Division of Environmental Strategies Research.

Keywords: Weighting; Valuation; Impact assessment; LCA; LCC.

ABSTRACT

Weighting is often used in environmental systems analysis tools. One method is Ecovalue which in its first version was published in 2011. In this paper an updated version is presented. New factors are for exotoxicological impacts and for particulates. The factor for climate change has been updated. The updated set of valuation weighting factors also includes default values in addition to low and high values. The new set is matched with the Recipe methodology except for abiotic resources where Cumulatative Exergy Demand is used. Results from an ICT product show that in this case climate change, toxic impacts and resources use are highlighted as important impact categories.

INTRODUCTION

In many environmental systems analysis tools, such as Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Cost-Benefit Analysis (CBA) weighting is used (Ahlroth et al, 2011). The purpose is to simplify the comparison between different impacts and alternatives. There are several methods available (Huppes et al, 2012) and they can give significantly different results. If the different weighting methods reflect different values, they should give different results. It is however interesting to note that many of the methods used have not been published in peer reviewed papers and may not include state-of-the art scientific methods and data.

In Ahlroth and Finnveden (2011) the valuation set Ecovalue08 is presented. It is a monetary weighting set using impact categories from LCA and values on the benefit loss caused by environmental degradation. The set includes the following impact categories: eutrophication, acidification, global warming, forming of tropospherical ozone, human toxicity and depletion of abiotic resources.

People's preferences changes with time, as does knowledge about environmental relationship. In this paper an updated version of Ecovalue is presented focused on Swedish conditions as well as an improved number of impact categories. The paper also presents a case study where the weighting set has been used.

METHODS

Values from the earlier weighting set have been reconsidered based on more recent studies and two more impact categories have been added. The values have been adjusted to 2010 year's monetary value. In Ahlroth & Finnveden (2011) the values are presented in a range to reflect the uncertainty in the valuation studies. This updated version also includes a default value in order to increase the usability.

The updated weighting set was tested in a LCA case study by Achachlouei et al (2013) on reading a magazine on a tablet. In the case study the weighting set is combined with the characterization methods ReCiPe (Goedkoop et al, 2009) and Cummulative Exergy Demand (Bösch et al, 2006).

RESULTS

The updated valuation set

Abiotic resources. The value of abiotic resources in the Ecovalue method is based on the monetary resource value which consists of the difference between the market price and the marginal production cost. This value is regarded as reflecting the valuation of the resource and the exergy method is used as a characterization method (Ahlroth & Finnveden, 2011). The values in Ahlroth & Finnveden (2011) are kept, but a mean value of SEK 0.12/MJ is proposed.

Global warming. Since the last version of Ecovalue several studies have shown that the damage costs from global warming might be higher but also uncertain (e.g. (Ackerman & Stanton, 2012; Anthoff, Tol, & Yohe, 2009; Botzen & van den Bergh, 2012; Tol, 2010). A higher maximum value than the previous presented in (Ahlroth & Finnveden, 2011) is proposed based on the studies above. The new, maximum value is SEK 5.6/ton CO_2. The mean value, SEK 2.85/kg CO_2-equivalents, is proposed.

Photochemical oxidation. The values for photochemical oxidation remains the same in this version, SEK 14-40/kg C_2H_2-equivalents, but the mean value is proposed, SEK 27/kg C_2H_2-equivalents.

Acidification. No further valuation studies on acidification in Swedish conditions have been made since the last version of the valuation set and the suggestion is kept.

Eutrophication. The values presented in Ahlroth & Finnveden (2011) are regarded as relevant. The mean values, SEK 670/kg P for freshwater eutrophication and SEK 90 /kg N for marine waters are proposed.

Human toxicity. The value on human toxicity is based on damage costs from emissions of different heavy metals. Updates have been made regarding these damage costs valid for the EU (Bruyn et al., 2010) and based on their findings the value SEK 2.81/kg DB-equivalents is suggested.

Marine toxicity. Marine toxicity was not included in Ecovalue08. The introduced value is based on a recent valuation study on Swedish coastal waters where the impacts of tributyltin compounds (TBT) have been valued (Noring et al. 2013). The value estimated is SEK 12/kg 1,4 DB-equivalents.

Particles. Also the value of particles is a new contribution to the weighting set. European estimates on damage costs made by Bruyn et al. (2010) constitutes the basis for the proposed value of 273 SEK/kg PM_{10}-equivalents. This value describes regional impacts. If local impacts are of concern, the value could be significantly higher.

All the updated values are presented in Table 1.

Table 1. The updated weighting set.

Impact category	Weighting: mean value	Weighting: interval
Abiotic resources	SEK 0.12 /MJ	SEK 0.004-0.24 /MJ
Global warming	SEK 2.85 /kg CO_2-eq	SEK 0.1-5.6 /kg CO_2-eq
Photochemical oxidation	SEK 27 /kg C_2H_2-eq	SEK 14-40 /kg C_2H_2-eq
Acidification	SEK 30 /kg SO_2-eq	SEK 30 /kg SO_2-eq
Eutrophication, marine	SEK 90/kg N	SEK 90/kg N
Eutrophication, fresh water	SEK 670/kg P	SEK 670/kg P
Human toxicity	SEK 2.81 /kg 1,4 DB-eq	SEK 0.02-4.89 /kg 1,4 DB-eq
Marine water toxicity	SEK 12 /kg 1,4 DB-eq	SEK 12 /kg 1,4 DB-eq
Particles	SEK 273 /kg PM_{10}-eq	SEK 273 /kg PM_{10}-eq

Case study
The weighting set was applied on a study on reading a magazine on a tablet (Achachlouei et al, 2013) and results from the case study is presented in Table 2.

Table 2. Environmental impact from reading a magazine on a tablet Results weighted with Ecovalue12 and expressed as SEK per reader and issue.

Impact category	Climate change	Human toxicity	Photochemical oxidant formation	Particulate matter formation	Terrestrial acidification	Freshwater eutrophication	Marine eutrophication	Marine ecotoxicity	Cumulative Exergy Demand	TOTAL
Tablet magazine	0,52	0,88	0,01	0,09	0,02	0,13	0,02	0,05	1,11	2,83

DISCUSSION AND CONCLUSIONS

Valuation weighting factors will always be uncertain and care should be taken when conclusions are drawn. The case study indicates that Climate change, Human toxicity and

Resources are important impact factors. This seems like relevant results for the case study. The new weighting factors for ecotoxicological impacts and particulates are in this case study not insignificant but are not dominating the results. More case studies are however needed before any conclusions about the relative importance of different impact categories are. It would also be of importance to compare the results with other weighting methods as well.

REFERENCES

Achachlouei, M.A., Moberg, Å and Hochschorner, E. (2013): Life cycle assessment of a magazine—part 1: tablet edition in emerging and mature states. Submitted

Ackerman, F., & Stanton, E. a. (2012). Climate Risks and Carbon Prices: Revising the Social Cost of Carbon. *Economics*, *6*, 0–26. doi:10.5018/economics-ejournal.ja.2012-10

Ahlroth, S., & Finnveden, G. (2011). Ecovalue08–A new valuation set for environmental systems analysis tools. *Journal of Cleaner Production*, *19*(17-18), 1994–2003. doi:10.1016/j.jclepro.2011.06.005

Ahlroth, S., Nilsson, M., Finnveden, G., Hjelm, O. and Hochschorner, E. (2011): Weighting and valuation in environmental systems analysis tools. *Journal of Cleaner Production*, 19, 145-156.

Anthoff, D., Tol, R. S. J., & Yohe, G. W. (2009). Risk aversion, time preference, and the social cost of carbon. *Environmental Research Letters*, *4*(2), 024002. doi:10.1088/1748-9326/4/2/024002

Bösch, M., Hellweg, S., Huijbregts, M. and Frischknecht, R. (2006): Applying cumulative exergy demand (CExD) indicators to the ecoinvent database. International Journal of Life Cycle Assessment, 12, 181-190

Botzen, W. W. J., & Van den Bergh, J. C. J. M. (2012). How sensitive is Nordhaus to Weitzman? Climate policy in DICE with an alternative damage function. *Economics Letters*, *117*(1), 372–374. doi:10.1016/j.econlet.2012.05.032

Bruyn, S. De, Korteland, M., Markowska, A., Davidson, M., De Jong, F., Bles, M., & Sevenster, M. (2010). *Shadow Prices Handbook: Valuation and weighting of emissions and environmental impacts* (pp. 1–140).

ESPREME (2008): Estimation of willingness-to-pay to reduce risks of exposure to heavy metals and cost-benefits analysis for reducing heavy metals occurrence in Europe. Final report. Contract No. 502527

Goedkoop, M., Heijungs, R., Huijbregts, M., De Scryver, A., Sruijs, J. and Van Zelm, R. (2009): ReCiPe 2008, Report 1: Characterization., Ministry of VROM, The Hague, The Netherlands.

Huppes, G., van Oers, L., Pretato, U. & Pennington, D.W.(2012): Weighting environmental effects: Analytical survey with operational evaluation methods and a meta-method. International Journal of Life Cycle Assessment, 17, 876-891.

NIER (1998): Swedish environmental accounts for sulphur and nitrogen. *Environmental accounts 1998:7, Stockholm.*

Noring, M., Håkansson, C., Boalt, E. (2013) Costs and benefits from the management of the coastal environment. In preparation.

Tol, R. S. J. (2010). The Economic Impact of Climate Change. *Perspektiven der Wirtschaftspolitik*, *11*, 13–37. doi:10.1111/j.1468-2516.2010.00326.x

A TOOL FOR CALCULATING EXTERNAL COSTS AND EFFICIENCY OF FREIGHT TRANSPORT SYSTEMS

Erik Fridell IVL Swedish Environmental Research Institute, Dan Andersson Chalmers University of Technology Department of Technology Management & Economics, Division of Logistics & Transport, Martin Jerksjö IVL Swedish Environmental Research Institute.*

**P.O. Box 5302, 400 14 Gothenburg, Sweden, erik.fridell@ivl.se*

Goods transport, External costs, Logistics efficiency

ABSTRACT

It becomes increasingly important to analyze the environmental impact and effectiveness of goods transport systems. The impact of transport on environment, climate and health can be calculated as external costs. This paper presents a tool that can be used to internalize the external effects and analyze the effect of changes in goods transport solutions. The tool provides estimates of 1) transport efficiency and effectiveness, expressed as total logistics cost, and 2) environmental and other external interference, expressed as external costs. The tool addresses all modes of transport and a wide variety of parameters besides CO_2 emissions. The tool has been tested in case studies with conflicts or synergies between environmental and logistical efficiency. A challenge in the case studies was to get the required data. In order to capture the intrinsic uncertainties in these types of models, uncertainty calculations are made.

INTRODUCTION

Goods transport comes with a number of unwanted external impacts. These comprise impact on climate, most notably through emissions of carbon dioxide, health risks through emissions of particles and other substances to air but also from noise emissions and of course accidents, environmental impact such as acidification, eutrophication, barrier effects, toxic emissions to water etc., and loss of peoples time though congestion.

These impacts can be valuated using the concept of external costs. These are costs that arise due to an activity, in this case goods transport, and are taken by others, in general society at large. The ways to calculate these costs vary between the impact categories. For example costs due to health problems from air pollution are calculated by assessing the exposure to humans using emission and dispersion models, and then dose-response functions are used to obtain mortality and morbidity associated with the emissions. These cases are then valuated to obtain the costs. There are also a number of other methods to assess the externalities (Maibach, 2008).

Goods transport systems are measured through the logistics efficiency and the direct costs but there are also external service effects that need to be accounted for and these are very hard to evaluate. It could be a matter of having long or short lead times, being on time or not, being able to deliver a complete order etc., which have consequences for the customer. In a similar way as for the external environmental effects there is a managerial advantage to internalize the external costs and be able to present a total cost and not only the direct transport costs. The logic for internalizing environmental and service effects is the same and so are the challenges. There is a lack of data or the data quality is bad, and when the costs are to be calculated there is limited knowledge about how to allocate costs to different service outcomes.

In this paper we describe a tool for calculating external costs and at the same time logistics efficiency and effectiveness for goods transport systems. The tool requires input from the user on certain details about the transport systems, direct costs etc. The tool explicitly calculates emissions of air pollutants and climate gases as well as external costs for these and for a number of other parameters. These are related to the direct transport costs and the time for delivery and precision of delivery. Further, as will be discussed, there are uncertainties, sometimes large, in the ingoing variables in the calculations. This especially applies to the valuation of external effects and the valuation of delivery precision. In order to capture this, the tool calculates uncertainties for all results using a Monte Carlo algorithm.

THE MODEL

With the model a certain goods transport system can be studied. The user needs to provide certain information about the goods (weight, volume, value) and the distance traveled. Further, the transport during rush hour and night time needs to be specified, the reason being that this influences driving patterns and external costs for congestion and noise. Additionally, some information about the fraction of the distance that is in urban respective rural areas should be given, the reason being that some impacts, notably emissions of particulate matter and noise, have more severe effects in highly populated areas. The tool associates externalities and costs to transport work rather than traffic and therefore load utilization factors are also needed.

The user further needs to choose mode of transport (air, road, sea or rail) and the specific vehicle/vessel from a list together with the type of fuel used. The list of vessels contains different sizes, types and emission classes. Normally there are several legs in a transport chain and these can have different modes and/or vehicles/vessels.

The logistics costs also need to be specified split into cost for transport, packaging, warehousing (costs for the warehouse itself, the warehouse personnel and their equipment, handling and storage), inventory carrying (cost of capital accumulation, risk costs, and inventory service costs) cost of loss (costs that arise due to loss of goods, e.g. insurance fees, loss of sales, additional administration and additional transport costs), delay costs (e.g. loss of sales, stand still cost, additional administration costs and extra transportation costs), value of early delivery (costs associated with waiting for e.g. spare parts), administration. The ability to deliver fast and/or with a high precision is normally difficult to capture but are included since they may explain the mode selection.

The emission calculations for road take use of emission factors from HBEFA (Hausberger, 2009) and uncertainties from COPERT (Kouridis, 2010). For rail the methods in ECOTRANSIT (EcoTransIT, 2011) are followed with the addition of uncertainty estimates, while the air calculations are done with emission factors for a large number of planes. The emissions for shipping are calculated using a recently developed model (www.ntmcalc.org) with the addition of uncertainties (Cooper, 2004). The external cost values for emissions are from a number of sources (Maibach, 2008, Steen). The values for congestion, accidents, noise, up/down stream, ecosystems, soil and water are from (Handbook).

In the total cost model described by Stock and Lambert (2001) the role of cost trade-offs in marketing is highlighted. Their idea of a total cost model of logistics is to minimize the total cost, and not only the cost of one single category. Another type of total cost analysis was developed by Ellram (1995) and this was called the total cost of ownership model (TCO).

As mentioned the uncertainties are calculated using the Monte Carlo method. This means that uncertainty estimates (shape and size) are needed for all ingoing parameters and that random numbers are used to make the calculations a large number of times giving the uncertainties in the resulting parameters from statistical analyses.

The calculations result in large amounts of data. For the total freight transport system, as well as for each leg, fuel consumption, emissions of climate gases (CO_2, N_2O, CH_4 as well as CO_2-equivalents), and air pollutants (NO_X, PM, CO and HC) are calculated. External costs for these are given together with external costs for the other categories listed above. The logistics costs are given together with valuation of transport time and precision.

DISCUSSION

There are a number of reasons why it is of interest to calculate the values of external costs for goods transports. One is to compare the different impact categories. Today most of the concern about external effects is about the impact on climate change. The values for external costs give a way to relate different impacts to each other. This opens up for focusing on reducing the most severe factors and to leave the less important ones. It also shows that there are other issues with transport systems than climate problems. Further, the model shows the total costs for goods transportation which is important for many stakeholders. For the freight owners this gives an idea of the future costs for transportations and for policy makers it shows the burden put on society and others from our transport systems. There is an ongoing trend in internalizing external costs which will mean that in the future there is a high likelihood that this will give higher transport costs. An example of this is the Eurovignette tax which is calculated from external cost values.

The tool also gives a way to calculate the benefits and drawbacks of the four transport modes and from different vehicles and vessels. This will give decision support when choosing, e.g., between rail, road and sea in a transport systems. It also highlights and valuates the benefits of choosing trucks of higher emission class and more environmentally benign fuels, and relates this to the potentially higher transportation costs.

There are a number of challenges in obtaining one single cost for a transport system, a cost that include the direct costs, the external costs as well as valuation of the logistics efficiency. The calculations of emissions are these days fairly accurate due to, for example, the modeling needed for the Kyoto protocol and the European Ceilings Directive. However, the valuation of external effects is often uncertain. This especially applies to greenhouse gases where different approaches and methods can give significant variations in the results. For example the valuation can be based on future impacts due to draught, flooding, deceases etc., and then the number obtained per kg of CO_2 emitted will be highly dependent on the discounting used; or it can be based on costs for replacing fossil fuels with biofuels. Further, the costs for some categories will depend on the time and place of the traffic, meaning that a high precision is needed in the input data. In reality this must lead to a compromise between accuracy (e.g., in dividing up the scale from megacities to rural in many steps) and usefulness in the sense that the user will not be able to collect all details about their transport systems.

The transport time and precision of delivery gives further challenges. It is highly relevant to include these parameters since they often are decisive in the design of a logistics system. As an example, this will capture the background to freight owners choosing air transportation over sea transportation in spite of the normally higher transportation costs and the (normally) higher external impact (due to high emissions of CO_2 per tonne-km).

The tool is intended to be used for a number of purposes including procurements, design of logistics systems and strategically in, e.g., the placement of units and warehouses. So far a number of case studies have shown the usefulness of the tool.

CONCLUSIONS

This paper presents a tool for calculating external costs and logistics efficiency for freight transport systems.

REFERENCES

Cooper, D., Gustafsson, T., (2004) "Methodology for calculating emissions from ships: 1. Update of emission factors"

EcoTransIT (2011): EcoTransIT: Ecological Transport Information Tool for Worldwide Transports. Available at: http://www.ecotransit.org/download/ecotransit_background_report.pdf. [Accessed 28 May 2013].

Ellram, L. M. (1995).) "Total cost of ownership. An analysis approach for purchasing", International Journal of Physical Distribution and Logistics Management, 25(8), 4-23.

Hausberger, S., Rexeis, M., Zallinger, M., Luz, R., Emission Factors from the Model PHEM for the HBEFA Version 3. Available at http://www.hbefa.net/e/documents/HBEFA_31_Docu_hot_emissionfactors_PC_LCV_HDV.pdf. [Accessed 29 May 2013].

Kouridis, C., Gkatzoflias, D., Kioutsioukis, I., Ntziachristos, L., Pastorello, C., Dilara, P., Uncertainty Estimates and Guidance for Road Transport Emission Calculations, EUR 24296 EN – 2010. Available at http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/14202/1/uncertainty%20eur%20report%20final%20for%20print.pdf. [Accessed 29 May 2013].

Maibach, M. Schreyer, C., Sutter, D., van Essen, H.P., Boon, B.H., Smokers, R., Schroten, A, Doll, C.,Pawlowska, B., Bak, M. (2008): Handbook on estimation of external cost in the transport sector. Produced within the study Internalisation Measures and Policies for All external Cost of Transport (IMPACT).Version 1.1. Available at http://ec.europa.eu/transport/sustainable/doc/2008_costs_handbook.pdf. [Accessed 28 May 2013].

Steen, B (2000): A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – Models and data of the default method. CPM report 1999:5. Available at http://www.cpm.chalmers.se/document/reports/99/1999_4.pdf. [Accessed 28 May 2013].

Stock, J.R., Lambert, D.M. (2001), Strategic Logistics Management, 4th edition, McGraw-Hill

CONCEPTUAL CHALLENGES FOR INTERNALISING EXTERNALITIES

Miguel Brandão (International Life Cycle Academy), Bo P. Weidema (Aalborg University)*
**International Life Cycle Academy, Passeig Pujades 1, 08003 Barcelona, Spain, Miguel@ilca.es*

Keywords: external costs; monetarisation; temporal distance; compensation; temporal benefit sharing.

ABSTRACT

We analyse a number of different externalities to identify conceptual challenges for the practical implementation of their internalisation. Three issues were identified: i) The balance between compensation and technology change and the respective effects on the nominal and real GDP; ii) The relevance and efficiency of different instruments for internalisation and compensation; and iii) Implementing internalisation over large geographical and temporal distances. We find taxation to be a more relevant and efficient tool for internalisation than insurance and litigation. With increasing geographical and especially temporal distance between the benefitting actor and the victim of the external cost, the involvement of a non-governmental intermediate actor becomes increasingly necessary to provide the short-term capital required to ensure a successful implementation.

METHODS

We analyse conceptually a number of different externalities (impact categories) in order to reveal any systematic relationships between the characteristics of the externalities and the challenges facing a practical implementation of their internalisation.

The analysed externalities cover social impacts (missing education, trade barriers, labour rights violations), biophysical impacts (emissions of greenhouse gases, toxic substances and long-range pollutants), and economic impacts (free-riding on infrastructure, traffic injuries).

The externalities were classified according to their characteristics:

- The nature of the externality (e.g. economic costs, foregone income, damage to health, damage to nature),
- The relative size of costs versus benefits,
- The extent to which the externalities are already monetised (although not internalised)
- Who bears the cost or receives the benefit, and
- How these actors are placed geographically, socially, and temporally.

Based on the analysis results, we assess the applicability and adequacy of different methods for internalisation and their dependency on the above characteristics of the externalities.

RESULTS

Our conceptual analysis did not reveal any systematic differences in implementation that could be related to the nature of the externalities *per se*, i.e. whether the impacts were on economic, social or biophysical safeguard subjects.

However, three implementation issues were identified by our analysis:

- A relationship between the relative size of costs and benefits on the one hand and the relevance of compensation for the impact versus technology change to avoid the impact on the other hand, and the respective effects on the nominal and real GDP,
- A relationship between the distance of benefitting actors and victims of costs on the one hand and the relevance and efficiency of compensation via insurance and litigation versus via taxation and subsidies on the other hand, and the most efficient supply chain location for public interventions.
- The increasing difficulty of implementing internalisation with increasing geographically and especially temporally distance between benefitting actor and victim of cost.

These are explained and discussed in the following section.

DISCUSSION

The balance between compensation and technology change and the effects on GDP

In some cases, the costs of an impact clearly exceed the value of the related benefits. In such cases, it does not make sense to internalise the cost, but rather to change the technology to avoid the impact. All the analysed social impact categories (missing education, trade barriers, labour rights violations) fall in this category. Missing education implies lost productivity in the future and trade barriers imply lost productivity both now and in the future. Labour rights violations imply losses in income and well-being for the workers. The benefits are largely cost savings for specific current actors. If the costs (i.e. the lost productivity, income, etc.) were to be internalised, the reason for creating the impact in the first place would disappear, i.e. there would be no advantage not to provide adequate (economically-optimal) education, to maintain trade barriers, nor to violate worker's rights.

In the opposite situation, where the benefits of the activity clearly exceed the costs, it makes sense to continue the activity even after internalisation of the costs. Examples can be found where the elasticity of demand is low, i.e. not sensitive to price changes, as for example private car usage (Goodwin et al. 2004, Graham & Glaister 2004). Thus, private car usage is likely to continue largely unchanged, even if the costs of traffic injuries were completely internalised (today these costs are already partly internalised, and even compensated, through insurance payments).

Between these two extremes we have the situations where internalising the costs will reduce the competitiveness of the activity, but not to an extent where it would cease to exist. Some users would be willing to pay the increased price, while at the same time we would see some users shift to other technologies, including changes in behaviour, and a stimulation of innovation.

We can illustrate these differences by the effect they have on the nominal and the real GDP.

Without any changes in technologies and demand, the internalisation of a cost, which was previously not paid for, will initially lead to an increase in the nominal GDP, while the real GDP does not change (since there was no change in technologies and demand and thus in activities). For externalities that are already monetised, i.e. where the costs are already paid for by another actor, internalisation would initially not even have an effect on the nominal GDP, since this would simply be a re-distribution of the existing costs. An example of the latter would be the introduction of road pricing to internalise the free-riding.

Secondly, the increased cost reduces the competitiveness of the technology and when there are attractive alternatives this would lead to a shift to these alternatives and thus an overall reduction in the internalised cost. This counteracts to some extent the increase in the nominal GDP while the real GDP now increases, due to the economy becoming more efficient.

Thus, the internalisation of a cost practically always leads to an increase of the GDP, initially because the cost previously non-monetised is now monetised and therefore becomes part of the GDP, and subsequently depending on the degree of improved economic efficiency resulting from the internalisation. This runs counter to the popular idea that a reduction in real GDP should be a desirable goal.

The relevance and efficiency of different instruments for internalisation and compensation

The relevant instruments for internalisation depend on the distance between the benefitting actors and the victims of external costs. For example, the relationship between the benefitting actor of road transport and the victims of traffic injuries is very close (too close you may say), while the distance between the emitting activity of long-range pollutants and their impacts on human health, agricultural yields and the natural environment is very large. In the case of traffic injuries, it is possible to internalise the cost via an insurance payment that covers the cost of compensating the victims, and the victims can obtain the compensation via litigation. Insurance and litigation may also be an option for the impacts from specific, low-mobility toxic substances, while the distance between the cause and the damage becomes too large for long-range pollutants to make insurance and litigation a realistic option. This becomes even more obvious for impacts that take place far into the future, such as those from emissions of greenhouse gases). It can be argued that even in the case of traffic injuries, the currently partly implemented internalisation and compensation involves too high transaction costs (mainly for the litigation) compared to a system of differentiated taxation on road traffic and a public payment for treatment, lost income and compensations for mortality and morbidity. With larger distance between benefitting actor and the victims of the cost, transaction costs would increase and the taxation option becomes even more obvious as the most efficient solution, both with and without subsequent compensation of the specific victims.

A second issue here is where in the supply chain such taxation is most efficiently implemented. While it is obvious that a tax or quota on the actual cause for the externality will lead to the least confounding or secondary distortions, there are cases where the transaction costs of such a direct implementation may be unreasonably high and it becomes relevant to look for another place in the supply chain where there are fewer flows or activities to be taxed. For example, the administration of a direct SO_2 or GHG emission tax will be more costly than a tax on the sulphur or carbon content of raw materials at their extraction.

Implementing internalisation over large geographical and temporal distances

With increasing geographical and especially temporal distance between the benefitting actor and the victim of the cost, the implementation of internalisation becomes more difficult, because the options for the victims to participate and exert pressure on the political process is limited or absent, while those currently benefiting from non-internalisation are both likely and able to provide opposition. A solution that can be seen as acceptable both to the current benefitting parties (who stand to loose from internalisation) and to the distant victims, could be one in which the benefit of internalisation is shared with the present-day losers of internalisation, so that their loss of benefits is at least partly compensated. Although it may seem unfair to take from the victims and give to those causing the impact, the alternative of non-internalisation would be even more unfair. The compensation of the present-day losers from internalising externalities needs of course to be phased out over a period, if the end-result is to be a full realisation of the efficiency gains from the internalisation.

A particular complication occurs when the impact, and thus the benefit of internalisation, lies in the future, while the cost of internalisation is immediate. The suggested compensation of the present-day losers (of internalisation) requires a transfer of future benefit to the current actors. Such long-term transfers can be difficult for governments that generally have a short-term policy horizon, due to the general opposition to taxation. A solution that avoids the need for increasing taxes in the short term would be to employ an intermediate actor that is able to provide the capital to compensate the present-day losers while recuperating this expenditure from the future benefits. The government would not need to provide payment instantly but simply would provide a guarantee of future payment based on the real increase in future tax revenue caused by the internalisation.

Among the analysed externalities several suffer from the distance problem and thus may require such interventions. Both greenhouse gas emissions and missing education are particularly subject to the temporal distance issue while trade barriers also have an aspect of geographical distance and labour rights violations also have an aspect of social distance. The proposed mechanism for temporal benefit sharing can also be extended to the geographical and social distance issues.

CONCLUSIONS

We identified and addressed several conceptual challenges for internalizing externalities. Specifically, we identified the distance between the benefitting actor and the victim of the cost as having a decisive influence on the instruments necessary for a successful implementation. A strong government role is required to ensure the functioning of the necessary transfers of benefits.

REFERENCES

Goodwin, P.B, Dargay, D and Hanly, M (2004): Elasticites of road traffic and fuel consumption with respect to price and income: A review. Transport Reviews 24(3):275-292.

Graham, D.J and Glaister, S (2004): Road traffic demand elasticities: A review. Transport Reviews 24(3):261-274.

CORPORATION'S EXTERNALITIES AND LIFE CYCLE ASSESSMENT (LCA)

Birgitte Holt Andersen (CWare, Belgium), Martha Emneus (Applied Economics and Health Research (ApEHR) Copenhagen)*

**Dreve Richelle 168, B-1410 Waterloo, bgha@cware.be*

***Larsbjoernsstraede 3, DK1454 Copenhagen, Martha.emneus@appliedeconomics.dk*

Keywords: externalities; socio-economic impact; LCA; creating shared value; strategy formulation.

ABSTRACT

This paper investigates how and to which degree the concept of LCA together with sustainability frameworks can provide an additional dimension to the assessment of corporations' externalities and thereby fill the gap in classic economic theory by address broader dimensions of societal issues.

The paper assess and compare different frameworks, 'socio-economic impact assessment, triple-bottom-line', corporate social responsibility (CSR) and on this background discuss and assess the complementarity role of LCA. The paper concludes by proposing the development of a combined framework for mapping and managing externalities as basis for the formulation of a sustainable business strategy where LCA plays an important role in mapping 'hot spot' externalities, ultimately to create shared value.

CORPORATIONS AND EXTERNALITIES

Corporations produces nearly everything we consume, they generate the majority of global GNP and are the main drivers of growth, jobs and social prosperity. As such there are many good sides to corporations, but also bad ones (Sukhdew, 2011). The unaccounted costs to society of doing business are also referred to as corporations' externalities. These costs are huge- in the order of 3% of GDP every year (Trucost, 2010) and represents trillions of € worth of 'market failures'.

Corporations - large and small - therefore could play a prominent role in bringing our sourcing, our production, and our consumption into a sustainable balance. In an ideal world externalities should be internalised and reflected in financial reporting of companies. Fortunately, corporations are increasingly recognising sustainability as a market opportunity.

Mapping corporations' externalities are becoming interesting for a number of reasons. Companies want to be more responsible to secure future supply chains and sustain a 'licence to operate'. Investors seek to minimise risks and costs. Consumers want transparency and trust in the products they consume. Authorities and governments impose restrictions on activities in the local communities.

What is externalities

In general economics terms an externality is a cost or benefit that is not transmitted through prices and encountered by a third-party not involved as either a buyer or seller of the goods or services causing the cost or benefit. In this paper we will regard an externality as any impact – good or bad - not included in the corporation's financial reporting having an impact on the society or environment in which it operates both up-stream and down-stream. That leaves us with two types of externalities; those caused by the corporations operations and those caused by others.

	Externality caused by the Corporation	External externality or societal issue
Positive	Popular workplace (Soc) Demand for local sourced organic grown cereals (Env) High tax net-contributor (Eco)	Access to high-qualified workforce (Soc) Rich on natural raw materials (Env) Low risk investment climate (Eco
Negative	Poor working conditions (Soc) Emission of pollutants (Env) Tax avoidance (Eco)	High crime rate(Soc) Scarce clean water access (Env) Insufficient transport infrastructure (Eco)

Table 1 Types of externalities with examples, Source: Authors own

FRAMEWORKS

Impact assessment *(IA)* is an analysis of the consequences of an intervention whether a new policy, project or technology and can be applied both ex ante and ex post. It includes economic, social and environmental issues and is therefore in concept very similar to the idea of the triple-bottom-line. The main difference perhaps is that while the TBL is mainly associated with business, impact assessment has emerged as a tool to justify 'public' interventions such as new policies, programmes or (infrastructure) projects. As such impact assessment has become main-stream in public expenditure decisions over the past more than 30 years and are now a very established and well documented discipline.

Traditionally an impact assessment includes mainly the direct impacts and perhaps second-order impacts but rarely the entire 'life-cycle-chain'. Impact assessment, also referred to as socio-economic impact assessment, is likewise closely related to Cost-benefit analysis (CBA), with the latter including cost aspects as well. IA and CBA often use a stakeholder model to identify 'beneficiaries'. Each economic actor has a number of stakeholders or interests groups, whether it is a company, a NGO or a public entity. In the following some hypothetical examples of stakeholders and societal issues are presented.

Figure 1 The externality wheel

Life-cycle assessment (LCA) is a technique to map and assess environmental impacts associated with all the stages of a product's life from-cradle-to-grave. Just as IAs and CBAs, LCA has over the past 30-50 years developed into a well-recognised and standardised approach to determine environmental impact and consequences of a given product or service. The LCA provides a snapshot of the products route from raw material to end-of-life; the focus of analysis is traditionally the physical product often measured in terms of energy consumption and CO_2 equivalence; an LCA therefore is independent of company or country boundaries. As opposed to the other frameworks mentioned in this paper, LCA is the only one not originated from the field of economics.

As a concept, the ***Triple-Bottom-Line (TBL)*** emerged in the nineteen-eighties, just before the concept of Sustainability was introduced in the Brundtland Report in 1987. The TBL concept suggested expanding the traditional financial accounting to embrace also the social and environmental performance of the company (Elkinton, 1997], hence the TBL was the first attempt to account for the full cost involved in doing business. TBL was adapted by a number of large corporations and government agencies in the beginning of this century, such as BP and Shell Australia alongside other similar frameworks such as ecological sustainability development or (in short) Sustainability Reporting.

Corporate social responsibility (CSR) is a form of corporate self-regulation integrated into the business operations with the basic idea that a company takes responsibility of its own social and environmental impacts. CSR originally developed from actions of purely philanthropic character in the local community (e.g. funding the local football team) into a corporate risk management tool at first focused on compliance and later moving onto the core of the corporate strategy formulation. CSR has become a mainstream business concept and grown ‘big’ in recent decades and most large corporations would have a dedicated CSR department feeding into to corporate strategy.

Yet another approach is increasingly gaining momentum among corporate strategists. Creating ***Shared Value (CSV)*** (Porter, 2012) challenges the traditional business profit-maximizing approach claiming that corporate success and social welfare are interdependent and that there is a large market potential to be gained by including the societal priorities into the business objectives. Shared value is a way to create welfare innovation by creating solutions that are ‘win-wins’ also for the society. This is Nestle providing nutrition instead of selling food. It is NIKE offering fitness and wellness rather than selling shoes. It is Novo Nordisk addressing in a holistic way the diabetes epidemic rather than selling insulin. Hence CSV seeks to integrate societal improvements (or addressing external ‘bads’) into economic value creation itself. By adopting such a much broader model of economic value creation, CSV argues that many more societal needs will be met and at the same time allowing growth and innovation to prosper.

Each framework has a specific focus. LCA, in particular, is strong in mapping and measuring the externalities through-out the entire life cycle independent of company boundaries. As such life cycle analysis often reveals eye-opening results which for many products results in the majority of externalities (environmental impacts) generated during the use-phase (in the hands or mouth of the consumer) rather than during the production phase. Likewise IA and CBA are dedicated to identify the impact areas and calculate their monetary values. As opposed to LCA, however the analysis is bounded to the company or the investment project in concern. The TBL entirely focuses on the company and extend the reporting to include the social and environmental balances to complement the financial. That was new at the time, but TBL never succeeded in solving the compatibility issue among the three bottom lines. Both CSR and CSV are corporate strategic tools concerned with turning corporate externalities into business opportunities. While CSR allocate values created within the company, CSV creates economic value by creating societal value.

	Mapping	Impact	Action
IA/CBA	√	√	÷
	Economic, social and environmental impacts of company	Willingness to pay, shadow prices, TEEB	Yes/No on investment decision
LCA	√	√	÷
	Entire Life-cycle	CO2 equivalence	Awareness raising
TBL	√	√	÷
	Economic, social and environmental impacts of company	Indicators for each bottom-line	Addresses ad hoc externalities, off-setting activities and communication
CSR	(÷)	÷	√
	Not systematically		Addresses ad hoc externalities, off-setting activities and communication
CSV	√	(√)	√
	Entire value-chain	By priority setting	Turning 'social needs' into business opportunities

Table 2 Overview of frameworks

CONCLUSIONS

Ideally, we strive to pick and choose the best of each of the frameworks to develop a combined framework allowing us to map, analyse and manage externalities.

LCA is unique in providing for a mapping of externalities throughout the value chain focusing on what it takes to make, use and get rid of an actual product – independent of company boundaries. The IA and CBA we can apply at company level – the economic actor and the stakeholders to be affected by any externalities imposed by the company or among whom a societal issue might represent a corporate opportunity.

Running the externality wheel through-out the life cycle or the value chain, allow us to identify the externality-hot-spots of the entire value chain, both those imposed by the company but also an identification of societal issues along the way. With CSR and in particular CSV we can formulate appropriate actions to address the identified 'externality-hot-spots' through-out the value chain.

Economic theory is impersonal, non-spatial and fails in describing the narratives. By combining the frameworks in a united analysis we get a very powerful tool allowing us to capture the narratives, understanding the course of the externalities and identify hot spots.

REFERENCES:

Elkington, J., "Cannibals with Forks: the Triple Bottom Line of 21st Century Business", Capstone, 1997.

JRC's Life Cycle Website, http://lct.jrc.ec.europa.eu/

Porter, Michael E and Kramer, Mark R.'Creating Shared Value, Harward Business Review, Jan-Feb 2011.

Savitz, A.W. and Weber, K., "The Triple Bottom Line: How Today's Best-Run Companies Are Achieving Economic, Social and Environmental Success—and How You Can Too", Jossey-Bass, 2006.

UNEP, Guidelines for Social Life Cycle Assessment of Products, 2009.

Willard, B., "The Sustainability Advantage: Seven Business Case Benefits of a Triple Bottom Line", New Society Publishers, 2002.

THE DISPROPORTIONATE COST PRINCIPLE UNDER VARIABLE ENVIRONMENTAL AND TECHNICAL SETTINGS

Till M. Bachmann, Jonathan van der Kamp, European Institute for Energy Research, Emmy-Noether-Str. 11, 76131 Karlsruhe, Germany, * Corresponding author: bachmann@eifer.org, phone: +49 721 6105 1361, fax: +49 721 6105 1332*

Keywords: Cost Benefit Analysis; external cost; industrial emission

ABSTRACT

As a new feature under the European Union's Industrial Emissions Directive, plant operators can apply for less strict emission limit values on the basis of the disproportionate cost principle, comparing environmental benefits to (private) costs. This study aims to assess to what extent the proportionality of emission abatement options depends on different environmental and technical settings. Through a cost-benefit analysis, private costs of retrofitting and operating a DeNOx at a typical coal-fired power plant at varied Western European locations are confronted with associated monetised environmental benefits, quantified with the tool EcoSenseWeb. Results are shown to be sensitive to the environmental setting and the operating time per year. Further methodological development is needed to make the assessment more robust.

INTRODUCTION

In the European Union (EU), emissions from industrial installations are largely addressed by requiring that best available techniques (BAT) are implemented. The current Industrial Emissions Directive (IED, Directive 2010/75/EU) sets stricter emission limit values (ELVs) for existing combustion plants to be respected from 2016 onwards than previous regulation. As a new feature, plant operators can apply for less strict ELVs on the basis of the disproportionate cost principle, comparing environmental benefits to (private) costs.

This study aims to present a way how to quantify environmental benefits related to reductions in air pollutant emissions in economic terms. It shall also be assessed to what extent the proportionality of abatement options depends on different environmental and technical settings.

METHODS

Cost-Benefit Analysis

Through a cost-benefit analysis (CBA), private costs of installing and operating the BAT at a given industrial site are confronted with associated monetised environmental benefits, following the net present value rule (cf. Pearce, Atkinson, & Mourato, 2006):

$$\{ \sum_{i,t} B_{i,t} * (1+s)^{-t} - \sum_{i,t} C_{i,t} * (1+s)^{-t} \} > 0 \quad \text{(Eq. 1)}$$

where *i*: affected individuals, *t*: time horizon (in years), *B*: benefits, *C*: costs and *s*: discount rate.

While assessing private costs is common practice, assessing environmental benefits (through reduced external costs) is more complex and requires adapted approaches.

External costs and their quantification

According to the prominent EU-funded Externalities of Energy (ExternE) project series, an external cost is defined to arise "when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group" (European Commission, 2005, p. 9).

External costs are quantified with help of a state-of-the-art tool for point sources in Europe, i.e. EcoSenseWeb (Preiss & Klotz, 2008). External costs from NO_x, SO_2 and particles are assessed following the marginal damage cost or impact pathway approach (European Commission, 2005; Pearce et al., 2006). Local as well as regional scale modelling results are used (2010 background emissions and default meteorology) while assuming equal toxicity of different primary and secondary particles on human health. Given the uncertainty in assessing associated impacts, greenhouse gas emissions are valued at 19€ per tonne of CO_2 emitted, according to the marginal abatement cost approach (cf. European Commission, 2005).

DeNOx retrofit at a hard-coal fired power plant

A hard-coal fired power plant unit has been investigated at three different sites, i.e. Brussels (BE), Cartagena (ES) and Helsinki (FI), varying in terms of population density, background emissions and meteorological conditions. The plant parameters remain constant. It is equipped with flue gas desulphurisation and an electrostatic precipitator for the abatement of particles. When installing the DeNOx retrofit (selective catalytic reduction, SCR), some technical parameters change (Table 1) while providing the same service of 2700 GWh/a for 20 years. More details are provided in Bachmann and van der Kamp (in preparation).

Table 1: Differences in technical characteristics

		Without DeNOx	**With DeNOx**
Net Electricity sent out	[MW]	600	597
Full load hours per year	[h/a]	4500	4523
NO_x emissions	[mg/Nm³]	820	200
CO_2 emissions	[tons/a]	2187000	2197935
CH_4 emissions	[tons/a]	27.0	27.1
N_2O emissions	[tons/a]	59.4	59.7

According to EGTEI (2012) and following the two-stage discounting procedure by Kolb and Scheraga (1990), employing an interest rate of 7% and a social discount rate of 4% (cf. European Commission, 2009), the annualised private costs of installing a SCR and primary abatement measures at a coal-fired power station amount to 6844012 $€_{2000}$ per year or 0.25 €-$cent_{2000}$ per kWh.

RESULTS

Annual environmental benefits and costs are compared in the following, the net present value being positive if benefits exceed costs.

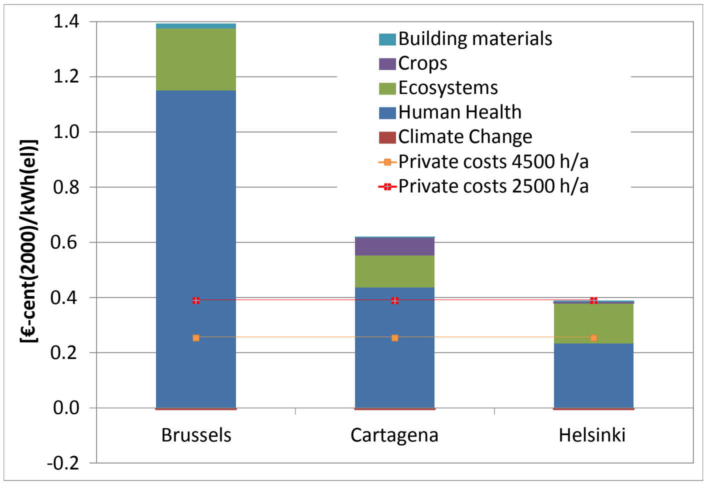


Figure 1. Annual external costs (bars) and private costs (lines) of a coal-fired power plant located at three sites: default case (lower line, orange); reduced full load hours (upper line, red)

Variation of site

The DeNOx retrofit can generally be assessed to be efficient at all investigated sites, i.e. the disproportionate cost criterion does not apply (Figure 1, 4500 h/a case). Nonetheless, the environmental setting substantially changes the magnitude of quantified environmental benefits.

Variation of full-load hours

Due to an increasing share of fluctuating power generation, for instance, the operation hours per year may be reduced from 4500 to 2500 and thus the overall electricity produced. Accordingly, the annualized private costs per kWh increase while the avoided external costs per kWh remain the same (Figure 1, 2500 h/a case). For the locations with the highest and lowest environmental benefits, the result suggests that less full load hours combined with less impacted people may make the DeNOx investment disproportionate. For Brussels, however, the decrease in full load hours does not alter the CBA result.

DISCUSSION

The study shows that the CBA results are sensitive to the environmental setting and key technical assumptions (e.g. full load hours). Besides, the results are subject to limitations (e.g. insufficient coverage of certain impacts, e.g. on biodiversity or ecosystem services, consistency issues, and questions on the ability of EcoSenseWeb to reliably estimate external costs from peak-load operation) and depend on methodological assumptions (e.g. particle toxicity) and other uncertainties as further discussed in Bachmann and van der Kamp (in preparation).

From an application point of view, the following can be noted. First, the IED is currently transposed into Member State legislation. To what extent the disproportionate costs criterion will apply in practice depends on the national context. Secondly, no EU-wide standard to calculate environmental benefits exist at present, noting related initiatives for standardisation in the past (Holland, Hunt, Hurley, Navrud, & Watkiss, 2005; UBA, 2008). Scientific progress is constantly made that should be considered accordingly. Thirdly, the IED is concerned also with emissions other than classical air pollutants. Related site-specific assessments are currently hardly available.

CONCLUSIONS

The disproportionate cost criterion of the EU's IED was tested for an emission abatement measure at a coal-fired power plant hypothetically located at three different sites. Site-specific external costs, assessed with the tool EcoSenseWeb, are a central input to the CBA. The measure is generally assessed not to lead to disproportionate costs. When reducing the operating time, the investment may become inefficient at sites with lower population exposure. Further methodological development is needed to make the assessment more robust and comprehensive, at best to be carried out in a harmonized way at EU level.

REFERENCES

Bachmann, T. M., & van der Kamp, J. (in preparation). Environmental Cost-Benefit Analysis and the EU Industrial Emissions Directive: comparing air emission abatement costs and environmental benefits to avoid social inefficiencies.

EGTEI. (2012). Expert Group on Techno-Economic Issues (EGTEI) Background documents - Combustion Installations in energy, transformation industries and industries, from http://citepaax.alias.domicile.fr/forums/egtei/egtei_doc-Comb-Ind.htm

European Commission. (2005). ExternE - Externalities of Energy: Methodology 2005 update. Luxembourg: Office for Official Publication of the European Communities.

European Commission. (2009). Impact Assessment Guidelines. Brussels: European Commission.

Holland, M., Hunt, A., Hurley, F., Navrud, S., & Watkiss, P. (2005). Methodology for the Cost-Benefit analysis for CAFE: Volume 1: Overview of Methodology (pp. 112). Harwell, UK: AEA Technology Environment.

Kolb, J. A., & Scheraga, J. D. (1990). Discounting the benefits and costs of environmental regulations. *Journal of Policy Analysis and Management*, *9*(3), 381-390. doi: 10.2307/3325282

Pearce, D., Atkinson, G., & Mourato, S. (2006). *Cost-Benefit Analysis and the Environment: Recent Developments*. Paris: Organisation for Economic Co-operation and Development (OECD).

Preiss, P., & Klotz, V. (2008). EcoSenseWeb V1.3 (pp. 63): Institute of Energy Economics and the Rational Use of Energy, University of Stuttgart.

UBA (Ed.). (2008). *Economic Valuation of Environmental Damage: Methodological Convention for Estimates of Environmental Externalities*. Dessau: Federal Environment Agency (UBA).

LCA HIGHLIGHTS: PECHAKUCHA

Monday, Aug 26: 3:30 pm - 5:00 pm

Session chairs: Claudia Peña, Chilean Network of LCA / University of Concepción, Chile
Carl Vadenbo, ETH Zurich, Switzerland

ASSESSMENT OF THE ENVIRONMENTAL PERFORMANCE EFFECTS ASSOCIATED WITH THE REPLACEMENT OF ETHYLENE FROM FOSSIL BY RENEWABLE RESOURCE IN GPPS PRODUCTION

Adriana Petrella Hansen and Luiz Kulay*

Chemical Engineering Department – Polytechnic School – University of Sao Paulo
Av. Prof. Lineu Prestes, 580 – Bloco 18 – 05508-000 – São Paulo – Brazil

adriana.phansen@usp.br

Keywords: Life Cycle Assessment; GPPS; renewable resource; ethylene.

ABSTRACT

This study analyzed the environmental effects associated with the replacement of ethylene produced from natural gas by an equivalent asset obtained by sugarcane in the processing of chain General Purpose Polystyrene (GPPS). The analysis was performed through Life Cycle Assessment (LCA) technique, which considered a cradle-to-gate approach for the production of 1.0 ton of GPPS according to the Brazilian operational condition. It was used ReCiPe – Midpoint (H) for the impact assessment. Consumptions of natural gas and crude oil influence significantly the environmental profile of fossil GPPS. Nevertheless, the agricultural activities required to renewable GPPS production resulted into increased environmental impacts of Climate Change, Agricultural Land Occupation, Human Toxicity, Freshwater Eutrophication and Terrestrial and Freshwater Ecotoxicity.

INTRODUCTION

The consequences of unregulated use of natural resources have mobilized humanity to design mechanisms that result in minimizing the impacts from the production of goods to improve their quality of life. The industry is directly involved in the issue as an important resource consumer and waste generator. The petrochemical industry stands out in this context because its products reduce global reserves of fossil resources. In this scenario fossil fuels play an important role in maintaining the expectations in the development of modern society due to current economic model which is based on power consumption. Despite that, the social awareness about the preservation of the environment has increased on the last three decades. This controversial condition led the petrochemical industry an uncomfortable standoff situation. The scenario in Brazil is not different. So, in order to coordinate the issue and present itself to the market more proactively, the segment has been researching for different alternatives. Regarding the production of polymeric derivatives, the main strategy is to replace the fossil resource by raw materials obtained from renewable resources, in order to rationalize crude oil and natural gas extractions and balance CO_2 emission.

This study discusses the validity regarding the environmental dimension of the same approach on the perspective provided by Life Cycle Thinking. Therefore, it was analyzed the effects of substitution of ethylene produced from natural gas by ethylene obtained by sugarcane ethanol dehydration in the production of General Purpose Polystyrene (GPPS). The objective was achieved by using the Life Cycle Assessment methodology. This analysis follows a cradle-to-gate approach for the production of 1 ton GPPS, according to average technology practiced for Brazilian companies.

METHODS

This LCA was carried out to comply with the patterns defined by ISO standards 14040:2006 and 14044:2006. The goal of the study consists in evaluate the effect of the introduction of an asset of renewable origin in the production of GPPS. This evaluation was developed comparing fossil GPPS with a homologous obtained from ethylene of bioethanol. Regarding to Scope Definition it was established as Reference Flow: "*to produce 1 ton of GPPS*". The Product System of fossil GPPS comprises the unit process of crude oil extraction, oil refining for naphtha production, ethylene and benzene obtaining and GPPS manufacture. The product system for renewable GPPS replaces the petrochemical processes for the ethylene production by an agricultural route. This case study considers cultivation of sugarcane, hydrous, and ethylene production via dehydration technic. Figures 1 and 2 detail both product systems.

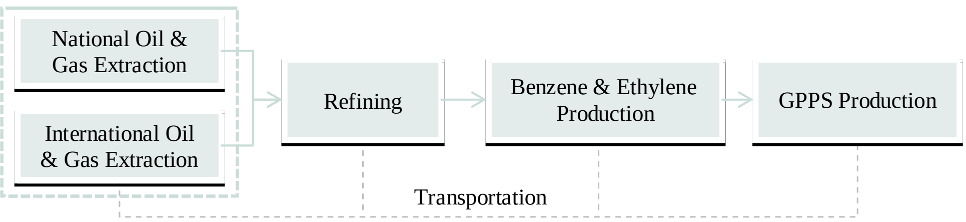


Figure 1: product system of GPPS produced from petrochemical derivatives

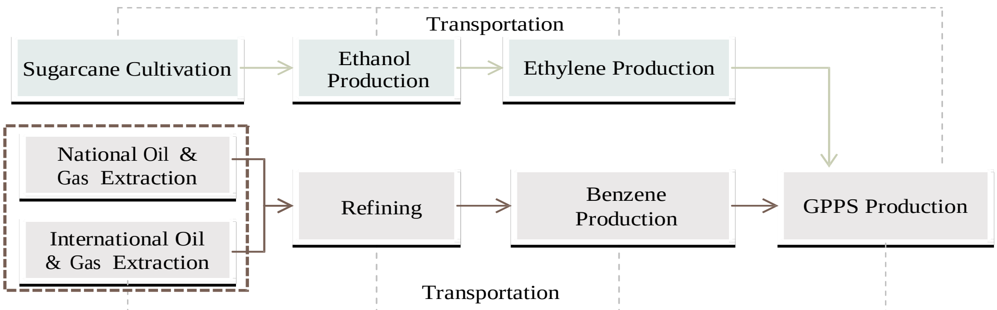


Figure 2: product system of GPPS obtained from ethylene from renewable origin

Regarding Geographical Coverage, all the processes in both product systems are carry out in Brazil. Exception occurs for the oil purchased overseas from Nigeria, Libya, Iraq, Saudi Arabia, Algeria and the natural gas from Bolivia (BEN, 2012). Temporal Coverage includes the period from 2008-2011. Finally, for Technological Coverage it was admitted the average technology practiced in the country by companies that operate in the polymers sector. Concerning Data Quality, secondary data were used to describe the environmental performance of GPPS production in Brazil. The procedures applied allowed to measure the uncertainty degree of the data set used in the preparation of the Life Cycle Inventory to make the results consistent. The allocation among petrol derivatives was done according energy criterion. The distribution of environmental aspects in ethanol and sugar production occurred from commercial criterion. Other cases where this kind of procedure is necessary, mass criterion was adopted. The application of cut-off criteria is aligned with ISO 14044 (2006) guidelines and considered 1 wt. % of the total material input for each elementary process. Life Cycle Impact Assessment was carry out by the method ReCiPe – midpoint (H) version 1.07. This analysis included only relevant environmental impact categories: Natural and Agricultural land occupation (NLT and ALO); Terrestrial and Freshwater Ecotoxicity (TEc and FEc); Fossil depletion (FD), Freshwater eutrophication (FEu) and Climate change (CC).

Description of the processes

Offshore oil production represents about 91% of the total Brazilian oil prospected. Furthermore, about 20% of the crude oil processed in the country is imported (BEN, 2012). The average refining technology employed in the country consist of crude-oil desalting, atmospheric and vacuum distillations, catalytic cracking, coking and hydrotreating processes (ANP, 2012). In 2010, over 70% of the natural gas produced in Brazil was from conventional oil fields. This amount corresponds to 42% of the total demand for the period. The remaining 58% came from Bolivia by importation (BEN, 2011). Natural gas and the naphtha produced along refining pass through a steam cracking stage in order to obtain ethylene (Antunes, 2007). In addition, naphtha is heated and fed into the catalytic reforming reactor to produce benzene (Netzer, 2005). Dehydration of sugarcane ethanol has emerged as an alternative to obtain ethylene. The potential advantage of the process is the renewability of the agricultural resource. Sugarcane is mainly cultivated in Central and Southeast zones from Brazil. The Stade of São Paulo leads the national production. This state accounted for 58% of total production in the country in the 2010-2011 harvest, with an average agricultural productivity of 83 ton/ha. The production of ethanol by fermentation occurs via *Saccharomyces cerevisiae* under controlled conditions. Distilleries makes use bagasse for cogeneration of electricity. The surplus energy is marketed (Sugawara, 2012). The ethanol dehydration occurs in continuous reactors. A temperature of 400°C is needed in order to shift the equilibrium and efficiently produce ethylene with a high conversion. Additionally, γ-Alumina is used as catalyst (Cameron et al, 2012). The alkylation of benzene and ethylene into ethyl-benzene over a synthetic zeolite catalyst starts the GPPS manufacturing. After this process, styrene is produced by the catalytic dehydrogenation of etil-benzene in presence of steam (Burri et. 2008). Free-radical polymerization of styrene monomers, primarily in solution of ethyl-benzene is the final step in the manufacture of GPPS (Martins, 2009).

RESULTS AND DISCUSSION

Table 1 presents the environmental results of the replacement of fossil ethylene by renewable resource in GPPS production. The most significant impacts of fossil GPPS occurs at NLO and FD categories. GPPS obtained by renewable ethylene presents significant environmental impacts at CC, FEu, HT, ALO, TEc and FEc. Sugarcane cultivation contributes for all of these negative effects. This results are related to fertilizers and pesticides used in the agricultural activities emit discharge N and P, plus diuron and ametryn to air, water and soil. These losses are responsible to increase FEu, HT, Tec and FEc. Emissions of CO_2 and CH_4 from biomass burning and N_2O occurred during soil preparing, are responsible for increases of CC. Furthermore, land is required to cultivation enhancing ALO and NLT.

Table 1: Environmental performance of fossil GPPS and GPPS partially made from sugarcane

Impact Categories	**Units**	**Fossil GPPS**	**Partially renewable GPPS**
Climate Change	kg $CO_{2\ eq}$	1,40E+06	3,23E+06
Freshwater eutrophication	kg P_{eq}	2,04E-02	5,50E-02
Terrestrial ecotoxicity	kg 1,4-DB_{eq}	9,32E-02	5,78E+06
Freshwater ecotoxicity	kg 1,4-DB_{eq}	1,54E+05	3,90E+05
Agricultural land occupation	m^2	7,37E-02	1,97E+06
Natural land transformation	m^2	1,21E-01	1,12E-02
Fossil Depletion	kg oil_{eq}	1,05E+06	1,00E+06

Replacing fossil resource by renewable raw material reduces the non-renewable depletion in GPPS production. From this point of view, the petrochemical companies that follow the conduct are acting in a proactive way. The electricity cogeneration in bioethanol industry reduces the overall energy consumption in the whole GPPS life cycle. In addition, a high impact as NLT is assigned to fossil GPPS because the prevalence of hydropower in the Brazilian grid.

CONCLUSIONS

Effective benefits of replacing fossil resource by renewable raw material in GPPS production were identify in two of impacts categories evaluated in the study - NLT and FD. On the other hand, fossil GPPS presented better environmental performance on the other six categories under analysis. This situation indicates that the use of renewable sources to replace fossil derived is valid in specific situations, of little availability of area and imminently scarcity of oil and its derivatives. Efforts in the fields of genetic engineering and cleaner production may improve this situation making feasible from an environmental perspective a route whose technology is already consolidated.

Acknowledgements

The authors thank Petrobras SA for the financial support for the development of this project

REFERENCES

BEN-Brazilian Energy Book. (2012). Statistics Yearbook 2011. http://www.brasilcom.com.br/dadosestatisticos

ANP Agência Nacional de Petróleo. (2012). *Esquemas de produção no refino de petróleo.* Brasília. 230pp.

A. Antunes (2007). *Setores da indústria química orgânica*, v1. 242p., Rio de Janeiro. ISBN: 9788576500773.

D. Burri, K. Choi., D. Han, N. Jiang, A. Burri, S. Park. *Oxidative dehydrogenation of ethyl benzene to styrene and CO_2 over SnO_2-ZrO_2 mixed oxide nanocomposite catalysts* (2009) *Ind. Eng. Chem. Res. 48* (23), p 10307-13

G. Cameron, L. Le, J. Levine, N. Nagulapalli (2012). *Process Design for the Production of Ethylene from Ethanol*. University of Pennsylvania. http://repository.upenn.edu/cbe sdr/39

A Martins (2009). *Projeto de um controlador PI-MIMO para uma planta de produção de poliestireno.* Master Thesis. (Chemical Engineering). University of Rio Grande do Sul – UFRS (in Portuguese), 2009.

D. Netzer, (2005). *Benzene supply trends and proposed method for enhanced recovery* http://www.petrochemicals.dnetzer.net/articles/article-3.05.pdf.

Sugawara, E. (2012). *Comparação dos desempenhos ambientais do B5 etílico de soja e do óleo diesel, por meio da ACV.* Master Thesis. (Chemical Engineering). University of Sao Paulo – USP (in Portuguese), 2012.

BIOSYNFUEL PRODUCTION VIA SLOW OR FAST PYROLYSIS? A LIFE-CYCLE ENERGY DEMAND AND GLOBAL WARMING APPROACH

Jens F. Peters[a], Diego Iribarren[a], Javier Dufour[a,b]*

[a] Instituto IMDEA Energía, Móstoles 28935 (Spain)
[b] Rey Juan Carlos University, Móstoles 28933 (Spain)
** Corresponding author: Jens F. Peters. Instituto IMDEA Energía. Av. Ramón de la Sagra, 3, E-28935 Móstoles (Spain). E-mail: jens.peters@imdea.org*

Keywords: biofuel; bio-oil; cumulative energy demand; life cycle assessment; system expansion.

ABSTRACT

Two pyrolysis-based biosynfuel pathways are compared via life cycle assessment regarding their cumulative non-renewable energy demand (CED) and global warming potential (GWP). An avoided burden approach is used for dealing with the different products. Biosynfuels are produced by slow or fast pyrolysis of short-rotation poplar followed by hydrotreating of the obtained bio-oil. Key inventory data of both energy systems are derived from Aspen Plus® simulations. The fast pyrolysis-based system shows higher fossil energy savings but lower GWP reduction, indicating a trade-off situation between the two impact categories. Overall, biosynfuel production by slow pyrolysis is found to be competitive under CED and GWP aspects and can be considered as an alternative to fast pyrolysis systems.

INTRODUCTION

Second generation biofuels permit the use of residues and lignocellulosic energy crops as feedstock and are therefore seen as an appropriate alternative to conventional biofuels (EC, 2012). Thermochemical decomposition by pyrolysis is one of the available options for processing lignocellulosic biomass (Venderbosch & Prins, 2010). The pyrolysis products are char, bio-oil and gas, with the obtained amounts of each fraction varying with feedstock type and process conditions (slow pyrolysis maximizing char and gas or fast pyrolysis maximizing liquid yields). The liquid fraction, the bio-oil, can be upgraded to high-quality biofuels by hydrotreating in biorefineries (Bridgwater, 2012).

Few publications on the environmental performance of pyrolysis-derived biofuels can be found in literature (Han et al., 2011, 2013; Hsu, 2012; Iribarren et al., 2012a, 2012b; Kauffman et al., 2011). Furthermore, existing studies of slow pyrolysis (SP) focus on heat and electricity generation or on charcoal production (Brown et al., 2011), while biofuels are produced exclusively via fast pyrolysis (FP). However, SP can be an option for biosynfuel production if a profitable use can be given to the co-produced char.

MATERIALS AND METHODS

In this work, two biorefinery scenarios for the production of synfuels via FP and SP are contrasted by means of life cycle assessment (LCA). Bio-oil is produced via fast and slow pyrolysis of hybrid poplar and then upgraded to gasoline and diesel in the biorefinery. The considered impact categories are cumulative non-renewable energy demand (CED) and global warming impact potential (GWP) according to the IPCC guidelines for a 100-year time horizon. An input-oriented functional unit (FU) is defined: 1 kg of poplar wood chips with 50% moisture content.

Inventory data for the conversion processes are derived from Aspen Plus® simulations. The pyrolysis process includes biomass pre-treatment, pyrolysis, product recovery, and gas combustion to produce the heat required by the pyrolysis reactor. The upgrading process contains a two-stage hydrotreatment (HT), product separation and distillation, hydrocracking (HC) of the heavy oil fraction, and steam reforming of light off-gas and natural gas to produce the hydrogen required by HT and HC. Remaining inventory data concerning cropping and transport are taken from earlier works (Iribarren et al., 2012a, 2012b), while background data come from the ecoinvent® database. Table 1 presents a selection of key inventory data of both systems. The assessment follows a cradle-to-gate approach, covering from the production of the feedstock to the refinery gate. Capital goods are excluded from the study.

Table 1. Selected inventory data of the two pyrolysis-based systems for biosynfuel production (values per FU).

Selected inputs	FP-based	SP-based	Selected outputs	FP-based	SP-based
Poplar chips (kg, wet)	1	1	Gasoline (kg)	0.075	0.023
Transport (t·km)	0.210	0.179	Diesel (kg)	0.071	0.026
Electricity (kWh)	0.229	0.183	Char (kg)	0.040	0.147
Natural gas (MJ)	1.576	0.604	Steam (MJ)	0.523	0.120
			CO_2 to air (kg, direct)	0.249	0.295

Both the pyrolysis and the upgrading processes are multifunctional. Four different products are obtained: gasoline, diesel, pyrolysis char, and process steam (the latter produced by cooling the hydrotreating reactors). In order to account for all products, a system expansion approach based on avoided burdens is used. As the evaluation of the global impact avoided by the processes is of principal interest for an input-related assessment, this is considered the most coherent method. The main challenge is the identification of the product that most probably would be replaced. This is easy for mass products with an existing market, but difficult for niche products such as pyrolysis char. In this work, biosynfuel is supposed to substitute fossil gasoline and diesel, steam substitutes process steam produced in a heat plant with natural gas, and the pyrolysis char is assumed to be used for energy purposes substituting fossil coal.

RESULTS

Figure 1 shows the GWP and CED results of both pyrolysis-based systems. The biofuel scenarios show GWP reductions of 0.549 kg CO_2 eq (SP-based) and 0.503 kg CO_2 eq (FP-based) per FU. Negative values are obtained as a result of the system expansion approach used through this study, where the products derived from the biomass all replace energy products from fossil origin.

While SP is found to give better GWP results, FP shows a more favourable performance in terms of CED. The differences between FP and SP systems stem principally from the external inputs required by the processes, with the most important contributors being electricity consumption, transport and natural gas consumption. Nevertheless, no key contributor with a decisive impact on the differences can be identified.

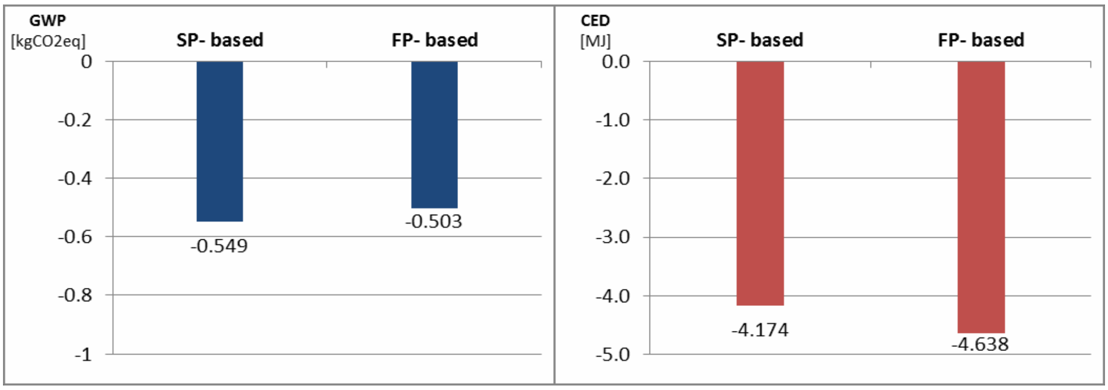


Figure 1. GWP and CED results of the two pyrolysis-based systems (values per FU).

DISCUSSION

The results obtained for the two assessed categories lead to opposite recommendations on the best-performing system. The FP-based system shows higher CED savings, but lower GWP reduction when compared to the SP-based system. This results in a trade-off between fossil energy savings and GWP reduction, which impedes the unambiguous identification of the best pathway under environmental aspects.

The SP-based system shows a surprisingly good performance in spite of the much lower synfuel yields achieved. This can be explained by the lower input required for the upgrading process. Lower bio-oil yields per FU lead to a lower amount of bio-oil to be upgraded and hence to lower overall inputs required for the processing plant. The SP plant itself is on the other hand less energy efficient than the FP plant and leads to a reversed picture under CED aspects. Nevertheless, although environmentally recommendable, the feasibility of a biofuel process based on SP can be questioned, as normally economic aspects would favour the FP process due to its much higher synfuel yields.

The system expansion approach gives comprehensive results for the given assessment and avoids the problem of assigning a common value to the different products as required for allocation. Nevertheless, the choice of the substituted product is often difficult and can be rather arbitrary, especially if no established market exists for the co-product (e.g., pyrolysis char). Using the char for substituting other products such as conventional charcoal could change the results significantly, as the GWP savings attributed to the avoided production of coal and steam make up significant shares of the overall GWP reduction. An assessment of the impacts of different substitution assumptions could be interesting in this regard.

CONCLUSIONS

Both biofuel processes show similar results in the two assessed categories. The FP process requires more external inputs and hence shows slightly lower GWP reduction, while the SP process scores worse under CED aspects due to the lower efficiency of the SP plant.

Although yielding much less biosynfuel per unit of biomass processed, SP-based systems can compete with FP-based ones under environmental aspects. They could hence be considered an environmentally favourable alternative for biofuel production.

REFERENCES

Bridgwater, A. V. (2012). Review of fast pyrolysis of biomass and product upgrading. *Biomass and Bioenergy*, 38(null), 68–94. doi:10.1016/j.biombioe.2011.01.048

Brown, T. R., Wright, M. M., & Brown, R. C. (2011). Estimating profitability of two biochar production scenarios: Slow pyrolysis vs. fast pyrolysis. *Biofuels, Bioproducts and Biorefining*, 5(1), 54–68. doi:10.1002/bbb

EC Proposal for a Directive of the European Parliament and of the Council amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources (2012). Brussels: European Commission.

Han, J., Elgowainy, A., Dunn, J. B., & Wang, M. Q. (2013). Life cycle analysis of fuel production from fast pyrolysis of biomass. *Bioresource Technology*, *133C*(null), 421–428. doi:10.1016/j.biortech.2013.01.141

Han, J., Elgowainy, A., Palou-Rivera, I., Dunn, J. B., & Wang, M. Q. (2011). *Well-to-wheels Analysis of Fast Pyrolysis Pathways with GREET*. Oak Ridge.

Hsu, D. D. (2012). Life cycle assessment of gasoline and diesel produced via fast pyrolysis and hydroprocessing. *Biomass and Bioenergy*, 45(null), 41–47. doi:10.1016/j.biombioe.2012.05.019

Iribarren, D., Peters, J. F., & Dufour, J. (2012a). Life cycle assessment of transportation fuels from biomass pyrolysis. *Fuel*, 97(null), 812–821. doi:10.1016/j.fuel.2012.02.053

Iribarren, D., Peters, J. F., Petrakopoulou, F., & Dufour, J. (2012b). Well-to-Wheels Comparison of the Environmental Profile of Pyrolysis-Based Biofuels. *20th European Biomass Conference and Exhibition*. doi:10.5071/20thEUBCE2012-5AV.1.7

Kauffman, N., Hayes, D., & Brown, R. (2011). A life cycle assessment of advanced biofuel production from a hectare of corn. *Fuel*, 90(11), 3306–3314. doi:10.1016/j.fuel.2011.06.031

Venderbosch, R., & Prins, W. (2010). Fast pyrolysis technology development. *Biofuels, Bioproducts and Biorefining*, 4(2), 178–208. doi:10.1002/bbb.205

COMPARATIVE LIFE CYCLE ASSESSMENT OF THE USE OF RECOVERED GLASS IN GLASS PACKAGING FOR FOOD

*Esther Roldán[1], Mª Rosa Pino[1]**, Alba Bala[2], Pere Fullana[2]. [1]Grupo de Investigación GIMACES, Universidad San Jorge. [2] Catedra Unesco de ciclo de vida y cambio climático. Universitat Pompeu Fabra. ** Universidad San Jorge. Campus Universitario Villanueva de Gállego Autovía A-23 Zaragoza-Huesca, km. 510 50830 Villanueva de Gállego. Zaragoza (Spain). rpino@usj.es*

Keywords: Life Cycle Assessment (LCA), glass packaging, glass recycling.

ABSTRACT

This study is part of the European project FENIX-Giving Packaging a New Life which aims to create an efficient tool that will be used to obtain results for the environmental impact of the packaging waste management through a methodology of Life Cycle Assessment (LCA). We present here a complete Life Cycle Assessment from cradle to cradle of glass packaging intended for food use from the Spanish-Portuguese geographical framework. Results have allowed us to evaluate the full environmental impact of the glass packaging waste (pretreatment, production of packaging glass and transports) considering the current waste management practices. These data could provide useful information to establish new recycling and production strategies and waste management in the sector.

INTRODUCTION

Glass is an inorganic hard and fragile material that is obtained from the fusion of silica sand, sodium carbonate, limestone and/or other materials and it is easily recoverable due to its characteristics. Glass packaging is 100% recyclable, i.e. from a used glass packaging, we can manufacture a new one with the same characteristics than the original one. A tonne of recovered glass replaces 1.2 tons of virgin raw materials that are required in the glass manufacturing process, which implies a considerable resources use reduction.

Traditionally, the glass packaging sector has been very important in Europe in that this industry fosters the European economy and employment and is the largest producer of glass packaging in the world. It employs 40,000 people in over 140 plants throughout Europe. The glass packaging industry has created new “ecological” recycling industries which are currently contributing to the recycling of over 62% of glass used across the European Union.

The main goal of this study is to analyse the environmental impacts of the life cycle of residual glass packaging (for food use) in Spain and Portugal, including pretreatment, production of packaging glass and associated transports.

MATERIALS AND METHODS

The study has been carried out following the ISO14040 Life Cycle Assessment (LCA) methodology (International Standardization Organization, 2006).

In the first place, we identified all processes involved in the overall life cycle of glass packaging waste in Spain and Portugal. Secondly, we modelled these processes and finally, we evaluated the environmental impact of the actual glass pretreatment and glass packaging industry processes.

The system boundaries of the study is from "cradle to cradle" and have comprised pretreatment, glass packaging industry, glass rejected treatment as well as several transfers. Lengthwise the lifecycle of glass packaging, small amounts of glass are rejected as these cannot be recycled and are disposed of. The management of the rejected glass (incineration and landfill) is included.

Transportation considered in this study, includes:

a) Glass transportation: transfer of waste glass collected from glass recycling containers to the glass pretreatment plant and transfer of the cullet from the pretreatment plant to the glass packaging manufacturing plant.

b) Raw material transportation: silica sand, limestone, soda and dolomite from their origin to the glass packaging manufacturing plant.

c) Waste transportation: non-hazardous waste from pretreatment to waste treatment, Hazardous waste from glass packaging manufacturing plant to waste treatment and glass rejected.

Transports from households to the recycling bins were excluded.

The functional unit specifically established for the system under study is one tonne of waste glass being treated.

Data have been sourced from a pretreatment company and from glass packaging manufacturing plant belonging to two different consortiums. The Ecoinvent database was also used as a reference and more precisely, data base of Packaging Glass (Hischier, 2007).

The LCA software tool GaBi 4.0 has been used for LCA modeling. The environmental impacts have been estimated according to the CML 2001 method (Guinee, 2001).

RESULTS

Inventory data. Inputs/outputs of the processes can be seen in the table 1 and impact assessment Impact indicators used for this study (Figure 1) are detailed next: ozone creation potential (POCP) in kg ethane-equiv; ozone layer depletion Potential (ODP) in kg R11-equiv.; global warming potential (GWP 100 years) in kg CO2-equiv.; eutrophication potential (EP) in kg phosphate-equiv.; acidification potential (AP) in kg SO2-equiv.; abiotic depletion (ADP fossil) in MJ.

GLASS PRETREATMENT						PRODUCTION OF PACKAGING GLASS					
Inputs						Inputs					
	Units	Quantity		Units	Quantity		Units	Quantity		Units	Quantity
Waste Glass	Ton	1	Raw Material (Manufacturing Oils ...)	Ton	0,0005	Power grid mix	KW/h	883,012	Soda	Ton	0,244
Power grid mix	KW/h	5,81				Natural Gas	KW/h	3764,358	Dolomite	Ton	0,045
Outputs						Cullet (external)	Ton	0,968	Cullet (internal)	Ton	0,384
Cullet	Ton	0,968	PET	Ton	0,0035	Silica Sand	Ton	0,933	Raw Material (Manufacturing Oils...)	Ton	0,001
Aluminum	Ton	0,0011	Plastic	Ton	0,0043	Limestone	Ton	0,209	Water	M^3	1,008
Cardboard	Ton	0,0025	Steel	Ton	0,0041	Outputs					
HDPE	Ton	0,0018	Tretrapack	Ton	0,0004	Waste Water	M^3	1,008			
LDPE	Ton	0,0015	Other	Ton	0,0112	Hazardous waste	Ton	0,0001	Reject Material (Cullet Internal)	Ton	0,384
Organic Waste	Ton	0,0009	Emissions	--	--	End Products (glass)	Ton	2,155			
						Glass rejected	Ton	0,153	Emissions*	--	--
TRANSPORT											
Waste Glass from glass recycling containers to pretreatment				Km.	300	Limestonefrom supplier to recycling plant				Km.	200
Non hazardous waste from pretreatment to waste treatment				Km.	40	Soda from supplier to recycling plant				Km.	490
Cullet from pretratment to recycling plant				Km.	100	Dolomite from supplier to recycling plant				Km.	100
Silica Sand from supplier to recycling plant				Km.	250	Hazardous waste from recycling plant to waste treatment				Km.	200

Table 1. Inventory data of the processes considered in the system boundaries

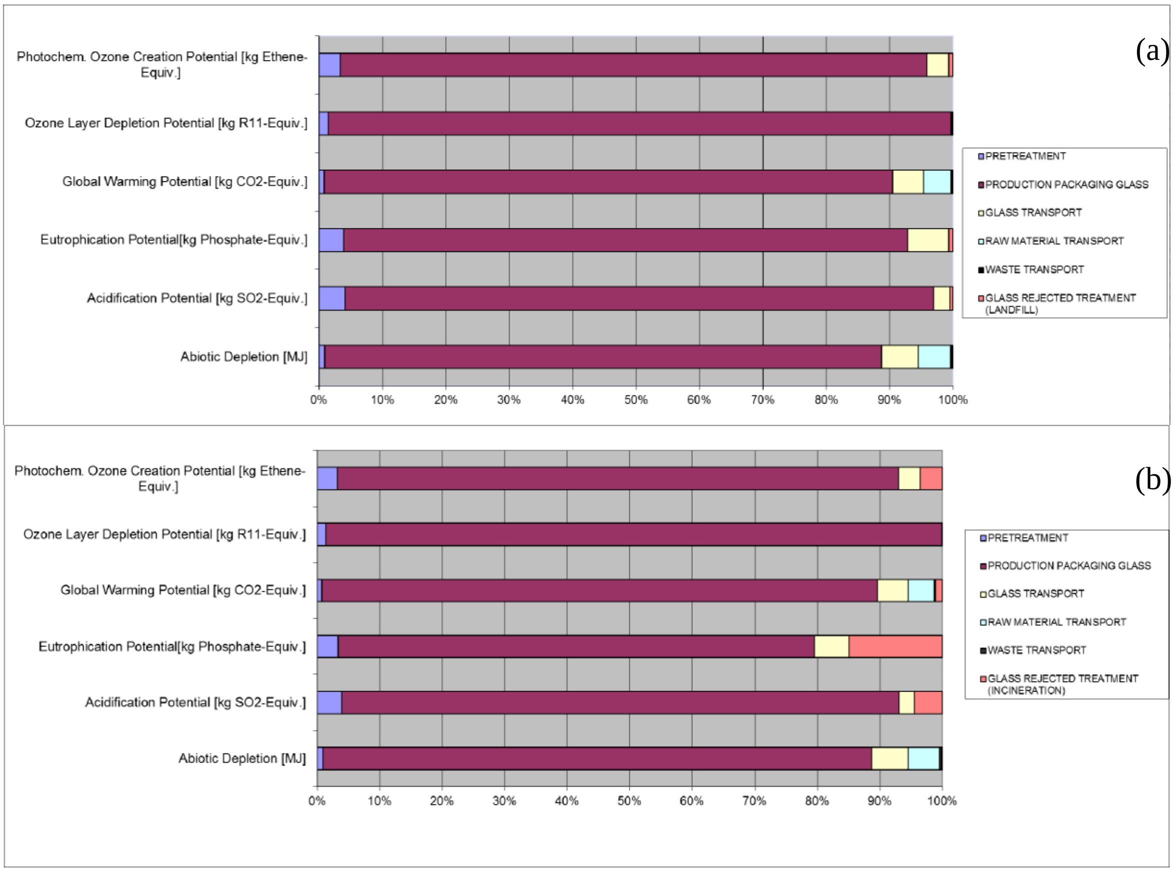


Figure 1. Contribution of different life cycle stages to the environmental impacts of the glass. (a) Glass rejected treatment by landfill or (b) by incineration.

DISCUSSION

The results from the analysis of the glass packaging life cycle environmental impacts confirm that glass packaging manufacturing process is a major “hot spot” contributing between the 85% and 95% to those impacts. Particularly, glass packaging industry contributes up and above of 85% to the Global Warming (551.04 kg de CO2 equiv. emitted). The production stage of the glass packaging has the highest climate change effect because very high temperature furnaces are used for their production with very high energy requirements. Road transportation of glass, raw material and waste has the second highest effect and contribute up to the 5-10% of the total impacts especially in global warming and abiotic depletion. Pretreatment and glass rejected treatment (landfill) shows similar low contributions (below 1%) in all the impacts studied because these processes need lower energy requirements. Nevertheless, when incineration is the treatment of choice for the rejected glass instead of landfill, the results show a considerable increase in the environmental impact of this process (between 1-15%). This is specifically remarkable in the case of eutrophication potential, acidification potential and ozone creation potential.

CONCLUSIONS

This study shows that glass packaging industry has the greatest impact in all environmental factors studied and this is related to the high energy consumption of this process. However, when incineration is chosen instead of landfill during the glass treatment process, this also has a significant impact on the environment up to 15% .The use of recycled glass as input in the production process facilitates a reduction in the consumption of other raw materials of primary origin (1 tonne of recycled glass saves 1.2 tonnes of raw materials as silica sand, limestone, soda, dolomite…) and a substantial reduction in energy consumption. This is due to the fact that recycled broken glass or calcin are made up of the same composition as smelting glass and eliminates the cost related to chemical reactions involved in the smelting process (2.5%-3% saving on energy per 10% of recycled glass). Note that in this study the percentage of glass that is recycled is 44%. But this is not sufficient as to prevent the production of packaging glass process from having the greatest environmental impact. So it seems clear that the implementation of incentive schemes to promote selective collection practices as well as the proper use of glass waste collection points that will allow the collection of greater amount of recycled glass could lead to a significant reduction of the environmental impacts associated with the life cycle of the glass packaging. These results provide useful information to establish new recycling, production strategies and waste management in the life cycle glass packaging aimed specifically to those processes that generate greater environmental impacts.

REFERENCES

Guinee, J. (2001). Handbook on life cycle assessment - Operational guide to the ISO standards. *International Journal of Life Cycle Assessment, 6, 255-255*. DOI: 10.1007/bf02978784

Hischier R. (2007). Life Cycle Inventories of Packagings and Graphical Papers. *Ecoinvent report Nº11*. Dübendorf , Switzerland: Swiss Center for Life Cycle Inventories.

ISO 14040 (International Standardization Organization). (2006). Environmental Management-Life Cycle Assessment—Principles and Framework. *International Standard ISO 14040*

ECO-EFFICIENCY MODELING BASED ON LIFE CYCLE ASSESSMENT

Dorota Burchart-Korol, Jerzy Korol, Piotr Krawczyk, Krystyna Czaplicka-Kolarz*

**Central Miting Institute, Plac Gwarków 1, Katowice, Poland, dburchart@gig.eu*

Keywords: eco-efficiency, life cycle assessment, material flow analysis, cost assessment, coal gasification

ABSTRACT

In this paper modeling of eco-efficiency based on life cycle approach was presented. Own methodology of eco-efficiency assessment was shown. Material Flow Network of eco-efficiency modeling were performed on the example of power generation via the Shell gasification process. According to EN ISO 14045:2012 eco-efficiency indicator is measured relating environmental performance of a product system to its product system value. In this paper for eco-efficiency analysis was used Life Cycle Assessment (LCA) and Life Cycle Cost (LCC). Material and energy flows of each unit process was done with Umberto for Eco-efficiency 5.6 software. System boundary included for eco-efficiency study comprised the all of life cycle phases: construction, operation and disposal.

INTRODUCTION

In this paper eco-efficiency was modeling to integrate economic and environmental indicators for the case study of Clean Coal Technologies (CCT). CCT allow to energy efficient and environmentally friendly use of coal. CCT include: coal upgrading, improvements in efficiency of existing power plants, advanced power generation technologies (eg Integrated Gasification Combined Cycle, IGCC), near zero-emission technologies and technologies for carbon capture and storage (CCS). IGCC could potentially capture and store carbon dioxide. It is important for further improvement of IGCC in terms of its economics and environmental impact (Smoliński et al. 2010). Thus model of eco-efficiency for IGCC (Shell gasifier) was done.

The eco-efficiency concept was first defined in 1989 by The World Business Council for Sustainable Development (WBCSD) as being achieved by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle to a level at least in line with the earth’s carrying capacity (www.wbcsd.org, 2013). According to EN ISO 14045:2012 eco-efficiency is an aspect of sustainability relating the environmental performance (measurable results related to environmental aspects) of a product system (collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product) to its product system value.

An eco-efficiency is a relative concept and a product system is only more-or-less eco-efficient in relation to another product system. Environmental assessment in eco-efficiency evaluation shall be based on Life Cycle Assessment (LCA) according to ISO 14040:2006. More information about LCA quantification of chosen production system was done by Burchart-Korol (2013).

The result of Life Cycle Inventory (LCI) study may be used directly as input to an eco-efficiency assessment. The product system value assessment shall consider the full life cycle of the product system. Material Flow Analysis (MFA) is a method to establish an inventory for an LCA. MFA is a systematic assessment of the flows and stocks of materials (Brunner et al. 2004). Eco-efficiency is important tool in the sustainable development.

MATERIALS AND/OR METHODS

Eco-efficiency indicator according to own methodology is measured relating environmental performance of a product system based on LCA to its product system value based on LCC (Life Cycle Cost) (Figure 1).

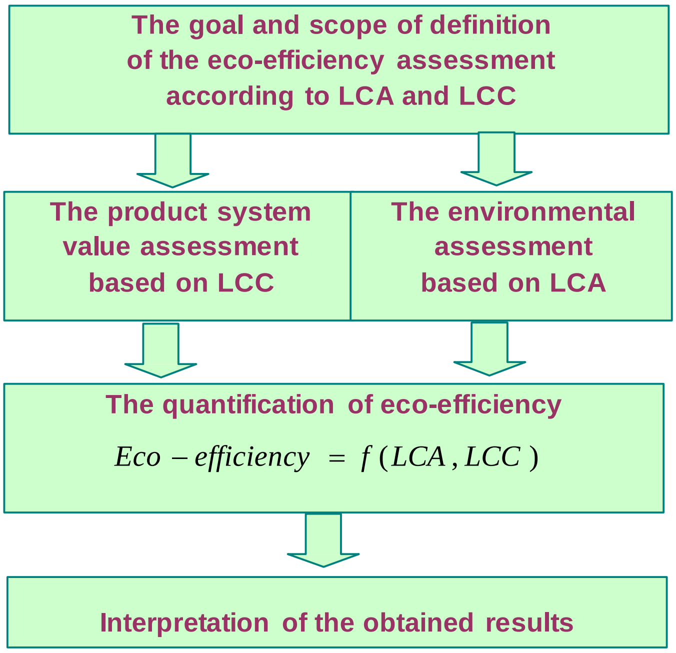


Figure 1. Eco-efficiency methodology with life cycle approach
Source: Own analyses based on EN ISO 14045:2012

The power generation via the Shell gasification process was developed with the software tool Umberto for Eco-efficiency (using inventory data from ecoinvent database) which is modeling tool for Material Flow Networks.

The eco-efficiency study comprises the all life cycle phases of the power generation system: construction, operation and disposal.

RESULTS

Material Flow Analysis (MFA) and Life Cycle Assessment (LCA) are the most suitable for environmental analysis. In this paper Umberto for Eco-efficiency 5.6 has been applied for Material Flow Analysis. MFA allowed to determine the material and energy flow for process optimization. MFA of power generation via the Shell gasification process is included in Figure 2. The list of inventory for cost and inventory analysis needed for eco-efficiency assessment of chosen power generation technologies is shown in Figure 3. The detailed results of eco-efficiency assessment was presented by Burchart-Korol et. al (2013).

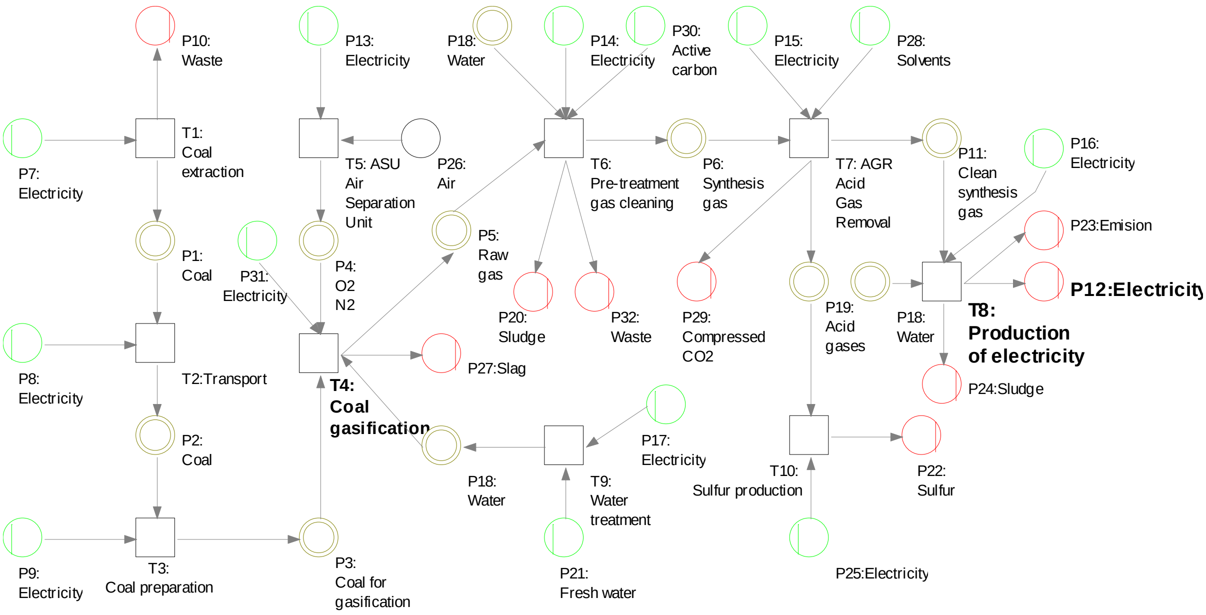


Figure 2. Material Flow Network of power generation via the Shell gasification

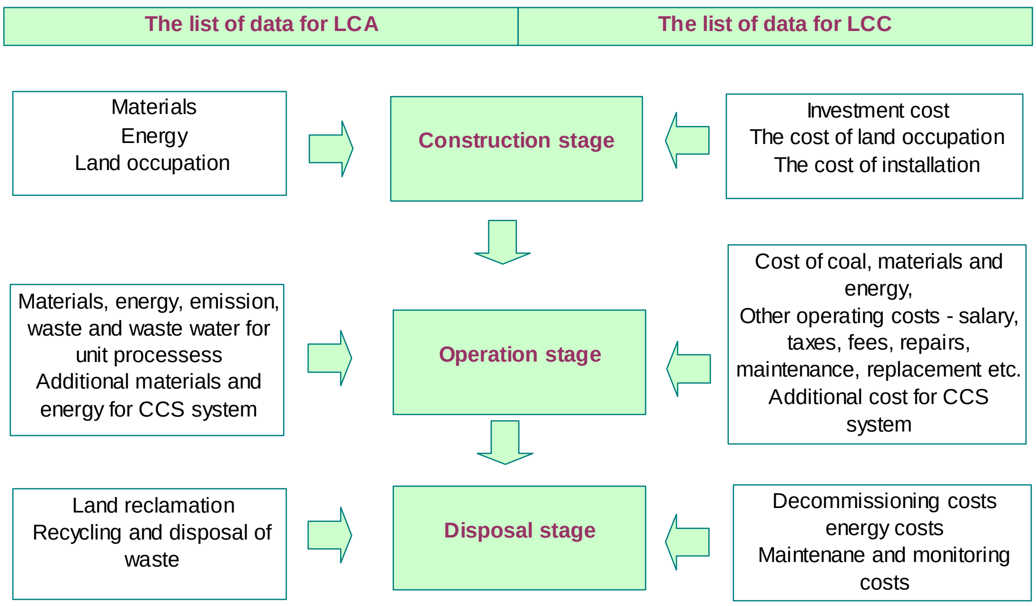


Figure 3. The list of inventory data needed for eco-efficiency assessment

DISCUSSION

Eco-efficiency modeling of power generation via the Shell gasification process with and without CCS, according to the requirements of norm ISO 14045:2012 concerning the rules and guidelines of eco-efficiency assessment, was presented in the paper. Own eco-efficiency analysis methodology was presented. In case of power generation via the Shell gasification process, coal mining and the carbon dioxide emissions are the main environment assessment determinants, whereas the main factor determining the investment cost and replacement investments, then to the cost of coal gasified. In technologies without the CCS the construction stage of the installation and the included costs has the biggest impact on its eco-efficiency. In case of power generation via the Shell gasification process with the CCS, eco-efficiency is influenced by the process of coal mining and its costs, whereas the emission costs are minimal. Detailed results of eco-efficiency analysis performed for the four variants (coal, lignite, with and without CCS) of coal gasification technology (Shell gasifier) were presented by Burchart-Korol et. al (2013).

CONCLUSIONS

The aim of the study was eco-efficiency modeling of chosen production system. Eco-efficiency modeling contains Material Flow Network and eco-efficiency assessment according to EN ISO 14045:2012 (own methodology). It was found out that eco-efficiency as the function of life cycle assessment and life cycle cost connects the basic business target (profit) and the basic production system target (costs) with environmental approach, thanks to which decision-makers in companies have the possibility to create innovative products fulfilling at the same time environmental criteria. In order to eco-efficiency modeling of products and technologies it should be taken into account all input and output for all unit processes and the cost assessment of all life cycle stages.

ACKNOWLEDGEMENTS

This paper is a part of the ongoing Research Task ‘Development of coal gasification technology for high production of fuels and energy’ funded by the National Center for Research and Development under the Strategic Programme for Research and Development entitled: ‘Advanced energy generation technologies’.

REFERENCES

Smoliński A., Howaniec N. 2010: Environment Friendly Coal Processing Technologies for Sustainable Development of Polish Energy Sector, *Ecological Chemistry and Engineering, Vol. 17, No. 3*

www.wbcsd.org, 2013.05.10

EN ISO 14045: 2012 Environmental management — Eco-efficiency assessment of product systems — Principles, requirements and guidelines

Burchart-Korol D., 2013: Life Cycle Assessment of Steel Production in Poland. A Case Study. *J. Clean. Prod., DOI 10.1016/j.jclepro.2013.04.031*

Brunner P. H., Rechberger H., 2004 : Practical Handbook of Material Flow Analysis. Lewis publishers, London

Burchart-Korol D., Krawczyk P., Śliwińska A., Czaplicka-Kolarz K., 2013: Eco-efficiency Assessment of the Production System of Coal Gasification Technology (in Polish), *Przemysł Chemiczny, No 3*

ECOLOGICAL FOOD PRODUCTS – NEW ROLES AND RESPONSIBILITIES FOR RETAILERS

Birgit Brunklaus [1], Michaela Raab [2].*

** [1] Environmental Systems Analysis, Chalmers University of Technology, S-41296 Gothenburg, Sweden. Email: birgitb@chalmers.se.*

[2] JOHANNES KEPLER UNIVERSITY LINZ, AUSTRIA

Keywords: organic; cucumber; retailer; actor analysis; Carbon Footprint.

ABSTRACT

.

More and more ecological food products are entering supermarkets, and the recent trend is to label as well the climate impact of food products. But, do ecological food products have better environmental performances than conventional ones? An Austrian, Swedish and Spanish cucumber was compared calculating the climate impact in a life cycle perspective using an actor analysis. Austrian conventional cucumbers and Spanish ecological cucumbers show similar values, while Swedish conventional cucumbers have the highest emissions. The actor analysis shows that retailers and the cooperative have most power. The introduction of Spanish ecological cucumbers shifts the environmental impact from heating of greenhouses to transport. The findings highlight the retailers' role and importance of green purchasing strategy considering the whole life cycle.

INTRODUCTION

In supermarkets retailers offer a wide range of vegetables such as potatoes, carrots, tomatoes, cucumbers, zucchini etc. all year round. On one hand consumers demand a large selection, on the other hand consumers are also looking for an organic alternative, especially for vegetables. Furthermore, food retailers come up with their own organic brand like "I love eco" by ICA and "Änglarmark" by COOP in Sweden. Beside reasons to use less pesticide and health reasons, the recent trend is to label as well the climate impact on food products. This makes the purchasing difficult for the retailers, since vegetables are not always available and they have to consider at least two environmental issues, the pesticides and climate change. When local organic production is not possible, retailers have to choose either local conventional or imported ecological products. The question for the retailers is: do ecological food products have a better carbon footprint than conventional ones, even if they are imported? This question will be answered with the example of ecological imported cucumbers from Spain and conventional cucumbers from Austria and Sweden.

This study is based on three levels to give the retailers an overview about those products and to gain important information for producers:

1st level: Environmental impacts of cucumber production (Carbon Footprint)

2nd level: Retailers' possibilities of reducing greenhouse gas emissions

3rd level: Retailers' influences on their own and other actors' actions

METHODS

Data for the comparison of ecological cucumbers from Spain and conventional cucumbers from Austria are based on field research in El Ejido in the province of Almería and in Simmering in the south of Vienna as well as on prior studies and data. The Swedish production is based on a study by Davis et al. (2011). The comparison of these products results from the diploma thesis at Johannes Kepler University Linz and an internship at Chalmers University of Technology (Raab & Brunklaus, 2012).

The method used to calculate the Carbon Footprint of cucumbers is based on the Life Cycle Assessment (LCA) guidelines according to ISO 14040 and 14044. Furthermore, this study will test the actor analysis (Brunklaus & Berlin, 2011) and the distinction of three levels, adapted from Brunklaus (2011). The actors of the cucumber chain are the (pre-)cultivators, cooperative, transport, retailer and consumer. Due to this actor analysis, the direct environmental impacts and possibilities of retailers and other actors can be shown. Furthermore, the retailers' influences on their and on the others' activities can be analyzed. Calculations are made from "cradle to grave" – from pre-cultivator to retailer including waste disposal from the period of January until end of May, when organic cucumber production is hardly possible in Austria (Bio Austria, 2010).

RESULTS

The results of the environmental impact of Spanish organic and Austrian and Swedish conventional greenhouse cucumbers (level 1) are illustrated in figure 1.

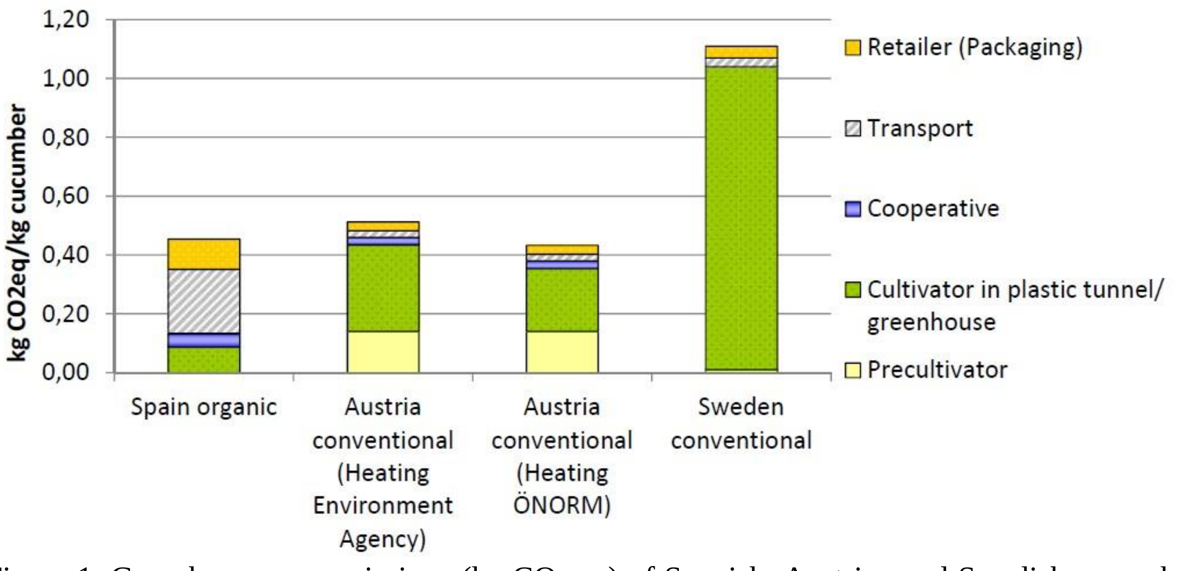


Figure 1. Greenhouse gas emissions (kg CO_2-eq) of Spanish, Austrian and Swedish cucumber production

One kilogram of Spanish organic cucumbers (1st column) shows in total 0,45 kg CO_2-eq and half of them are caused by transports. The second and third column indicates the Austrian conventional cucumber production. There are two scenarios, because of different calculation methods of district heating. The second column (0,51 kg CO_2-eq/kg cucumber) is according to the Environment Agency Austria (Umweltbundesamt) by Pölz (2007) and the third one (0,43 kg CO_2-eq/kg cucumber) according to the standardized method ÖNORM EN 15316-4-5 of the Austrian Energy Agency. The Swedish conventional cucumber shows the highest emissions (1,11 kg CO_2-eq/kg cucumber) in column four. Reasons for that are a high heating amount and a predominant share of fossil fuels. Both conventional cucumbers have their hotspots in cultivation in the greenhouse.

The retailers' possibilities of reducing greenhouse gas emissions are low while other actors have larger possibilities (2nd level). Those are: transport for Spanish ecological cucumbers; CO_2-gas and nitrogen fertilization for Austrian conventional cucumbers at cultivator; and heating and use of fossil fuels for Swedish conventional cucumbers at cultivator.

The retailers' influence (3rd level) on other actors can be direct or indirect. In this case the retailer can influence the consumer, as well as the cooperative and the transport directly, while the cultivator can be influenced indirectly (figure 2). Direct influence means also more power. Indirect influence is evident with all actors and it's the matter (figure 2, dotted line), which keeps the production chain together (Raab & Brunklaus, 2012).

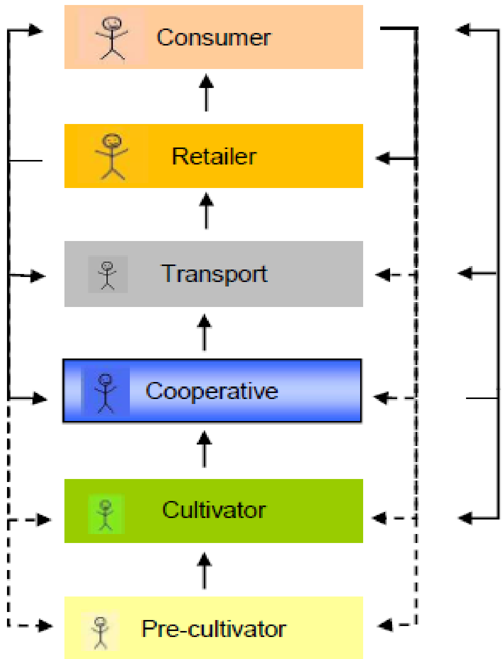


Figure 2. Actors' influences in the cucumber production

Together, the retailers' low possibilities and high influence on other actors, gives another picture of retailers' role and responsibilities. Retailers can influence transports directly and cultivators indirectly. The introduction of Spanish ecological cucumbers shifts the indirect influence in heating of greenhouses to direct influence of transport.

DISCUSSION

The distinction of three analysis levels in combination with the Carbon Footprint works well. Important information could be gained especially for producers and retailers. For retailers and consumers the Carbon Footprint is a start to raise awareness of environmental issues in cucumber production, but it is just the beginning. Other environmental and social impacts based on Life Cycle Assessment, such as water footprint and social LCA might be important as well. The Swedish production was difficult to compare with the Austrian one, because some information was missing or inexact. In case of heating the greenhouses Swedish producers still mostly heat with fossil fuels, which might be changed in the coming years (Höhne et. al, 2011). The introduction of Spanish ecological cucumbers shifts the environmental impact from heating of greenhouses to transport, which means larger possibilities for retailers.

CONCLUSIONS

For retailers green purchasing strategy, decisions on imported organic or local conventional cucumbers are important. As shown in figure 1 (column 1-3) it is difficult for retailers in Austria, while for retailers in Sweden, the imported cucumbers from Spain have a better Carbon Footprint. Nevertheless, the actor analysis of Carbon Footprints can be a significant tool for retailers and other actors. The cucumber's life cycle can be structured in its single production steps, the actors can analyze the hotspots out of it and strive for ecological improvements. Apart from improvements in the cultivators' greenhouse, retailers can contribute a lot to environmentally responsible decisions. Retailers can improve the transport especially from Spain by using green cargo. Furthermore, they decide about packaging material (plastic film wrap, trays) and can reduce cucumber wastage with good conditions of storing, cooling and high product circulation. Retailers have direct contact to consumers and with precise product information they could raise consumer awareness of the cucumber production. Overall, the retailers' role and importance of environmentally responsible decisions is evident throughout the whole life cycle.

REFERENCES

Bio Austria (2010). Produktionsrichtlinien, Fassung September 2010. Wien: Niederösterreichisches Pressehaus Druck- und Verlagsgesellschaft m.b.H.

Brunklaus, B. (2011). Actor's behavior matter – organizing green product chains. Poster presented at the ISE conferences, 7-10th of June 2011, University of Berkley, San Francisco, USA.

Brunklaus, B. & Berlin, J. (2010). Actor Based Life Cycle Assessment - towards green food chains for eco-products. Research project within ORAGNIC PRODUCTION 2010-2013 FORMAS.

Davis, J., Wallman, M., Sund, V., Emanuelsson, A., Cederberg, C. & Sonesson, U. (2011). Emissions of Greenhouse Gases from Production of Horticultural Products - Analysis of 17 products cultivated in Sweden. Göteborg: SIK.

Höhne, N., Geurts, F. & Teckenburg, E. (2011). Sweden 2011. http://www.climatepolicytracker.eu/sweden 04.07.2012

Pölz, W. (2007). Emissionen der Fernwärme Wien 2005. Report REP-0076. Wien: Umweltbundesamt GmbH.

Raab, M. & Brunklaus, B. (2012). Carbon Footprint of organic Spanish compared to conventional Austrian/Swedish cucumbers - Consumer and producer perspective on reducing greenhouse gas emissions. Gothenburg: Chalmers University of Technology.

ENVIRONMENTAL EVALUATION OF DIFFERENT WASTEWATER TREATMENT SYSTEMS: ACTIVATED SLUDGE, UASB AND STABILIZATION PONDS IN LATIN AMERICAN AND THE CARIBBEAN

F. Hernández-Padilla, P. Güereca-Hernández, A. Noyola. Instituto de Ingeniería – Universidad Nacional Autónoma de México. Circuito Escolar s/n, Ciudad Universitaria, México, D.F., C.P. 04510, México.fhernandezp@iingen.unam.mx*

Keywords: wastewater treatment; activated sludge; UASB; stabilization ponds, life cycle assessment.

ABSTRACT

Environmental evaluation of water treatment systems was developed for three technologies of wastewater treatment: activated sludge, upflow anaerobic sludge blanket reactors (UASB) and stabilization ponds. Life Cycle Assessment (LCA) was developed for 9 scenarios (S1 to S9) for the current situation in the Latin America and the Caribbean (LAC). Results show that S2, S5 and S8 (stabilization ponds) have greater impacts in global warming potential (GWP) and photochemical oxidation due to CH4 emissions from anaerobic ponds, likewise S1, S4 and S7 (activated sludge) have impacts in acidification and abiotic resource reduction due to electricity consumption in the aeration tank. Scenarios with UASB reactors have lower impacts in GWP and medium on formation of photochemical oxidants.

INTRODUCTION

With 33% of the renewable water resources of the world, Latin America and the Caribbean (LAC) is the continent with the highest water availability; its 3100 m^3 of water per capita per year, doubles the global per capita average (World Bank, 2004). Although the region has experienced an increase in drinking water coverage from 90% in 2000 to 94% in 2011 (World Health Organization, 2013), 35 million people still lack access to water. Sanitation coverage is limited to 82%, resulting in 106 million inhabitants without access to sanitation facilities (WHO, 2013).

A growing concern is related to the absence of an integrated management of the resource An important element in this approach is the need of sound, appropriate investments in infrastructure for wastewater treatment systems. In this context it is necessary to identify the more sustainable treatment technologies for the region.

There are few published LCA studies on wastewater treatment systems for some particular cases such as Benetto et al. (2009) which develops a comparative LCA in an office building in Luxembourg; Hospido et al. (2004) and Rodriguez-Garcia et al. (2011) carried out studies for some regions of Europe, but the region of LAC has been poorly studied

The aim of this study is to present a Life Cycle Assessment for wastewater treatment systems in LAC by analyzing the effect of each unit process within the more representative treatment technologies in the LAC region, based on 9 scenarios.

METHODS

Technologies selection and definition of 9 scenarios

The representative configurations of wastewater treatment plants (WWTP) for LAC were selected according to the findings of Noyola et al. (2012), based on a sample of 2774 WWTP in six LAC countries (Brazil, Chile, Colombia, Guatemala, Mexico and the Dominican Republic). As a result, the treatment systems considered were: activated sludge (extended aeration and conventional processes), stabilization ponds, upflow anaerobic sludge blanket reactors (UASB), and trickling filter as a post-treatment for UASB. The model considered that 80% of biogas from UASB reactors is collected and burned.

The environmental effect of each unit process was analyzed considering three flows: small, medium and large; the former within a range from 0.1 to 25 L s^{-1}, the medium from 25 to 250 L s^{-1} and the latter from 250 to 2500 L s^{-1}, resulting in 9 scenarios (Table 1).

Table 1: Treatment scenarios considered for the LCA

Small flow	Medium flow	Large flow
S1. Extended aeration	S4. Extended aeration	S7.Conventional Activated Sludge
S2. Stabilization ponds	S5. Stabilization ponds	S8. Stabilization ponds
S3. UASB + Trickling filter	S6. UASB + Stabilization ponds	S9. UASB + Activated Sludge

The sludge treatment option varied depending on the scenarios: S1, S3 and S4 considered a simple drying bed; S2, S5, S6 and S8 dried their sludge in the same pond (once isolated from the treatment system); S7 had a mesophilic anaerobic sludge digester followed by a centrifuge for dewatering; S9 considered a centrifuge for dewatering.

Functional unit

In this work, the functional unit was defined as the treatment of 1 m^3 of wastewater municipal over 20 years considering specific effluent and biosolids quality.

The effluent quality was defined as BOD (biochemical oxygen demand) of 30 mg L-1 and TSS (total suspended solids) of 30 mg L-1 according to an analysis of the discharge standards of the region. The quality of the resulting sludge was defined in accordance with the regulations for application of biosolids to agricultural lands "Class B" of the United Stated EPA regulations (USEPA, 1992, 1999), considering that in the region only some countries have biosolids standards and the majority of these regulations are based on those of EPA.

Life Cycle Inventory

The Life cycle inventory (LCI) obtained for this work considered more than 40 chemical compounds emitted to air, water and soil, as well as raw materials and energy used. In this study, a representative electricity mix for LAC region was obtained from WB (2010): Coal 5.9%, Gas 20.9%, Oil, 14.6%; hydro,55.8% and nuclear, 2.8%.

The characterization of municipal wastewater influent was defined according to statistical analysis of the data collected within a sample of 158 WWTP as presented by Noyola et al. (2012). The sludge stabilization and subsequent disposal in soil was considered, with their corresponding emissions, taking into account their heavy metals content.

In this study, the CML2000 method was used to evaluate the impact categories: Abiotic depletion (AD), Acidification (AC), Global warming (GWP100), Eutrophication (EU), Photochemical oxidation (PHO), and Terrestrial toxicity (TT).

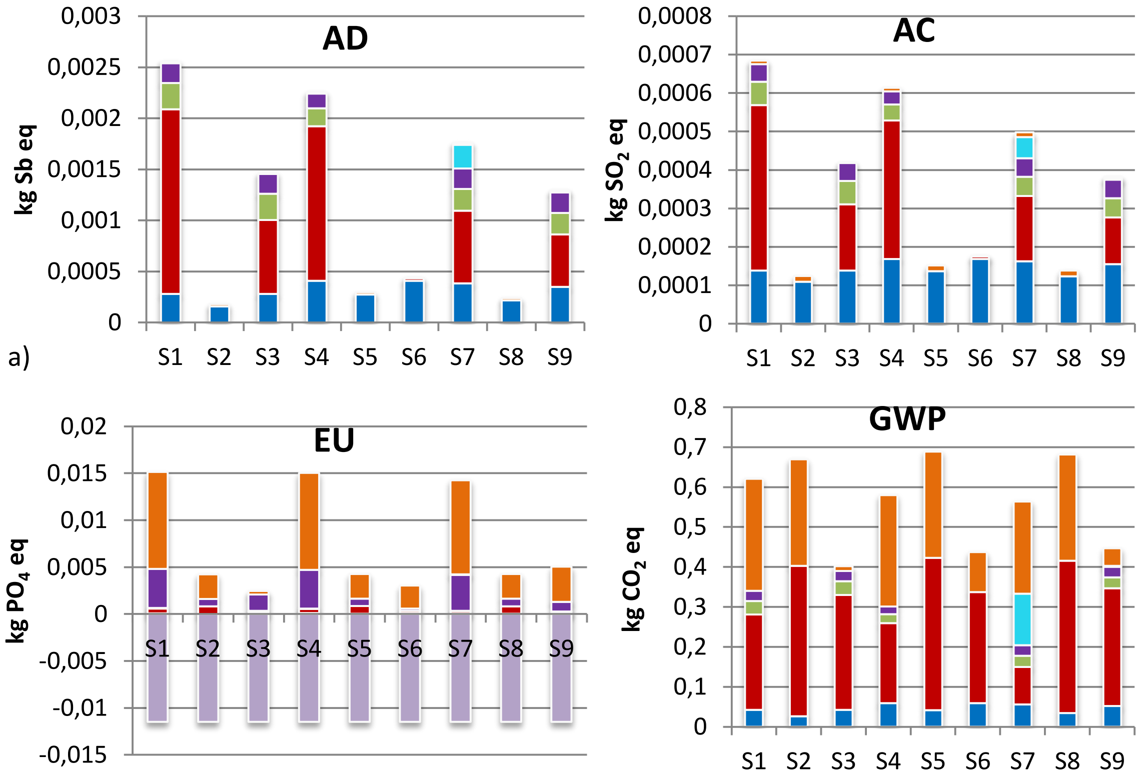
RESULTS AND DISCUSSION

Figure 1 shows the results of environmental performance for each unit process for the 9 scenarios.

The scenarios S1, S3, S4, S7 and S9 have major impacts in AD because of their use of electricity, mainly in the aeration tank of the activated sludge process. Those systems involving stabilization ponds (S2, S5, S6 and S8) presents much lower impacts on this category (Figure 1a). Moreover, Figure 1b shows that S1, S3, S4, S7 and S9 have higher impacts in AC on the secondary treatment (59 to 83%) due to SO2 (68%) and NOx (31%) emissions in the electricity production with the given generation mix.

In each scenario, the impacts on EU have negative values (avoided or positive impact) due to the reduction of pollutants in the discharged treated wastewater. In fact, WWTP are built and operated in order to reduce this specific impact, among other public health related issues. However, S1, S4 and S7 present similar impact values as those avoided, resulting in nearly neutral processes for this specific impact category, mainly due to the contribution of sludge disposal (land application). The scenarios considered final water disposal to a river and shows minor impact (2 to 8%) for this operation. With the exception of S3, in all scenarios sludge disposal had higher EU impact than water discharge.

Scenarios S2, S5 and S8 have greater impacts (67%) in GWP, and particularly in PHO, due to CH_4 emissions from anaerobic ponds. Also, S1 and S4 have high impacts, as a result of the contributions of the aeration tank (50%) due to the emission of fossil CO_2 (91% of the total impact) produced for electricity generation. The pretreatment operation has a similar behavior in each of the scenarios, due to emissions of residues from the solid waste screening disposed in the landfill, mainly associated with dichloroethane emissions by 91%.



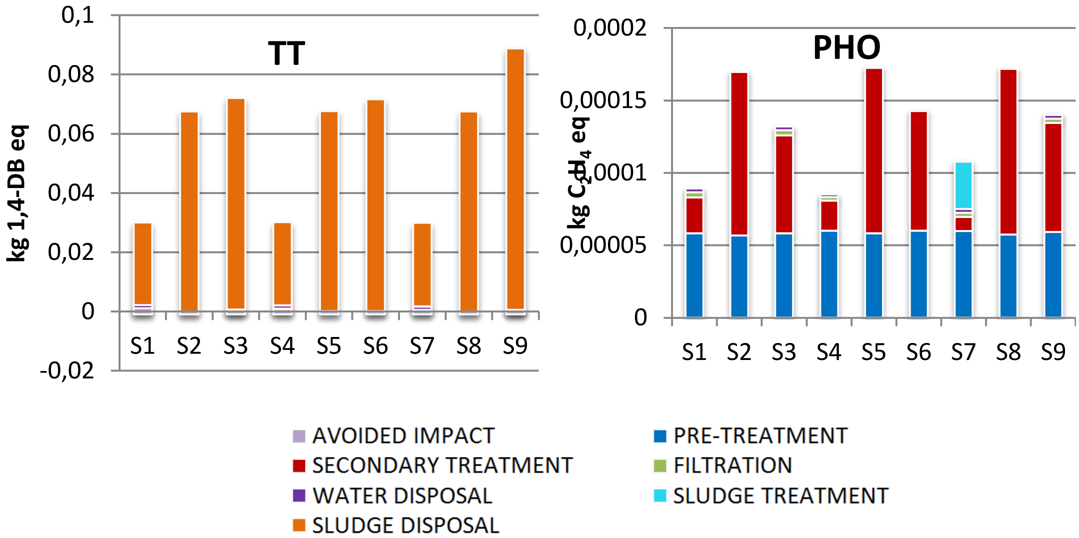


Figure 1. Environmental performance of the 9 scenarios

Sludge disposal in all scenarios is responsible for 95% of impacts in TT. The UASB scenarios (S3, S6 and S9) have major impacts in each flow size, due to the higher concentration of heavy metals in this kind of sludge, precipitated as metallic sulfides, which are disposed on soil.

CONCLUSIONS

The impact analysis of the contribution of each unit operation and process involved in each scenario allows to identify that scenarios with electricity use have major impacts in the categories of acidification, abiotic resource reduction and terrestrial toxicity. Anaerobic ponds have major impacts in the category of global warming and photochemical oxidation. However, UASB with biogas burning shows the lower impact on GWP. Furthermore, scenarios with UASB have greater impact on terrestrial toxicity category due to the concentration of sludge disposed in the soil. In the eutrophication category, scenarios with greater generation of sludge (involving the activated sludge technology) have the greater impact due to nutrients disposed on soil.

REFERENCES

Benetto E., Nguyen D., Lohmann B. and Schosseler P. (2009). Life cycle assessment of ecological sanitation system for small-scale wastewater treatment. *Science of the Total Environment, 407(2009), 1506-1516.*

Hospido A., Moreira M.T., Fernández-Couto M. and Feijoo G. (2004). Environmental Performance of a Municipal Wastewater Treatment Plant. *International Journal LCA, 9(4), 261-271.*

Rodriguez-Garcia G., Molinos-Senante M., Hospido A., Hernández Sancho F., Moreira M.T. and Feijoo G. (2011). Environmental and economic profile of six typologies of wastewater treatment plants. *Water Research 45(2011), 5997-6010.*

United States Environmental Protection Agency. (1999). *Control of Pathogens and Vector Attraction in Sewage Sludge*. Washington DC.

United States Environmental Protection Agency. (1999). *Sewage Sludge Regulations 40 CFR Rule 503*. Washington DC.

World Bank. (2010). *World Development indica*tors 2010, http://data.worldbank.org/sites/default/files/wdi-final.pdf (accessed 10 July 2011).

World Health Organization. (2013). Progres son Sanitation and drinking water 2013 update. www. wssinfo.org (accessed 10 may 2013)

FRESHWATER ASSESSMENT IN LCA: A CASE STUDY OF SPECIFIC AUTOMOTIVE COMPONENT

Moreno Pastor, Miriam [1,2], Hinrichsen, Olaf [2], Wagner, Volkmar [1], Traverso, Marzia [1], Kluge, Juliane [1], Brattig, Stefan [1]. 1: BMW Group, Germany; 2: Lehrstuhl I für Technische Chemie, Technische Universität München, Germany.*Knorrstr. 147, 80788 Munich, Germany, Miriam.MP.Moreno-Pastor@bmw.*

Keywords: water consumption, life cycle assessment, supply chain, water scarcity.

ABSTRACT

An assessment of consumptive water use was implemented for a compact vehicle supporting tube composed of aluminium from three different sources: primary, secondary and aluminium produced from renewable energy. The aim of the study was to show the possible potentials and limits for a future water assessment of a whole vehicle. Primary manufacturing data, as well as published studies modeled in the software GaBi 4.4 were employed to draw up the life cycle inventory. Characterization factors based on local scarcity were applied, in order to obtain midpoint indicators. The results show the supporting tube composed of primary materials as the most water intensive alternative. A further practical approach for a comprehensive assessment of freshwater in automotive industry is under development.

INTRODUCTION

Water is one of the most fundamental conditions for survival, therefore, safe and clean drinking water and sanitation is recognized as human right for securing an adequate standard for living (UN, 2010). Identifying, measuring and addressing impacts arising from water use in BMW Group operations are anchored in the Group strategy. The Life Cycle Assessment (LCA) can provide transparency on the consumption of resources, emissions and potential environmental impacts of a product (ISO 14040, 2006) along its life cycle, from the design stage of product itself. Several methods to quantify and assess freshwater use of products throughout their life cycle have been developed (Kounina et al., 2013). Experts from the LCA scientific community are collaborating in a water working group of the UNEP-SETAC (WULCA, 2013) and an ISO standard for Water Footprint is under development. The developed methods should be implemented for industrial products in order to prove their applicability. Berger and colleagues published in 2012 (Berger et al., 2012) a study assessing the water consumption of three whole vehicles under different methods. Concurrently, in 2011, BMW Group completed a study with the aim to understand the impacts of its products related to water scarcity. This work is described in this short paper; it was focused on the assessment of freshwater consumption of a selected automotive component with different material alternatives. The supply chain of the three scenarios where analyzed in detail, in order to identify the site of every process step and the corresponding variability of the water scarcity at a local level. It allowed a quantitative comparison between material and processes in terms of their potentials to contribute to water scarcity. Limitations in the implementation of the assessment for the automotive products were identified.

MATERIALS AND METHODS

The supporting of the instrument panel of a BMW Group compact vehicle was chosen as the functional unit for this assessment in order to complete the conventional LCA impact categories. The study compared the results of freshwater consumption of the component composed of aluminium from three different sources: primary, secondary and aluminium produced from renewable energy. The component was assessed from the raw material extraction up to its manufacturing (cradle to gate). The water consumption of the product in the use phase and at end-of-life was neglected due to the low impact of less that 1%.

For the evaluation of water use in the raw material extraction stage of the product life cycle, the contacting of the specific suppliers involved globally was a challenge. Therefore, information from the European Aluminium Association served as input (EAA, 2008) and various sources were consulted in order to perform a sensitivity analysis of the obtained data (Hutter, 1999). For the assessment of the semi-finished production and component manufacture phases, no average data was available. Therefore, a detailed inventory with primary data sourced from the BMW Group manufacturing processes for the year 2011 was compiled. . These processes were subsequently modelled with the software Gabi 4 (PE International AG, 2011).

As practitioners of the Water Footprint methodology (Hoekstra et al., 2011) and LCA experts (Bayart et al., 2010) pointed out, the analysed volume of water consumed refers to the fraction of water use in the process that is not returned to the same river basin from which it was withdrawn due to evaporation, product integration, or discharge into other watersheds or to the sea. To obtain the midpoint indicator water deprivation, the water stress index (WSI) developed by Pfister and colleagues (Pfister, Koehler and Hellweg, 2009) was applied to each producer identified for each process step. The site of every life cycle of the component was defined as precisely as possible, based on international production data. Initially, information on weighted import countries was obtained from the international associations (EAA, 2011 and IAA, 2011). Subsequently, the producers' site for the different process steps was identified with Google Maps and the respective WSI layer developed with Google Earth (Google, 2011).

RESULTS

The results are shown in Fig.1 for the three material scenarios: scenario I for the primary aluminium alternative, scenario II for secondary aluminium and scenario III and aluminium from renewable energy sources. The diagram allows the differentiation of direct process freshwater and indirect freshwater consumed at the inventory level. The indirect freshwater consumption covers the background processes: water consumed by the production of energy and auxiliary processes. The impact assessment results at the midpoint level are represented as freshwater deprivation in litre freshwater equivalent (depicted black lines) and as volumetric water consumption in litre freshwater (depicted in bars). The scenarios considering the supporting tube composed of primary material show that the raw material extraction and preparation as well as the semi-finished production phases were the most water intensive life cycle stages in the life cycle. For all scenarios the biggest impact on water resources takes place during raw material extraction and preparation as well as the semi-finished production life cycle phases.

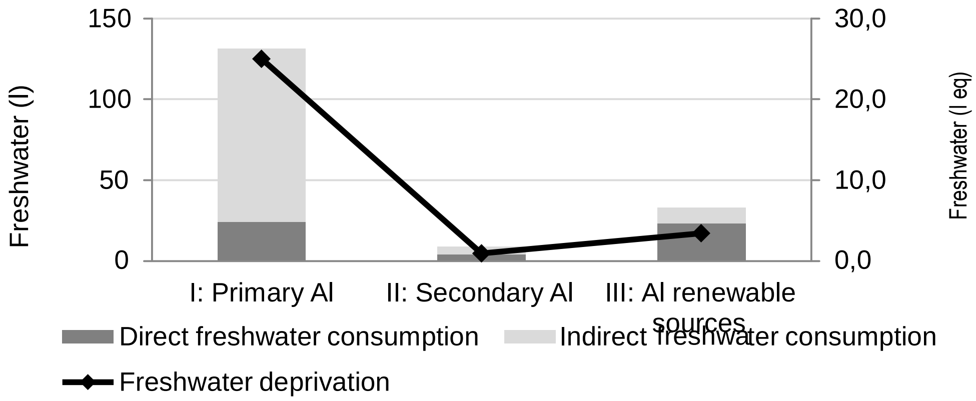


Fig. 1: direct and indirect water consumed (l) and water deprivation (l eq) for the supporting tube of the different scenarios.

DISCUSSION AND CONCLUSIONS

This study demonstrates that water use assessment can be applied for an automotive industrial product. A supporting tube of a compact vehicle was assessed. The results show that the main water intensive steps are non-renewable energy intensive processes and clearly demonstrate the correlation between water and energy consumption. Limitations such as data availability were identified representing a challenge for such a complex and globally manufactured product such as an entire vehicle. For a comprehensive assessment of an entire vehicle analysis of further materials and processes with respect to their consumptive water use is initially necessary. Therefore, the BMW Group is currently working on a more comprehensive approach covering environmental and socioeconomic aspects related to water use impacts. The concept comprises the environmental assessment of water consumption and degradation use according to Boulay et al. (Boulay et al., 2011) however, specifically developed for the automotive industry. For the comprehensive approach, various components of a conventional vehicle are selected in order to enable a future consistent assessment for the whole vehicle. The local conditions, on which the environmental, economic and social impacts of freshwater use strongly depend, are considered. In order to identify this impact currently an assessment is performed of components by varying the site of production. BMW Group plants located in Germany, South Africa and China with different freshwater stresses, freshwater qualities and supply chains are taken herby into account. Furthermore, different economic and social conditions at local and technology level will be considered.

REFERENCES

Bayart, J.-B., Bulle, C., Deschênes, L., Margni, M., Pfister, S., Vince, F., Koehler, A. (2010). A framework for assessing off-stream freshwater use in LCA. *The International Journal of Life Cycle Assessment*, *15*(5), 439–453. doi:10.1007/s11367-010-0172-7

Berger, M., Warsen, J., Krinke, S., Bach, V., Finkbeiner, M. (2012). Water Footprint of European Cars: Potential Impacts of Water Consumption along Automobile Life Cycles. *Environmental Science and Technology*, 4091–4099. Retrieved from http://pubs.acs.org/doi/ipdf/10.1021/es2040043

Boulay, A.M., Bulle, C., Bayart, J.B., Deschênes, L., Margni, M. (2011). Regional characterization of freshwater use in LCA. *Environmental Science and Technology*, *45*(20), 8948-8957. doi: 10.1021/es1030883.

European Aluminium Association (EAA). (2008). *Environmental Profile Report for the European Aluminium Industry. April 2008.: Life Cycle Inventory data for aluminium production and transformation processes in Europe.* Retrieved from http://www.alueurope.eu/wp-content/uploads/2011/08/EAA_Environmental-_profile_report-May081.pdf

Google. Google Maps and Google Earth (2011). http://maps.google.com/ and http://earth.google.com/.

The water footprint assessment manual: Setting the global standard. London, Washington, DC: Earthscan.

Hutter, C. (1999). *Ganzheitliche Bilanzierung von Grundstoffen und Halbzeugen*. München. Retrieved from http://www.ffe.de/download/langberichte/FfE_GaBiE_Bilanzierung_Halbzeugen_Grundstoffen.pdf

ISO (2006) ISO 14040: Environmental managements - life cycle assessments - principles and framework. International Organization for Standardization: Geneva.

International Aluminium Institute (2011). http://www.world-aluminium.org/

Kounina, A., Margni, M., Bayart, J.-B., Boulay, A.-M., Berger, M., Bulle, C., Frischknecht, R., Koehler, A., Milá i Canals, Ll., Motoshita, M., Núñez, M., Peters, G., Pfister, S., Ridoutt, B., van Zelm, R., Verones, Humbert, S.(2013). Review of methods addressing freshwater use in life cycle inventory and impact assessment. *The International Journal of Life Cycle Assessment*, *18*(3), 707–721. doi:10.1007/s11367-012-0519-3

PE International AG. (2011). GaBi 4: Software und Datenbank zur Ganzheitlichen Bilanzierung.

Assessing the Environmental Impacts of Freshwater Consumption in LCA. *Environmental Science & Technology*, *43*(11), 4098–4104. doi:10.1021/es802423e

UN, Office of the High Commissioner for Human Rights. (2010). *Fact Sheet No. 35, The Right to Water.* Retrieved from http://www.unhcr.org/refworld/docid/4ca45fed2.html

WULCA (2013) Assessment of use and depletion of water resources within the LCA Framework. UNEP/SETAC Life Cycle Initiative. http://www.wulca-waterlca.org/#P1

GWP BENEFITS FROM PAPER AND BOARD RECYCLING WITH CONSEQUENTIAL LIFE CYCLE ASSESSMENT: SPANISH CASE STUDY CONSIDERING THE INTERACTION WITH GLOBAL MARKETS

Eva Sevigne[a], Carles M. Gasol[a, b], Joan Rieradevall[a ,c] and Xavier Gabarrell[a, c] [a]Sostenipra (ICTA-IRTA-Inèdit). Institute of Environmental Science and Technology (ICTA). Universitat Autònoma de Barcelona (UAB). Campus de la UAB s/n, 08193, Bellaterra (Barcelona), Spain - *Corresponding author: eva.sevigne@uab.cat*

[b]Inèdit Innovació, Carretera de Cabrils, km 2 -IRTA-, 08348 Cabrils, Barcelona, Spain

[c]Department of Chemical Engineering, School of Engineering, University of Santiago de Compostela, 15782- Santiago de Compostela, Spain

Keywords: kraft pulp, environmental impact, local market, global market

ABSTRACT

There is a lack of data of greenhouse gases emissions (GHG) of paper recycling for Spain but they are necessary in order to guide waste management policies. The aim of this work is to calculate the environmental consequences of paper recycling in Spain. We have applied a consequential life cycle assessment (cLCA). Different scenarios were evaluated and results vary per ton of paper collected from -3 kg to -579 kg CO_2 eq., depending on the economic competitiveness of the virgin pulp producer, or if the avoided wood is used to produce bioenergy. These results show that the benefits of recycling could depend on market conditions, as markets are highly interrelated and results of one country could affect other markets.

INTRODUCTION

Different GHG savings in CO_2 eq. have been reported for paper-cardboard in the literature but none of them were calculated for Spain. In addition, several assumptions has been done but in most cases there is not provided detailed information. Recycling is methodologically a case of multifunctionality, with the product to be recycled having two functions: firstly the function the product is primarily made for and secondly the function of providing secondary resources for use in subsequent life cycles/systems (ILCD, 2011). The correct way how to model recycling has been extensively discussed over the past two decades and many approaches have been suggested. It can also be observed that most of the discussions on how to model recycling are in fact discussions on whether to use attributional life cycle assessment (aLCA) or consequential life cycle assessment (cLCA) in the first place (McMillan, 2011). A consequential approach considers that by undertaking recycling other alternative activities are not undertaken as a consequence. In other words, the cLCA is more akin to marginal economic assessment, as it looks at the consequences, in production terms and environmental emissions, of increasing or decreasing demand for specific goods and services (Weidema, 2009). Thus, by applying a cLCA, the environmental consequences of recycling can be evaluated by analyzing market mechanism and market trends. Therefore, the aim of this study is to calculate the environmental consequences of recycling in Spain through a cLCA.

MATERIALS AND/OR METHODS

One characteristic of cLCA is that marginal technologies (those able to adjust the production capacity to new demand) are used instead of considering average technologies where constrained technologies are included. In this sense, the marginal supply of wood pulp was identified as Bleached Hardwood Kraft Pulp (BHKP) from *Eucalyptus* in Brazil or Indonesia (Reinhard et al., 2010) based on the idea that the market pulp can be considered increasing on a global scale what means that for long-term changes the most sensitive supplier is identical to the most competitive (Weidema, 2009). However, other author have pointed out that if more recovered paper is available for recycling, the avoided virgin pulp production will be the least competitive which in this case, the identified marginal supply is the Spanish BHKP from *Eucalyptus* (James, 2012). Based on this information and taken as reference Spanish data from 2011 we have considered four scenarios summarizes in Table 1 considering that the consequences of recycling are that virgin pulp production is avoided (Scenario A and B); and in addition, the avoided wood could be used for production of energy to substitute for fossil fuels in a second system expansion (scenario C and D). Besides, due to market conditions industry has changed in recent years and important quantities of waste paper are sending from Spain to China. We have quantified these impacts in all scenarios. The functional unit (FU) has been defined as the increase 1 ton of waste paper collected in Spain for recycling.

Table 1: Scenarios projected for the calculation of the recycling impacts of paper in Spain

	Avoided virgin pulp production	**Avoided energy production**
Scenario A	*Eucalyptus* BHKP Brazil	NO
Scenario B	*Eucalyptus* BHKP Spain	NO
Scenario C	*Eucalyptus* BHKP Brazil	YES
Scenario D	*Eucalyptus* BHKP Spain	YES

RESULTS

Figure 1 presents the results for scenario A and from scenario B when the system expansion to include the avoid energy production is not included and projecting same quantity waste paper collection as in 2011. GHG emissions per ton of paper collected for scenario A are -131 kg of CO_2 eq. while when the avoided virgin pulp is the BHKP from Spanish *Eucalyptus*, the GHG are -3 kg of CO_2 eq. per ton of paper collected (scenario B).

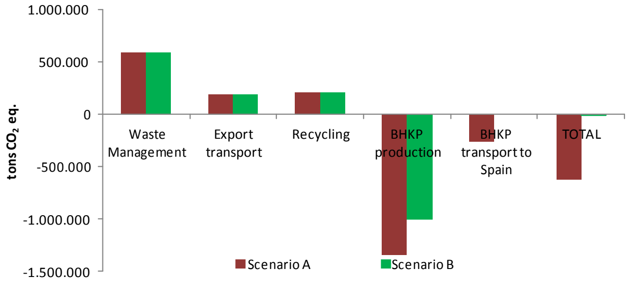


Figure 1: Total GHG emissions for scenario A and scenario B for Spain

As shown in Figure 1, the environmental benefits of recycling are considerably higher when the assumption of virgin pulp from Brazil is considered. In this case, total GHG emissions avoided to Spain would be around 618,000 tons of CO_2 eq. of which 60% of emissions correspond to waste management stage while 84% of the avoided emissions would be due to the production of virgin pulp. In Scenario A when we have considered that virgin pulp is produced in Spain, global GHG emissions avoided would be around 13,000 tons of CO_2 eq. In both scenarios the emissions due to waste management, recycling and transportation of waste to China are the same as we have used same data. The following Figure 2 presents the results for scenario C and scenario D. As collection, export transport, recycling and sorting are equal as in scenario A and scenario B, these stages are summarizes as waste management & recycling. In these scenarios the GHG emissions avoided are per ton of paper collected -579 kg CO_2 eq. and -383 kg CO_2 eq. for scenario C and scenario D, respectively. Avoided emissions are higher than in the previous scenarios and when we expanded the system to include energy production, the total difference between the two scenarios decreases. However, when considering that the virgin pulp production in Brazil is avoided; more emissions are avoided because the production in that country has higher energy consumption. In addition, international transport from Brazil is also avoided.

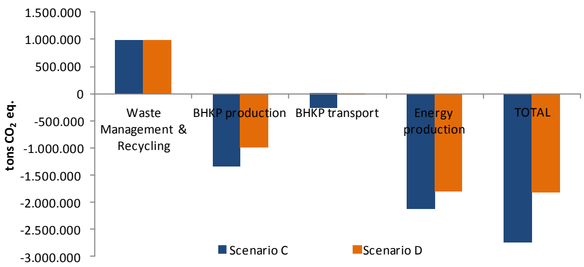


Figure 2: Total GHG emissions for scenario C and scenario D for Spain

DISCUSSION

The results show that the market perspective is very important and can affect the results obtained. In this sense, there is no study in Spain which analyzes the environmental impacts of recycling paper from a consequential perspective. In other international sources, we can found very different results ranging from -3,100 kg of CO_2 eq. per ton in the U.S. (US EPA, 2006) to -0.3 kg of CO_2 eq. per ton when the study is developed by the Bureau International

Research (BIR, 2008). In addition to the methodological assumptions existing between these methodologies, the differences due to different management systems and data by country indicate that it is necessary to calculate these impacts by countries and that the use of these data in countries with different waste management profiles can lead to erroneous results. On the other hand, to the knowledge of the authors, in no case the origin of virgin pulp or the destination of the export flows due to market conditions were evaluated. In this sense, the cLCA allows the inclusion of the influence of markets by establishing that the consequences resulting will affect one production system or another depending on for instance, their economic competitiveness.

CONCLUSION

The results show that the benefits of recycling could vary between years and countries, and could depend on market conditions, as markets are highly interrelated and that the results of one country could affect other markets. All this shows that in general, we need more information and research on the influence of international markets on recycling processes. In this sense, the market based approach methodology (Ekvall, 2000) which considers that the consequences of recycling can be evaluated depending on the price elasticity of supply and demand of recovered material, could be evaluated in future research. Besides, in the case of paper recycling in Spain, we still needs to improve our inventory in order to have quality data to calculate the environmental impacts of recycling related to international markets and to use these results to conduct our waste management policies.

REFERENCES

BIR (2008). Report on the environmental benefits of recycling, Bureau of International Recycling (BIR). Brussels, www.bir.org/assets/Documents/publications/brochures/BIR_CO2_report.pdf.

Ekvall, .T (2000). A market based approach to allocation of open-loop recycling. *Resource Conservation and Recycling*, 29, 91-109.

International Reference Life Cycle Data System (ILCD) Handbook - *General guide for Life Cycle Assessment - Detailed guidance*. European Commission - Joint Research Centre - Institute for Environment and Sustainability: First edition March 2010. EUR 24708 EN. Luxembourg. Publications Office of the European Union; 2010.

James, K. (2012). An investigation of the relationship between recycling paper and card and greenhouse gases emissions from land use change. *Resource Conservation and Recycling*. 67, 44-55, DOI: 10.1016/j.resconrec.2012.07.003

McMillan, A.C. (2011). Modeling Temporal Aluminum Material Flows and Greenhouse Gas Emissions to Evaluate Metals Recycling Allocation in Life Cycle Assessment. Michigan. Center for Sustainable Systems, University of Michigan. Report No. CSS11-05.

Reinhard, J., Weidema, B.P., Schmidt, J.H. (2010). Identifying the marginal supply of pulp wood. 2.-0 LCA consultants, Aalborg, Denmark.

US EPA (2006). Solid Waste Management and Greenhouse Gases. A Life Cycle Assessment of Emissions and Sinks; U.S. Environmental Protection Agency (US EPA).

Weidema, B,P., Ekvall, T., Heijungs, R. (2009). Guidelines for applications of deepened and broadened LCA. (Deliverable D18 of work package 5 of the CALCAS project).

HEDGING THE BET: INTRODUCING BIOCROPS IN THE LUXEMBOURGISH AGRICULTURAL SYSTEM

Ian Vázquez-Rowe, Antonino Marvuglia, Sameer Rege, Enrico Benetto*
Public Research Centre Henri Tudor (CRPHT) / Resource Centre for Environmental Technologies (CRTE) - 6A, avenue des Hauts-Fourneaux, L-4362, Esch-sur-Alzette, Luxembourg.

** Corresponding author: ian.vazquez@tudor.lu*

Keywords: biocrops; consequential LCA; Luxembourg; maize.

ABSTRACT

In the context of fulfilling EU targets for bioenergy use by 2020, the use of Consequential Life Cycle Assessment has shown to be a suitable method to monitor the environmental performance of future energy scenarios and strategies. Hence, the aim of this study was to analysis the environmental consequences linked to an increase in maize production for bioenergy purposes, for the specific case of Luxembourg. Different land use change scenarios were modeled through the use of an auxiliary partial equilibrium model based on farmers' revenue maximization. Results showed minor, but increasing shifts in environmental impacts related to an additional production of 80,000 t of maize, and the environmental profile of the final biomethane product is higher than that of conventional natural gas.

INTRODUCTION

Luxembourg should comply with the EU 2020 targets to reduce GHG emissions by increasing its share of total energy production arriving from renewable sources to 20% by 2020, including 11% of biofuels in final energy consumption (EC, 2007). Due to the domestic limitations of using other energy sources, the use of biomass for biogas generation in power plants is a key strategy promoted by authorities to meet the targets. However, the use of agricultural crops for producing energy has shown to cause important impacts in other environmental issues (e.g. toxicity). Moreover, recent studies have demonstrated the minimal GHG emissions reductions that some biocrops generate due to land use changes–LUCs (Searchinger et al. 2008). Thanks to its comprehensiveness, the use of Life Cycle Assessment (LCA) appears as an appropriate method to evaluate the actual environmental suitability of biofuel production and policies. However, it should be noted that since an attributional-LCA (A-LCA) perspective does not consider the indirect consequences linked to increased biocrops cultivation, a consequential-LCA approach (C-LCA) may be more suitable to understand how physical flows and the derived environmental impacts vary in response to the changes, including potential changes associated with the expansion, displacement or intensification of crops (Kløverpris et al., 2008). The main aim of this study is to evaluate the environmental consequences of increasing maize production for biomethane in Luxembourg in the 2009-2020 timeframe using C-LCA, by modeling a series of scenarios based on a partial equilibrium model (PEM) to determine the LUCs.

METHODS

An additional 80,000 tonnes of maize production for energy generation were modeled, considering that the target of 144 GWh of energy produced from biogas in Luxembourg would be arriving from maize crops exclusively. The LUCs expected in the Luxembourgish agricultural system were modeled by using the PEM that was created for the study. The structure of the model was based on the maximization of revenues by farmers, by maximizing the sum of all opportunity values which are subject to restrictions of the maximum possible replacement allowed for each crop. Therefore, opportunity values were calculated individually for each crop considering different operational inputs, such as subsidies, fertilizers, variable and fixed costs, as well as the yield or market prices. Thereafter, the model was computed using GAMS (Rosenthal, 2011). Nevertheless, it should be noted that two different perspectives were assumed when developing the model. The first perspective only included the costs and revenues related to the crops themselves, while the second one accounted also for livestock activities in order to consider also the opportunities of reducing costs related to fodder and feed products. Three main approaches were followed to calculate the environmental consequences associated with LUCs. The first one, *Approach A*, monitored the crop rotation patterns from a revenue maximization perspective without the inclusion of the shock (i.e. 80,000 tonnes), to understand the natural evolution of the agricultural system in the period 2009-2020 without any policy or strategy implementation regarding biogas. *Approach B* considers the entire shock of increase maize production in a farmer's perspective to maximize the revenues while integrating the bioenergy strategy in the system. Finally, *Approach C* enlarges the scope by adding a full policy oriented perspective, to analyze not only the consequences on the agricultural system in Luxembourg, but also the import/export flows and the final energy consequences.

Functional unit and system boundaries

The functional unit (FU) considered for each approach was based on their specific function. In *Approach A* the FU was the entire Luxembourgish agricultural system, while in *Approach B* the FU was the shock of 80,000 tonnes on the agricultural system. Finally, in *Approach C*, where the main function is to provide environmentally robust results to support policy-makers, the FU was fixed at 1 MJ of biogas injected in the grid from the described shock. Therefore it shall be noted that the three approaches are not directly comparable. Unlike in an A-LCA approach, the system boundaries in C-LCA are flexible, due to the need to enlarge the boundaries based on the consequences that may be generated by the shock that is exerted on the main production system. In fact, in Approaches *A* and *B* the system boundaries were limited to the Luxembourgish agricultural system, in *Approach C* these boundaries were amplified to include the entire production chain of biomethane production, as well as the environmental consequences occurring outside Luxembourg's national borders due to changes in the agricultural system. Finally, while livestock was included to compute the LUCs, they were not included in the LCA under the assumption that it will not change significantly between 2009 and 2020 (any change would be, however, rather unpredictable).

Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA) methods

The LCI varied slightly between approaches to meet the data requirements of the different functions. Background processes were based on the ecoinvent® database, while primary data were retrieved based on national and EU databases. Biomethane production from maize was modeled on Jury et al. (2010). For the assessment method, ReCiPe endpoint was used to compute the results (Goedkoop et al., 2009).

RESULTS

The LUCs, which are reflected in more detail in Vázquez-Rowe et al. (2013a; 2013b), varied substantially between scenarios, mainly associated with the inclusion or exclusion of livestock activities in the PEM. As shown in Fig. 1, the natural flow of the agricultural system in Luxembourg is expected to present considerable shifts in environmental impacts depending on the assumptions, especially in terms of land use and climate change.

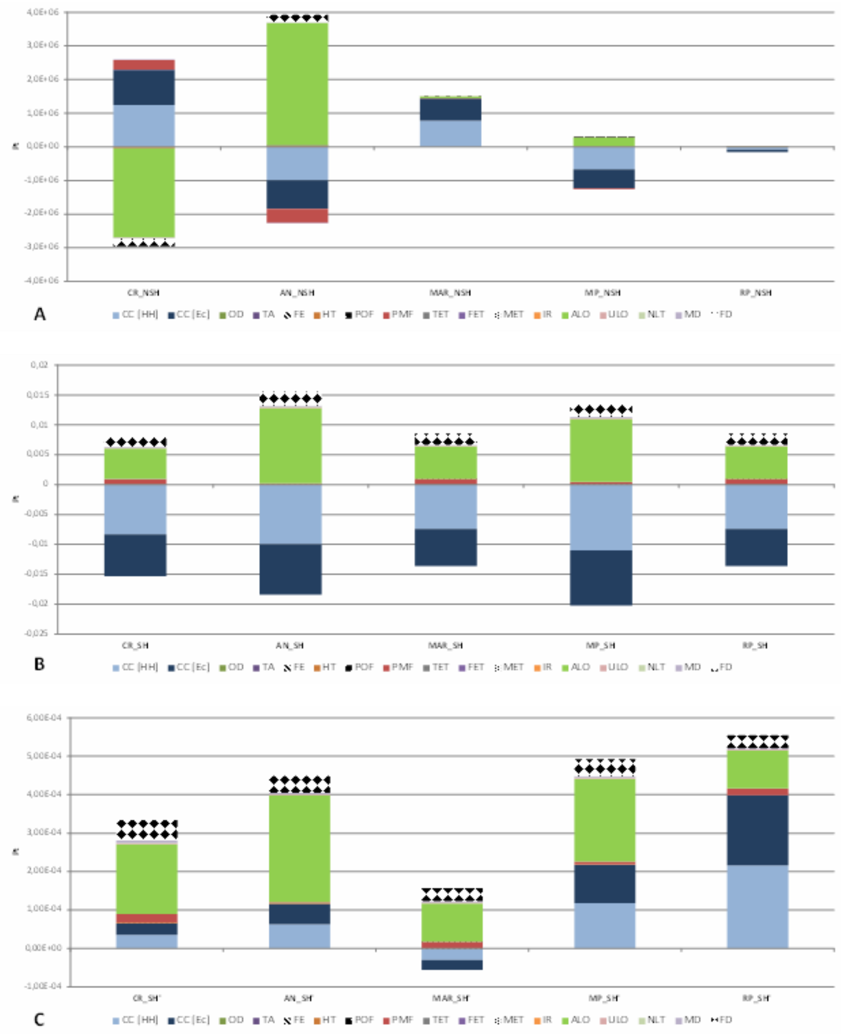


Figure 1. Single score endpoint values for each scenario in all three approaches[1]

[1] NSH= no shock applied in the PEM; SH= shock of 80,000 t applied in the PEM; SH'= shock of 80,000 tonnes applied to the model plus new import/export flows; CR= scenario 1 – exclusion of livestock in PEM; AN= scenario 2 – inclusion of livestock in PEM; MAR= scenario 3 – decrease in the minimum feed requirement for livestock; MP= scenario 4 – inclusion of meadows and pastures in the PEM; RP= scenario 5 – higher LUC rate allowed for rapeseed.

In *Approach B*, however, small environmental improvements were identified as compared to the baseline scenario in the different scenarios, ranging from 2% to 8%. These improvements are associated with sharp reductions in climate change impacts due to higher carbon sequestration in fields, which manage to compensate the strong increase in land use and fossil depletion impacts. Finally, in *Approach C* the environmental benefits shown in the previous approach are neutralized due to the inclusion of a higher detail of consequences, which is linked to higher environmental impacts in the post-agricultural stages of biogas production, making the overall environmental impacts of biomethane production up to 20-25% higher than those of using natural gas.

DISCUSSION AND CONCLUSIONS

The results shown in this case study show the effects that increased bioenergy production in Luxembourg may have on the agricultural sector. Direct variations in LUCs demonstrate a clear reduction of the availability of arable land for the production of food and feed due to crop displacement and, therefore, a subsequent outsourcing of uses of land to produce feed outside Luxembourgish borders. However, domestic LUCs did not trigger significant changes in the environmental impacts. In fact, domestic impacts are slightly more favorable when the shock is considered due to the higher aerial sequestration of carbon in maize cultivations. However, the results presented for *Approach C* show an increase of environmental impacts as compared to the baseline scenario in 2009 due to the new import/export flows of food and fodder products. Therefore, the use of maize-based biofuels has shown to increase GHG emissions and other environmental impacts (e.g. land occupation or fossil depletion). However, these increases are considerably lower than those occurring in other areas of the planet (e.g. Brazil) due to the current status quo regarding arable land extension in many European countries, which tends to remain stable. Therefore, in terms of policy support, the results suggest minor environmental benefits of implementing biocrops production strategies. Finally, the PEM demonstrated to provide an accurate analysis on the Luxembourgish agricultural LUCs through the collection of economic data that allowed forecasting future equilibriums between supply and demand.

REFERENCES

EC. (2007). European Commission. The impact of a minimum 10% obligation for biofuel us ein the EU-27 in 2020 on agricultural markets. Economic analysis of EU agriculture. Brussels, April 30th 2007.

Jury C, Benetto E, Koster D, Schmitt B, Welfring J. (2010). Life Cycle Assessment of biogas production by monofermentation of energy crops and injection into the natural gas grid. *Biomass Bioenerg 34, 54-66.*

Kløverpris J, Wenzel H, Nielsen PH. (2008). Life cycle inventory modeling of land induced by crop consumption. Part 1: Conceptual analysis and methodological proposal. *Int J Life Cycle Assess, 13, 13-22.*

Rosenthal RE. (2011). GAMS – A user guide. GAMS Development Corporation. Washington DC.

Searchinger T, Heimlich R, Houghton RA, et al. (2008). Use of US croplands for biofuels increases greenhouse gases through emissions from land-use change. *Science, 319, 1238-1240.*

Vázquez-Rowe I, Rege S, Marvuglia A, et al. (2013a). Application of three independent consequential LCA approaches to the agricultural sector in Luxembourg. *Int J Life Cycle Assess,* doi= 10.1007/s11367-013-0604-2.

Vázquez-Rowe I, Marvuglia A, Rege S, Benetto E. (2013b). Applying C-LCA to support energy policy in Luxembourg: land use change effects of bioenergy production. *Energy Environ Sci, submitted.*

INFLUENCE OF REMANUFACTURING ON LIFE CYCLE STEPS: AIR COMPRESSOR STUDY CASE IN BRAZIL

Guilherme M. Zanghelini1; Edivan Cherubini; Sebastião R. Soares. CICLOG – Life Cycle Assessment Research Group, Universidade Federal de Santa Catarina. *Professor José Brasilício de Souza Street, nº99,Zip Code 88036530, Trindade - Florianópolis, Santa Catarina – Brazil. zanghelini@ens.ufsc.br*

Keywords: End-of-Life; Remanufacturing; Life Cycle Assessment; Air compressor.

ABSTRACT

Remanufacturing is a key scenario in end-of-life (EOL) management. From Life Cycle Assessment's (LCA) point of view, means more elementary processes after the product's use phase. However, this choice affects the early steps of its life cycle, usually by decreasing demand on acquisition of raw-materials, lower need of manufacturing processes, and an adition of life time. This paper aimed to discuss the influences of the Remanufacturing Scenario on early steps of its life cycle. The methodology used was the LCA based on LCA standards. We used as study case an air compressor and compared the Remanufacturing Scenario with a Reference Scenario where the final disposal was set the equipment to a landfill. The Life Cycle Impact Assessment was performed with the software SimaPro®7.3 and CML2000 method for Abiotic Depletion and Global Warming, and Total Acumulative Energy Demand (single issue). The case study showed that the Remanufacturing as EOL Scenario is able to decrease until 47% of the impacts compared to the Reference Scenario. However, this improvement can not always represents a better environmental performance when considered a numerical balance of the impacts inside each phase.

INTRODUCTION

Remanufacturing is a key scenario in end-of-life (EOL) management of products, besides its economic benefits is a feasible option to achieve many of the goals of sustainable development. For some authors as Kerr and Ryan (2001), Guide Jr et al. (2000) and Amezquita et al. (1995) this final disposal's strategy is able to minimize the environmental impact of industry by reusing materials and consequently decreasing natural resources consumption, reducing energy use and the need to landfilling industrial products.

There are many definitions for remanufacturing, but most are variations of the same basic idea of product rebuilding. It can be understood as a process of 'restoring a product to like-new condition by reusing, reconditioning, and replacing parts'. Nowadays there are more companies that are implementing remanufacturing strategies in order to retain the accumulated value of products and components or comply with the recent laws of integrated responsability of EOL products, as in European Union Directive 2002/96/EC on Waste

Electric and Electronic Equipment (WEEE) and the National Policy on Solid Waste in Brazil (2010). These laws describe waste reduction in the font as first measure to ensure the sustainability, positioning the remanufacturing as preferable final destination.

From Life Cycle Assessment's (LCA) point of view, this EOL scenario means more elementary processes after the product's use phase including more inputs and outputs and new components consumption by replacement. That consequently generates more environmental impacts. Usually it is necessary some basic processes as disassembly, testing, remanufacturing (or repair) and reassembly. The logistic is also more complex, because involves the reverse flux of the EOL product to the manufacturer and then a return to the market for second use. However, this choice for waste management affects the early steps of its life cycle, usually by decreasing demand on acquisition of raw-materials (by the reuse of parts), lower need of manufacturing processes, and an adition of life time of the product that usually reflects on a positive environment impact balance.

This paper aimed to discuss the influences of the Remanufacturing Scenario on early steps of its life cycle related to the generation of environmental impacts, analysing positive and negative aspects on the major four phases in a life cycle.

MATERIALS AND/OR METHODS

The methodology used was the Life Cycle Assessment (LCA) based on the standards ABNT ISO 14040 (2009a) and 14044 (2009b) using as study case an air compressor. In order to better understand these influences we compared the Remanufacturing Scenario with a Reference Scenario composed of a life cycle without returning of the equipment to the consumer, where the final disposal was set to a landfill.

The functional unit was established by the total amount of compressed air produced during the primary operation phase, 1;180;000.00 m³ at 7.5 BAR of pressure operating for 10 years. This means a reference flux of 0.66 compressors to Remanufacturing Scenario since this final disposal scenario adds 5 years of life to the equipment and 1.00 compressor to Reference Scenario. The Use phase is therefore equalysed by the reference flux and wasn't accounted on environmental impact assessment.

The Product's system was a reciprocating air compressor with electrical operation manufactured by a major metal-mechanic industry located on southern of Brazil. Once the main goal of this paper was to understand the influences of the remanufacturing on life cycle, the boundaries were positioned envolving all four major life cycle's steps, from acquisition of raw materials to final disposal, with system expansion to avoid allocation when there were co-products of processes (i.e. metal scraps). As we opted for system expansion, we had positive environmental impacts associated with the avoided products.

Both, Reference and Remanufacturing Scenario starts with the acquisition of raw materials from natural resources and primary manufacturing of the components that are sent to the manufacturing line where there are manufacturing processes to built and to assemble this parts to the final product. Then the equipment is sent to the consumers where operates during ten years. Until this point, the inputs and outputs are identical but have different values because of the reference flux. After the use phase, the Reference Scenario disposes the obsolete compressor in the landfill involving reverse logistic to the landfill. Meanwhile the

Remanufacturing Scenario has the reverse logistic to the company for entering in remanufacturing processes, that were proposed in order to guarantee a second life to the equipment, increasing in five years the original use lifetime. During remanufacturing processes, waste is generated, headed by the non-reusable components of the compressor. The destination was set to the industry foundry, recycling centers and landfilling. After its disassembly, it was assumed that the recyclable parts would be sent to the company's foundry and recyclers sites, to landfilling for non-recyclibe fractions and electrical motor's devolution for its own manufacturer.

For build the inventory, primary data were collected from the company to all life cycle of the compressor, with secondary complementation by Ecoinvent Database®. The early steps of its life cycle were raised from production control, while the use phase from Testing Sector. Negative impacts related to components consumption on remanufacturing processes were considered on 'Acquisition of Raw-Materials', as well as positive impacts associated to avoided products from recycled materials. Other impacts were accounted to 'Final Disposal' phase.

The Life Cycle Impact Assessment was performed with the software SimaPro® 7.3 using the CML 2000 method with adaptations, including Total Acumulative Energy Demand (single issue). Besides this adapted impact category, we analysed Abiotic Depletion and Global Warming.

RESULTS AND DISCUSSION

The case study showed that the Remanufacturing as EOL Scenario is able to decrease until 46% of the impacts for Abiotic Depletion, 47% for Global Warming and 39% in Total Energy Demand, compared to the Reference Scenario (see 'Total' column in Table 1).

However, this improvement can not always represents a better environmental performance when considered a numerical balance of the impacts inside each phase. It is the case of the final disposal phase where although remanufacturing generates less environmental impacts considering all life cycle, this Scenario ended up increasing them to this step by 76% to Abiotic Depletion, 70% for Global Warming and 72% in Energy Demand as shown in Table 1. This behavior occurred due the increase of complexity of processes, logistics, input consumptions and output generations that overpasses the environamental gain generated by the extention of the use life time, accounted by the dilution of impacts by the reference flux. On the other way, for the Manufacturing phase the reduction is exactly 33% for the three impact categories once the EOL Scenario as Remanufacturing reduces the need of manufacturing processes in the same temporal horixonte.

Analysing the Acquisition of raw-materials' phase, the Remanufacturing Scenario reached 69% of reduction for Abiotic Depletion, 75% for Global Warming and 57% of reduction on Energy Demand compared to Reference Scenario. Negative impacts are increased by the raw materials consumed by replaced components while the original consumption of raw materials reduces 33% by the reference flux. This sum would be more impactant than the Acquisition of raw material's phase from Reference Scenario if it hadn't been considered the avoided products from recycling metals. As we considered this conception, positive impacts were associated to this recycled fractions and then to this life cycle phase.

Abiotic Depletion (kg SO2 eq.)				Total
LCA Phases	Acquisition of Raw Materials	Manufacturing	Final Disposal	-
Reference Scenario	3,02	0,68	0,16	3,86
Remanufacturing Scenario	0,94	0,46	0,68	2,08
Global Warming GWP100 (kg CO2 eq.)				Total
LCA Phases	Acquisition of Raw Materials	Manufacturing	Final Disposal	-
Reference Scenario	309,89	81,34	26,29	417,52
Remanufacturing Scenario	78,21	54,23	87,23	219,67
Total Cumulative Energy Demand (MJ eq.)				Total
LCA Phases	Acquisition of Raw Materials	Manufacturing	Final Disposal	-
Reference Scenario	7103,67	1920,21	388,18	9412,06
Remanufacturing Scenario	3077,30	1280,14	1393,77	5751,21

Table 1. Environmental impacts of the air compressor divided by LCA phases for Remanufacturing and Reference Scenarios.

CONCLUSIONS

With the results obtained with this study we can better understand the dynamic of the environmental impacts generation when applied remanufacturing as an EOL scenario. According to this scope definition and the product system used as an example, only the Final Disposal step demonstrated an increase of impacts, other all steps shown only environmenral improvements, being able to reach arround 46% and 47% of reduction in Abiotic Depletion and Global Warming respectively and 39% of Energy Demand when encopassed all life cycle, reinforcing the remanufacturing as better EOL scenario to sustainable development. It is also clear that changes on last life cycle step can cause different reactions to the early phases, showing the vital importance of the inclusion of the early steps at the assessment. For instance, assessing only the final disposal phase, remanufacturing would be the worst environmental scenario according to the scope in this LCA and consequently could induce to a misleading choice.

REFERENCES

Associação Brasileira De Normas Técnicas (2009a). NBR ISO 14040: Avaliação do Ciclo de Vida: Princípios e Estrutura, 21. Rio de Janeiro.

Associação Brasileira De Normas Técnicas (2009b). NBR ISO 14044: Gestão Ambiental: Avaliação do Ciclo de Vida: Requisitos e Orientações, 46. Rio de Janeiro.

Amezquita, T., Hammond, R., Salazar, M., Bras, B., 1995. Characterizing the remanufacturability of engineering systems. In: Proceedings of the 1995 ASME Advances in Design Automation Conference. Boston, September 17–20.

BRASIL. PNRS - Lei nº 12.305, de 2 de agosto de 2010.

EUROPEAN UNION DIRECTIVE 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE); 2002.

Guide Jr., V.D.R., Jayaraman, V., Srivastava, R., Benton, W.C. (2000). Supply-Chain Management for Recoverable Manufacturing Systems. INTERFACES 30: 3 May–June (pp. 125–142).

Kerr, W,. Ryan, C., (2001). Eco-efficiency gains from remanufacturing: A case study of photocopier remanufacturing at Fuji Xerox Australia. Journal of Cleaner Production. Volume 9, Issue 1, February 2001, Pages 75–81

INNOVATIVE DESIGN OF PACKAGING IN THE FOOD SECTOR TO REACH HIGHER SUSTAINABILITY

Luca Zampori, Giovanni Dotelli. Dipartimento di Chimica, Materiali e Ingegneria Chimica "G.Natta", Politecnico di Milano – INSTM R.U. Politecnico di Milano*

**Piazza Leonardo da Vinci 32, 20133 Milano, Italy. giovanni.dotelli@polimi.it*

Keywords: LCA; packaging; food; poultry

ABSTRACT

The choice of a sustainable packaging alternative is a key issue for the improvement of the environmental performances of a product. The present study is focused on the life cycle assessment of two packaging alternatives of a poultry product; in particular a polystyrene-based tray and an aluminum bowl were considered. The aluminum bowl was carefully designed in order to allow its use during the cooking stage in oven and reducing of cooking time. The cooking stage resulted to be the most impacting one over the entire life cycle of the two alternatives considered (taking into account production, transports, cooking and end-of-life), so the specific design of the packaging bowl/tray can allow significant lowering of the overall impacts.

INTRODUCTION

Generally it is believed that a packaging with low impacts during its production and end-of-life (i.e. biopolymer and biodegradable polymers) is also the most sustainable one (Colwill et al., 2012). Packaging is usually seen as a container with no other function than just containing the product to be carried in it, so when this concept is applied to food packaging the choice of a packaging that best suites the requirements of fresh food is driven by issues such as cost, shelf life, safety, practicality and, in the last years, environmental sustainability (Meneses et al. 2012, Suwanmanee et al. 2012).

The aim of the present paper is to show that life cycle assessment (LCA) may be a useful tool in order to improve the environmental performances of a packaging system by the use of a material, such as aluminum, that allows for its direct use in the cooking stage, avoids the use of another container in oven and, if properly designed according to the food contained, it can allow for further savings during the cooking itself.

MATERIALS AND METHODS

In the present study life cycle assessment of two different packaging options was carried out. The perspective was "from cradle to grave", so both the use stage and end-of-life of the two options were considered.

Option 1: Aluminum bowl, 60 wt% primary and 40 wt% secondary aluminum. Weight: 23.5 g This option will be defined as AL-P in the manuscript.

Option 2: Polystyrene bowl. Weight 13.15 g. This option will be defined as PS-P in the manuscript.

All the other components of the two packaging options, such as polyethylene labels, PVC films and glue, that are similar for the two alternatives, were included in the LCA also considering their transports, packaging and production.

Use stage: the aluminum bowl was carefully designed in order to allow its use during the cooking stage in oven of the poultry product and reduce the cooking time (40 minutes instead of 50 minutes needed when using a conventional bowl) at 200 °C: cooking time reduction allowed electric energy savings equal to 0.21 kWh (1.38 kWh instead of 1.59 kWh). The only energy source considered is grid electricity, so the Italian energy mix was used and the consequent emissions accounted for when calculating the GHG (GreenHouse Gases) emissions. It was assumed that the Italian energy mix accounts for 0.605 kg CO_2-eq for each kWh (Ecoinvent, 2010)

End-of-life: this stage is dominated by recycling of trays materials. In this paper the approach suggested by (PAS 2050 : 2011), defined as “recycled content” was used. End-of-life was modeled taking into account Italian waste management and statistics for aluminum and plastic wastes.

Two different methods were used for Life Cycle Impact Assessment (LCIA):

- Greenhouse Gas Protocol (GGP): allows the calculation of the total GHG emissions for a product inventory are calculated as the sum of GHG emissions, in CO_2eq, of all foreground processes and significant background processes within the system boundary

- Recipe Endpoint H: it is a multicategory method whose results are calculated according to endpoint perspective.

RESULTS AND DISCUSSION

GGP results are reported in table 1

Tab 1 – GGP, excluding use phase and end-of-life

Category	Unit	AL-P	PS-P
Total	kg CO2 eq	0.343	0.131
Fossil CO2 eq	kg CO2 eq	0.369	0.161
Biogenic CO2 eq	kg CO2 eq	0.060	0.052
CO2 eq from land transformation	kg CO2 eq	0.000	0.000
CO2 uptake	kg CO2 eq	-0.085	-0.082

The AL-P alternative resulted less sustainable than PS-P when excluding the cooking stage and end-of-life. The difference, expressed as kg CO_2 eq, between AL-P and PS-P was equal to

0.212 kg CO_2 eq. When the LCA perspective included also use and end-of-life stage, results obtained are the ones reported in table 2.

Tab 2 – GGP, including use phase and end-of-life.

Category	Unit	AL-P	PS-P
Total	kg CO2 eq	1.18	1.07
Fossil CO2 eq	kg CO2 eq	1.20	1.11
Biogenic CO2 eq	kg CO2 eq	0.07	0.07
CO2 eq from land transformation	kg CO2 eq	0.00	0.00
CO2 uptake	kg CO2 eq	-0.09	-0.10

From data reported in table 1 and 2, AL-P resulted less sustainable than PS-P. However its specific design allowed for lower impacts during the cooking stage, so that the difference between AL-P and PS-P, when the whole life cycle was considered, was reduced to 0.110 kg CO_2eq.

It is argued that the assessment of the life cycle of a product by using only CO_2eq quantification may have some limitations (Laurent et al. 2012): indeed results obtained with a second method taking into account different impact categories, such as Recipe H Endpoint (including use phase and end-of-life), showed that impacts of the two trays, according to GGP, are higher for PS-P. However, when considering the whole life cycle (fig.1) AL-P option was more sustainable, due to its lower impacts during the cooking stage.

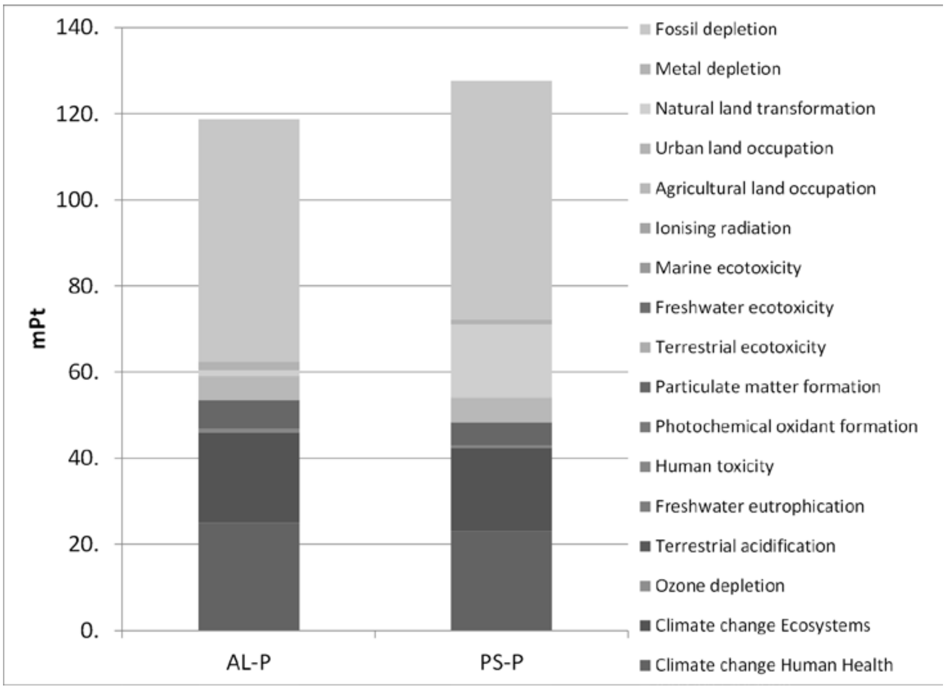


Fig. 1 – Recipe H Endpoint, from cradle-to-gate perspective

CONCLUSIONS

LCA from "cradle-to-gate", excluding use phase and end-of-life, showed that PS-P tray is more sustainable than the aluminum one; nevertheless the AL-P tray was specifically designed to allow for energy savings during the cooking stage of the poultry product contained in the tray. The cooking stage resulted to be the most impacting one over the entire life cycle of the two alternatives (taking into account production, transports, cooking and end-of-life), so the specific design of the tray itself allowed significant lowering of the overall emissions according to Recipe Endpoint H and GGP methods. When considering Recipe Endpoint H AL-P resulted more sustainable than PS-P

REFERENCES

Colwill JA, Wright EI, Rahimifard S (2012) A Holistic Approach to Design Support for Bio-polymer Based Packaging. Journal of Polymers and the Environment 20 (4):1112-1123. doi:10.1007/s10924-012-0545-z

Ecoinvent (2010) database version 2.2

Laurent A, Olsen SI, Hauschild MZ (2012) Limitations of Carbon Footprint as Indicator of Environmental Sustainability. Environmental Science & Technology 46 (7):4100-4108. doi:10.1021/es204163f

Meneses M, Pasqualino J, Castells F (2012) Environmental assessment of the milk life cycle: The effect of packaging selection and the variability of milk production data. Journal of Environmental Management 107:76-83. doi:10.1016/j.jenvman.2012.04.019

Suwanmanee U, Varabuntoonvit V, Chaiwutthinan P, Tajan M, Mungcharoen T, Leejarkpai T (2012) Life cycle assessment of single use thermoform boxes made from polystyrene (PS), polylactic acid, (PLA), and PLA/starch: cradle to consumer gate. The International Journal of Life Cycle Assessment. doi:10.1007/s11367-012-0479-7

LIFE CYCLE ASSESSMENT OF AN ADHESIVE FOR THE LAYING OF CERAMIC TILES

*R. Spinelli, * M. Pini, P. Neri, A.M. Ferrari*
University of Modena and Reggio Emilia, Department of Science and Engineering Methods, Reggio Emilia, Italy,
martina.pini@unimore.it,
Keywords: Life cycle assessment; adhesive; recycling; co-product.

ABSTRACT

The aim of the study is a comparative assessment of the environmental damage of an adhesive for the laying of ceramic tiles, obtained by the manufacturing of waste ceramic tiles and natural aggregates. The LCA analysis basically shows that the production of the sand by the recycling process is more impactful because of the energy consumptions required to reprocess the waste ceramic tiles.

1 INTRODUCTION

The building sector is still largely dominated by recourse to natural resources with growing consumes: the necessary request of natural aggregates generate a strong impact on the territory because of extractive activities.

The growing attention and interest towards the environment led to a wider interest in reusing and recycling building materials. Consequently it is necessary to pay attention on the contribution that the secondary aggregates may lead to the satisfaction of the building society needs. For this reason it is necessary evaluate the environmental burdens associated to the needed industrial operations to obtain the secondary raw materials, with respect the natural aggregates, obtained from extractive activities. To investigate the environmental performance of both secondary raw materials and natural aggregates it is important to adopt the life cycle approach. A product is usually defined as eco-friendly when it is solely composed by recycled materials, since the consumption of raw materials and the production of waste are limited. However, in this way, it cannot taken into account of the energy consumption during the reprocessing, that often reduces the advantage of the raw material savings.

2 MATERIALS AND METHODS

2.1 Goal definition

The scope of the present study is to assess the environmental impacts of an adhesive for the laying of ceramic tiles obtained by the manufacturing of waste ceramic tiles and natural aggregates.

2.2 System, functional unit and function of the system

The studied system is the manufacture of an adhesive for the laying of ceramic tiles produced by a company of the Sassuolo ceramic district (Italy). The functional unit is the hourly production of the adhesive: 200t/h. The function of the system is the laying of the ceramic tiles.

2.3 System boundaries

The system boundaries for the analysis ranging from raw material extraction to the final packaging, thus obtaining “a cradle to the gate” overview. Plants, devices and equipment, and therefore the energy consumptions have been considered in the study.

2.4 Impact assessment methodology

The analysis is conducted using the SimaPro 7.3.3 software and the IMPACT 2002+ evaluation method to assess the environmental impacts. In order to give more representativeness of the studied system, the following modifications have been implemented: the *transformation to forest intensive, normal, to forest intensive* and *to arable* have been introduced in the land use impact category; *silver, gravel, sand, lithium, bromine and water in ground* have been introduced with the same characterization factors considered in the Mineral impact category of Eco-indicator99 method; it has been evaluated the *volume occupied by the radioactive wastes* considering the same characterization and normalization factors of EPID 2003 method; the *depletion of water* has been added and a new indicator (*Soil*) has been introduced to assess the damage on the ground generated by the sand extraction and to consider the depletion of a natural resources.

2.5 Life cycle inventory

The inventory analysis has been conducted using primary and secondary data. The data relating to the plants, the energy consumptions, the recycling of waste ceramic tiles and the emissions in air have been directly provided by a company of the Sassuolo ceramic district. The remaining data have been obtained from the EcoInvent database (Life Cycle Inventories, 2009). Regarding the production process of an adhesive obtain by the recycling of waste ceramic tile, two different scenario have been hypothised. In the first scenario (A) it has been considered only the damage associated to the transportation of the secondary materials. In the second one (B), the waste ceramic tiles have been considered as a co-product to which is attributed a portion of damage belonging to the production of ceramic tiles. Product and co-product has been allocated on an economic basis: a market price has been assigned to the product and co-product and their percentage of the total cost has been calculated.

3 IMPACT ASSESSMENT AND CONCLUDING REMARKS

The analysis of the results shows that the production of sand by the manufacturing of waste ceramic tiles produce a higher environmental impact. In particular, considering the two different recycling scenario (transport A and co-product B) the A perspective shows a considerable damage increase with the respect to the B one (Fig. 2).

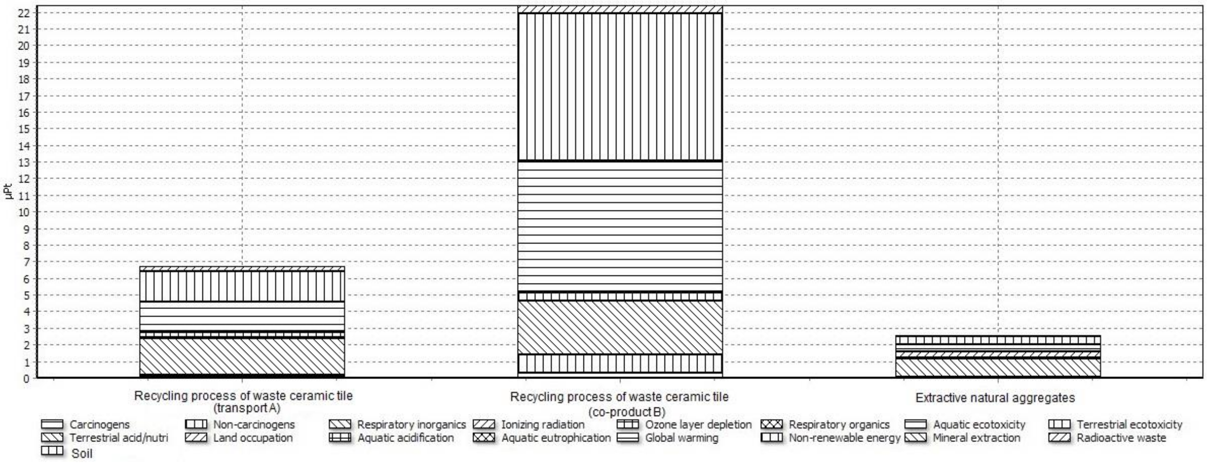


Figure 1 Comparison by impact categories of 1 kg of adhesive produced by recycling process of waste ceramic tiles (A and B scenarios) and the extractive natural aggregates

According to Ecoinvent procedure the A scenario has been adopted in the present study to compare the environmental impacts of an adhesive for the laying of ceramic tiles obtained by the manufacturing of waste ceramic tiles and natural aggregates. Analysis of the results shows that the process of recycling produces a significant increase of the damage for each of the environmental impact categories with the exception of the categories Land occupation and Land (Fig. 2). The damage is mainly caused by Respiratory inorganics, Non-Radioactive waste and renewable energy impacts categories. The damage in Respiratory inorganics is due to the emissions generated during the grinding of waste materials. In Non-renewable energy, Radioactive waste and Global Warming impact categories the damage is due to the energy derived from the electricity grind necessary to the reprocessing of waste ceramic tiles. In Land Occupation the damage is mainly caused by (47.14%) *Occupation, industrial area* in particular for the the recycling process of sand, while the extraction process of sand the damage in the same impact category is mainly due to *Occupation, mineral extraction site* (54.09%). To improve the Life Cycle Impact Assessment it is ongoing studies to evaluate in depth the new indicator (Soil) which assesses the damage on the ground generated by the sand extraction and the depletion of a natural resources. The recycling process, compared with the production of natural sand, causes an increase of environmental impact due to the energy consumption in the reprocessing step. In this way the advantage obtained by the raw materials saving is nullify. For this reason it is not always possible to express a positive opinion on the environmental sustainability of recycling processes.

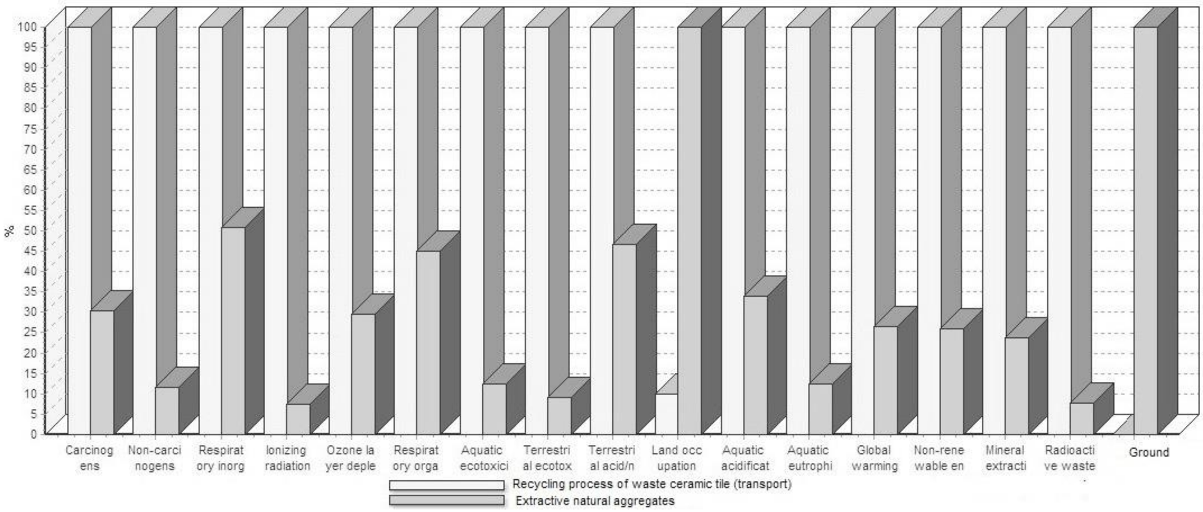


Figure 2 Comparison by impact categories of 1 kg of adhesive produced by recycling process of waste tile (A scenario) and the extractive aggregates

ACKNOWLEDGEMENTS

The authors would like to thank Adesital S.p.A., for its contribution to data collection.

REFERENCES

ANPAR, 2005, The production of recycled aggregates in Italy in 2004, www.anpar.org

European Commission - Joint Research Centre - Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. First edition March 2010. EUR 24708 EN. Luxembourg. Publications Office of the European Union; 2010

Jolliet O, Margni M, Charles R et al. (2003) IMPACT 2002+: A new life cycle impact assessment methodology. International Journal of Life Cycle Assessment 8 (6): 324-330

Life Cycle Inventories (2009) Ecoinvent Database. Version 2.0. December 2010. http://www.ecoinvent.ch/

Neri P., Falconi F., Olivieri G., Ferrari Am., Barbieri L., Lancelotti I., Pozzi P., Cervino M., Gallimbeni R.(2009), Analisi Ambientale della gestione dei rifiuti con il metodo LCA, Pubblicazione elettronica. ISBN, 978-88-900772-2-7, Edizione: Cnr Area Ricerca Bologna www.lcarifiuti.it

LIFE CYCLE ASSESSMENT OF NEW BIO-HARDBOARDS USING A LACCASE ACTIVATED SYSTEM

Sara González-García[a,b,], Gumersindo Feijoo[b], Carol Heathcote[c], Andreas Kandelbauer[c] and Mª Teresa Moreira[b]*

[a] *CESAM, Department of Environment and Planning – University of Aveiro, 3810-193 Aveiro, Portugal. *Corresponding author: sara.gez.garcia@gmail.com*

[b] *Department of Chemical Engineering, Institute of Technology, University of Santiago de Compostela. 15782- Santiago de Compostela, Spain.*

[c] *Kompetenzzentrum Holz, WOOD Carinthian Competence Centre, A-9300 St. Veit an der Glan, Austria.*

Keywords: fibreboard; LCA; laccase; lignosulfonate; wet process.

ABSTRACT

The use of petroleum-based resins in wood panels manufacture involves negative environmental effects mainly related to formaldehyde emissions. The substitution of these resins by formaldehyde free adhesives is proposed in this study. The environmental profile of a bio-hardboard formulated with a wood-based phenolic material and a phenol-oxidizing enzyme has been evaluated following the Life Cycle Assessment methodology and compared with those from the conventional process where phenol-formaldehyde (PF) resin is used as base adhesive.

The results indicate that the bio-hardboards meet the specifications of hardboards produced with the conventional process. The substitution of the PF resin by the bio-resin improves the environmental profile with reductions in both greenhouse gases and photochemical oxidants emissions. Special attention must be paid on the energy requirements of laccase production, which entails acidifying and eutrophying emissions.

INTRODUCTION

Wood based panels are characterized by their variable physical and mechanical properties as well as their multiple uses. These materials are composite boards which are manufactured using large amounts of synthetic resins derived from non-renewable resources (such as petroleum), which are increasingly more expensive (Widsten and Kandelbauer, 2008; Moubarik et al., 2009). Examples of the most extended conventional adhesives are urea and phenol formaldehyde resins (UF and PF respectively). Moreover, the use of these petroleum based adhesives implies formaldehyde emissions during the production and end-use of the boards. These emissions are a concern for society due to their negative environmental and health effects (Imam et al., 1999; Widsten et al., 2009). Therefore, there is a growing concern on the development of alternative and formaldehyde free adhesives which are expected to be more environmental friendly (Moubarik et al., 2009). Efforts are being devoted to develop these bio-adhesives as a green strategy using phenolic substitutes (Imam et al., 1999). Examples of potential bio-adhesives are composed by lignin based materials such as lignosulfonates and black liquor as well as bark tannins (quebracho) or starch (corn) which can be partially combined with UF and PF resins (Moubarik et al., 2009). The activation of lignin for bonding can be performed by oxidation with phenol-oxidizing enzymes (laccase and peroxidases) produced by white-rot fungi (Widsten and Kandelbauer, 2008).

The objective of this study is to evaluate the environmental consequences of using a two-component bio-adhesive with a wood-based phenolic material (lignosulfonate) and a phenol-oxidizing enzyme (laccase) instead of using the conventional PF resin. The evaluation has been performed following the Life Cycle Assessment (LCA) methodology since it has been proved to be a valuable method for evaluating the environmental impacts of products and for decision-making processes.

MATERIALS AND METHODS

As mentioned before, the main goal of this study is to assess the environmental consequences derived from the production of bio-hardboards by means of a green strategy where PF resin is totally substituted by a laccase activated system. To do so, an Austrian wood based panels factory has been assessed and inventoried in detail from a cradle-to-gate perspective following the ISO standards (ISO 14040, 2006). The functional unit (FU) considered in this study has been defined as 1 m^3 of hardboard (7% moisture content) for indoor uses.

Hardboards are fibreboards of uniform density ($\geq$ 900 $kg \cdot m^{-3}$) consisting on lignocellulosic fibres of European beech and Norway spruce processed under heat and pressure. The studied production system uses a smooth-one-side type production process, which renders into good natural fiber to fiber interfelting and bonding with minimum added binder required and provides a moist surface of high plasticity giving the desired embossing sensitivity (González-García et al., 2009a; 2011a). The green production of the hardboards bonded with both PF resin (conventional panel) or lignosulfonate and laccase (bio-panel) is carried out in a wet process.

Inventory data for the foreground system are related to the hardboard production process and consisted of average annual data (inputs and outputs) obtained by on-site measurements in the factory. Detailed description of both production lines (conventional and green) can be found in González-García et al. (2009a) and González-García et al. (2011a). Concerning the background system, inventory data were taken from bibliographic sources such as the production of wood (González-García et al., 2009b), laccase (Nielsen et al., 2007), lignosulfonate (González-García et al., 2011b) and the production of chemicals (e.g. PF resin) and electricity (Austrian profile) (Ecoinvent, 2007).

RESULTS AND DISCUSSION

The environmental study was performed using the characterization factors reported by the Centre of Environmental Science of Leiden University - CML 2001 method v2.04 (Guinée et al. 2001). This study is focused on four impact categories: acidification potential (AP), eutrophication potential (EP), global warming potential (GWP) and photochemical oxidant formation potential (POFP). Software SimaPro 7.3.2 was used for the computational implementation of all the inventories (PRé Consultants, 2013).

According to the comparative results reported in Figure 1, it is possible to obtain environmental benefits if the PF resin is totally substituted by a laccase activated bio-adhesive. These environmental improvements are achieved in categories such as GWP and POFP with reductions of 1% and 54% respectively. On the contrary, worse results have been achieved in terms of AP and EP.

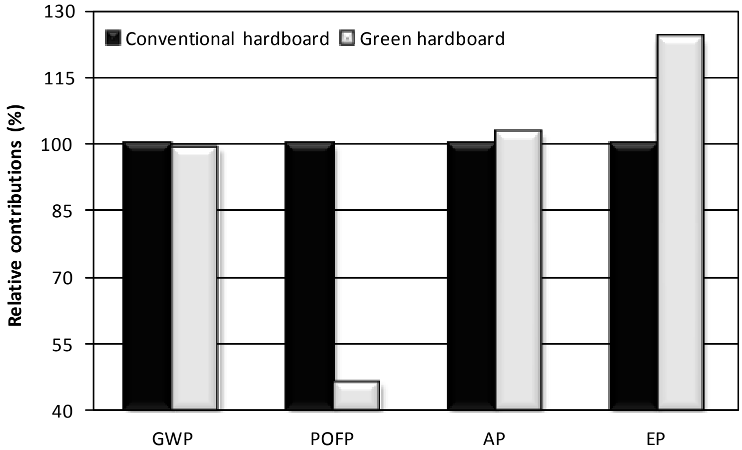


Figure 1. Comparative environmental profile of hardboards manufacture under conventional and green strategies.

Concerning energy requirements all over the life cycle, it is possible to obtain reductions of up to 30% for the green production system. However, special attention must be paid on the adhesives production. The conventional process requires 34 kg of PF resin as bonding agent per m^3 (González-García et al., 2009a) and the bio-hardboard requires 10.5 kg of laccase and 40 kg of lignosulfonate (González-García et al., 20011a), which is a co-product from dissolving pulp mills (González-García et al., 20011b).

The production of the PF resin is one of the most important processes responsible of environmental impacts derived from the conventional process specifically in terms of GWP and POFP as well as in toxicity related impact (which have not been assessed here). Thermal energy production process (from biomass) is the main responsible of acidifying and eutrophying emissions (AP and EP) due to nitrogen oxides emission (González-García et al., 2009a).

The bio-adhesive is composed by lignosulfonate and laccase. The contributions to the environmental profile from the lignosulfonate are almost negligible since it is a renewable material derived from wood and produced under a biorefinery concept (González-García et al., 20011b). The laccase production process is a high energy intensive process being remarkable its contribution to categories such as GWP and POFP (González-García et al., 20011a). However, in absolute values, its contribution is lower than the PF resin reducing the GWP and POFP.

Concerning AP and EP, thermal energy production is the main *hotspot* as in the conventional process. However, the contribution from laccase production process is considerably high involving higher absolute values.

CONCLUSIONS

LCA is a valuable tool for assessing the environmental profile of industrial systems and supports decision-making processes towards their sustainability. In this study, the LCA allowed to establish that environmental improvements can be achieved when petroleum based adhesives are substituted by bio-adhesives identifying the most critical contributor. However, more research must be carried out on the laccase production process in order to reduce its energy demand and thus, the environmental profile derived from the green hardboards. In addition, cost assessment should be required due to the large costs associated to laccase in comparison with formaldehyde based resins.

REFERENCES

Ecoinvent database (2007). http://www.ecoinvent.ch/

González-García, S., Feijoo, G., Widsten, P., Kandelbauer, A., Zikulnig-Rusch, E., Moreira, M.T. (2009a). Environmental performance assessment of hardboard manufacture. *International Journal of Life Cycle Assessment*. 14, 456-466.

González-García, S., Berg, S., Feijoo, G., Moreira, M.T. (2009b). Environmental impacts of production and supply of pulpwood: Spanish and Swedish case studies. *International Journal of Life Cycle Assessment*. 14, 340-353.

González-García, S., Feijoo, G., Heathcote, C., Kandelbauer, A., Moreira, M.T. (2011a). Environmental assessment of Green hardboard production coupled with a Laccase activated system. *Journal of Cleaner Production*. 19, 445-453.

González-García, S., Hospido, A., Agnemo, R., Svensson, P., Selling, E., Moreira, M.T., Feijoo, G. (2011b). Environmental life cycle assessment of a Swedish dissolving pulp mill integrated biorefinery. *Journal of Industrial Ecology*. 15(4): 568-583.

Guinée JB, Gorrée M, Heijungs R, Huppes G, Kleijn R, de Koning A, van Oers L, Wegener A, Suh S, Udo de Haes HA (2001) Life cycle assessment. An operational guide to the ISO standards. Centre of Environmental Science, Leiden.

Imam, S.H., Mao, L., Chen, L., Greene, R.V. (1999). Wood adhesive from crosslinked poly (vinyl alcohol) and partially gelatinized starch: preparation and properties. *Starch-Stärke* 51, 225-229.

ISO 14040 (2006). Environmental Management. Life Cycle Assessment. Principles and Framework.

Moubarik, A., Pizzi, A., Allal, A., Charrier, F., Charrier, B. (2009). Cornstarch and tannin in phenol-formaldehyde resins for plywood production. *Industrial Crops & Products*. 30,188-193.

Nielsen, P.H., Oxenbøll, K.M., Wenzel, H. (2007). Cradle-to-gate environmental assessment of enzyme products produced industrially by Novozymes A/S. *International Journal of Life Cycle Assessment*. 12 (6), 432-438.

PRé Consultants (2013). http://www.pre.nl

Widsten, P., Kandelbauer, A. (2008). Adhesion improvement of lignocellulosic products by enzymatic pre-treatment. *Biotechnology Advances*. 26, 379-386.

Widsten, P., Hummer, A., Heathcote, C., Kandelbauer, A. (2009). A preliminary study of green production of fiberboard bonded with tannin and laccase in a wet process. *Holzforschung* 63, 545-550.

LIFE CYCLE ASSESSMENT OF THREE TYPES OF PRIMARY DRUG PACKAGING

*Mª Rosa Pino[1]**, Esther Roldán[1], Natalia Loste[1], Rita Puig[2]. [1] Grupo de Investigación GIMACES, Universidad San Jorge, Spain. [2] Grupo de Investigación GIR_Ambiental, Universidad Politécnica de Cataluña, Spain. ** Universidad San Jorge. Campus Universitario Villanueva de Gállego Autovía A-23 Zaragoza-Huesca, km. 510, 50830 Villanueva de Gállego. Zaragoza (Spain). rpino@usj.*

Keywords: Life Cycle Assessment (LCA), drugs packaging

ABSTRACT

In this project, a comparative Life Cycle Inventory (LCI) of most common primary containers (sachet, blister pack and pot) for several drugs has been carried out. In addition, different stages in the Life Cycle Assessment (LCA) during the packaging process of drugs have been studied.

The results have provided the identification of the impacts associated to the life cycle of the studied packaging drugs, as well as providing a comparative study between different types of primary packaging material. The data obtained from the assessment of the impacts associated with the primary packaging material throughout its life cycle have provided useful information to establish new preventive strategies within the sector.

INTRODUCTION

All the pharmaceutical industry is a strategic sector for any advanced economy. It has experienced a period of unprecedented prosperity in the last half of the 20th century, resulting on an increased capacity to innovate. This has produced a great proliferation of new drugs that need to be protected, identified and dosed so that they can get in perfect conditions to users and this requires the use of a wide variety of containers. The containers are associated with an environmental impact throughout its life cycle (from obtaining of the raw materials to their treatment and disposal as waste) that has not been analyzed and evaluated in so much detail as it has been the drug itself. Accordingly, important developments such as the elimination of superfluous packaging, the weight reduction of the materials used or changes in the composition of the container have been achieved. However, these actions have not been studied from a life cycle perspective in its entirety and very few studies can be found about LCA of drugs packaging (Belboom, Renzoni, Verjans, Leonard & Germain, 2011). Therefore the likely consequences or transfers of impacts from some life cycle stages to others have not been evaluated yet.

The main goal of this study is the initial analysis of the environmental impacts of common types of primary packaging of several drugs for which the life cycle takes place in Aragón (Spain).

MATERIALS AND METHODS

The study has been carried out following the ISO14040 Life Cycle Assessment (LCA) methodology (International Standardization Organization, 2006).

The study was conducted following the life cycle for six drugs widely used in Aragon for which the life cycle takes place almost on its entirety within this territory. To do this, we first identify agents involved as well as the primary packaging materials of these selected drugs. We developed a complete inventory of life cycle of these drugs packaging and subsequently we modeled these processes. Finally, we evaluated the environmental impact of some stages of the total life cycle.

The system boundaries of the LCI is “from cradle to grave” and data have comprised three manufacturers of packaging, a laboratory that performs the packaging of drugs, a depot, three pharmacies and a company of packaging waste management as well as all associated transport that is specified below. The system boundaries of the LCA addressed in this study are “gate to grave” (Figure 1).

The functional unit (UF) specific to the system under study is one container offered for sale.

The LCA software tool GaBi 4.0 has been used for LCA modeling. The environmental impacts have been estimated according to CML 2001 method (Guinee, 2001).

RESULTS

The criteria for the selection of the containers for the study took into account that they were drugs widely distributioned in Aragón, traceable (the life cycle took mostly place within this territory) and with representative primary packages. The selected drugs were: Ibuprofen 600 mg (blister pack), Omeprazole 20 mg (blister pack), Ibuprofen 600 mg arginine (sachet), Paracetamol 1g (sachet), Acetylcysteine 600 mg (sachet) and Omeprazole 20 mg (pot).

Once the drugs under study were selected, the LCI was started considering all stakeholders involved: three manufacturers of packaging; a laboratory, depot supplying to pharmacies, three pharmacies and the company responsible for the management of packaging waste. The different steps involves in the life cycle for the drugs containers considered can be seen in Figure 1.

After these drugs LCI data were available (subject confidentiality) we decided to tackle the LCA of two of these drugs of very similar functions but packed one in sachet and the other in blister pack. The selected drugs were: Ibuprofen 600 mg arginine in sachet and Ibuprofen 600 mg in blister pack.

We focused on the LCA of these two packaging drugs in the next processes (discontinuous red line in the Figure 1): transportation from laboratory to the depot (190 Km/UF); storage, distribution and product preparation within the depot; transportation from the depot to the pharmacies, average of the total of annual kilometers all 650 pharmacies that serve the haulier (0,026 Km/UF sachet and 0,009 Km/UF blister pack); transportation of returned waste packaging of drugs collected from pharmacies to the depot (0,026 Km/UF sachet and 0,009 Km/UF blister pack); transportation of expired drugs packaging returned from pharmacies to the depot (0,026 Km/UF sachet and 0,009 Km/UF blister pack); transportation of the packaging waste from the depot to waste management company (460 Km/UF); transportation of expired drugs returned from the depot to original laboratory (190 Km/UF); transportation of hazardous wastes (generated in the process) from the depot to hazardous waste management company (24 Km/UF); transportation of non-hazardous wastes (generated in the process) from the depot to non-hazardous waste management plant company (62 Km/UF).

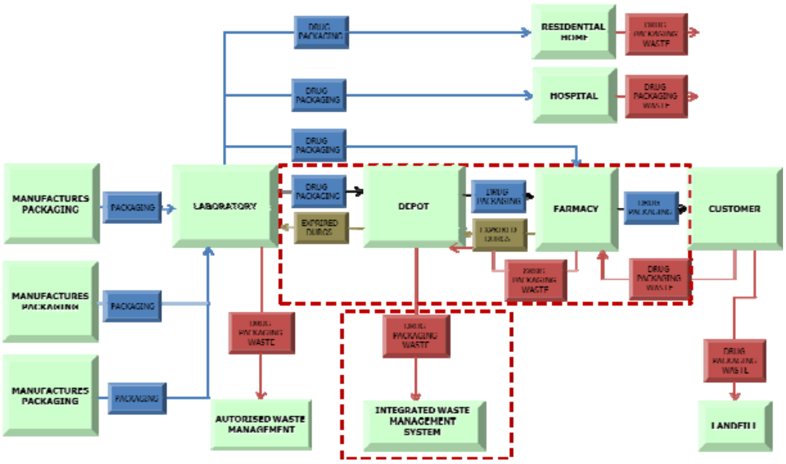


Figure 1. System boundaries of the LCI study. Discontinuous red line shows system boundaries of the LCA.

Impact assessment indicators used for this study are detailed below:

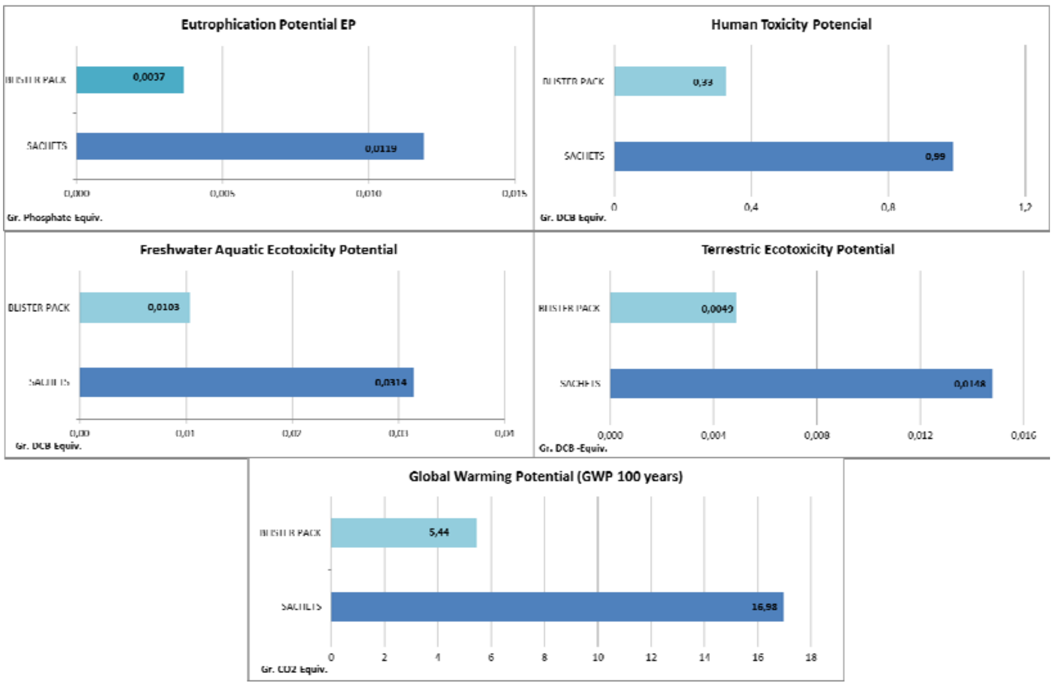


Figure 2. Comparison of five selected environmental impacts of distribution and transport of one container offered for sale (functional unit) of the same drug (Ibuprofen 600 mg) in sachet or in blister pack.

DISCUSSION

This study dealt with a LCI of several drugs with three different packaging types: sachet, blister pack and pot. It has also started the analysis of LCA focusing on two packaging of one same drug and their transportation and distribution processes. The results show that sachet packaging transport has greater environmental impact than blister pack transport per functional unit (one container offered for sale), for all the studied impacts. The magnitude of the increase is on the order of double and even triple in the case of global warming.

These results can be explained because the unit of sale of ibuprofen 600 mg in sachets is much heavier than the case of ibuprofen in blister pack, on the order of three times more. Although both presentations have the same amount of drug (20 one-dose dispenser each of them), one container offered for sale of Ibuprofen in sachet weighs 191 gr and in blister pack only 58,165 gr. Furthermore it should be noted that the volume of unit of sale in sachets is bigger than the blister pack (three times higher).

CONCLUSIONS

The greatest environmental impact generated by the transport and distribution of a same drug (Ibuprofen 600 mg) packaged in sachet against which produces packaging in blister pack, is explained due to a heavier weight of the Ibuprofen in sachet four times higher than the Ibuprofen in blister pack. Although this study shows information about the environmental impacts associated with the transportation of different types of packaging of drugs, to carry out a full study of the complete impact of these two types of containers, it is necessary to expand the system boundaries of the LCA, including laboratory and especially to manufacturing companies as well as to the company responsible for the management of packaging waste. Likewise, addressing a representative study, LCA of other common types of primary containers such as the pot should be also analyzed.

In this study, drug packagings were investigated only from the environmental point of view. It should be supported with other decision-making tools taking into consideration the economic and social effects of packages.

REFERENCES

Belboom, S; Renzoni, R; Verjans, B; Leonard, A & Germain, A. (2011). A life cycle assessment of injectable drug primary packaging: comparing the traditional process in glass vials with the closed vial technology (polymer vials). *International Journal of Life Cycle Assessment, 16, 159-167*. doi: 10.1007/s11367-011-0248-z

Guinee, J. (2001). Handbook on life cycle assessment - Operational guide to the ISO standards. *International Journal of Life Cycle Assessment, 6, 255-255*. doi: 10.1007/bf02978784

ISO 14040 (International Standardization Organization). (2006). Environmental Management-Life Cycle Assessment—Principles and Framework. *International Standard ISO 14040*

LIFE-CYCLE EVALUATION OF THE CERAMIC BLOCK WITH A FOCUS ON SOCIAL INTEREST HOUSING

*Maria Cecilia Araujo Santos **
**MSc. Engenharia Civil – Escola Politécnica de Pernambuco / Universidade de Pernambuco, Rua Benfica, 455, Madalena,Recife – Pernambuco/Brasil. E-mail: ceciliasantosx@gmail.com*
*Arnaldo Cardim de Carvalho Filho***
***Dr. Engenharia Civil – Escola Politécnica de Pernambuco / Universidade de Pernambuco, Rua Benfica, 455, Madalena, Recife – Pernambuco/Brasil. E-mail: cardim@poli.br*

Keywords: life-cycle evaluation, ceramic block, social interest housing.

ABSTRACT

This research creates an inventory of the production process of the ceramic block, using the methodology of Life-Cycle Assessment (LCA) as defined by ISO 14040. It is an experimental research conducted in three industries of the state of Pernambuco, Brazil, where the reference flow used is of 1 ton of clay, to quantify energy consumption (thermal and electrical) and estimate CO2 emissions. The analysis allows identifying that the ceramic block may be a viable alternative for the use in housing of social interest, besides clay being a raw material in abundance in the state, the production process can adopt measures to minimize environmental impact. The results can be applied to other buildings, and compared to products with similar function.

INTRODUCTION

Climate change, air and water pollution, destruction of nature, soil erosion, water scarcity and biodiversity loss are the most serious problems of developing countries, aggravated on low-income populations. The researches and applications of principles aimed at sustainability have shown that it is possible to promote a balanced economic growth, reduce poverty and ensure the quality of life of the society (IEG, 2008). This research mainly aims to use the LCA tool to identify energy consumption and CO2 emissions in the production process of the ceramic block, incorporated to the Social Interest Housing in the state of Pernambuco, Brazil.

INVENTORY OF THE LIFE-CYCLE OF THE CERAMIC BLOCK (LCI)

The LCI of the ceramic block was performed from the construction of an inventory of its own production process, with data referring to the consumption of materials and energy, and CO2 emissions. For the LCI to three industries in the state of Pernambuco: one located in Camaragibe, and two located in Paudalho, 40 km from the capital. It is important to stand out that this study is limited to the production phase of the ceramic block. For a complete demonstration of the scope of the research, a tree process of the ceramic block chain was created (Figure 1), based on studies from Soares Pereira and Breitenbach (2002), who delimits the cutting criteria and defines the inputs and outputs of the life-cycle of the ceramic block. The production process of the ceramic block is divided into three basic stages:

preparation of the raw material, molding the material and burning of the product, as shown in Figure 1.

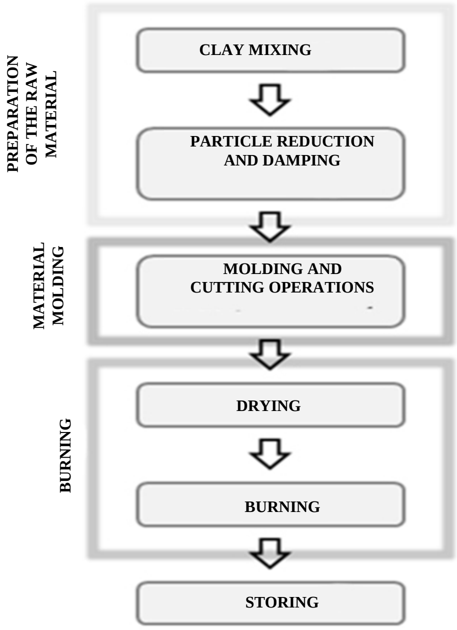


Figure 1 – Tree process of the ceramic block production process.

The preparation of the raw material is accomplished by mixing the clay with a loading shovel. After the raw material is reduced into smaller particles and moistened. The molding of the material is done by a mill, which compresses the raw material under vacuum and shapes the product. By means of a cutter, the blocks take its dimension for the beginning of the burning process. At all stages, there is electric or thermal energy consumption and only at the stage of molding the material there are no CO2 emissions.

DATA COLLECTION

A total of 18 industries informed by Sindicer, only 3 facilitated the access and data collection, whereas two are located in the Zona da Mata mesoregion (Paudalho) and one in the Metropolitan Region (Camaragibe). Data collection was based on the daily production of the industries visited. To survey CO2 emissions, a digital instrument was used, which measures the CO2 concentration in 30 seconds. Data were collected at a one-hour period and recorded every twenty minutes. For the collection of data of the consumption of natural resources, the information is provided by industries and for the values of other resources, information was sometimes provided, or sometimes measured onsite

INVENTORY EVALUATION OF THE LIFE CYCLE OF THE CERAMIC BLOCK

During the production process, the preparation of the raw material and the molding are the steps of greater electricity consumption due to the use of high power equipment, such as the laminator and the mill. The step of burning, is characterized by being the phase of greater environmental impact due to the combustion of biomass. It is noteworthy to say that industries B and C use mesquite wood as a component for combustion. Industry A presents the highest value in relation to energy consumption and CO2 emissions, which indicates the use of equipment with high power engines and use of more polluting biomass than other industries. Machines run daily for nine hours and the furnace for 24 hours in the production of ceramic blocks. Although it is presented as the most polluting material, the cane briquette is a byproduct, a feature that minimizes the environmental burden generated by emissions. Industry B showed lower results concerning energy consumption - due to the use of equipment with low power engines, even with hours of operation equal to industry A - and CO2 emissions. Industry C, on the other hand, in order to reduce the consumption of electricity, replaces the matrix by a generator that works on burning diesel for four hours, contributing to gaseous emissions.

The Table 1 presents a summary of the data obtained, corresponding to a ton of clay.

Table 1 - Data obtained referring to a ton of clay.

		Ind. A	Ind. B	Ind. C
INPUTS	Electric power consumption (kWh/t)	23	11	12
	Thermal power consumption (MJ/t)	356	465	77.000
OUTPUTS	CO_2 Emission (kg/t)	0,0053	0,0032	0,0042
	Blocks (unit/t)	333	333	354

INTERPRETATION OF THE RESULTS

The data regarding the biomass show that the cane briquette (industry A) has lower calorific value and energy than firewood and sawdust (industry B) - however, as a byproduct, it can achieve better results and be used along with products of high calorific value, such as vegetable oil, used in industry C. The consumption of biomass in industry C is superior to other industries because of the use of the two methods of burning. Despite not showing lower results, it is possible to consider that industry C consumes less energy and has a lower amount of emissions by making more products with a ton of clay. In the phase of preparation of the raw material, the power consumption is very important and this can lead to the study of alternatives with positive contribution to the environment. The burning phase is relevant for the study of consumption of thermal energy for being the only step that uses biomass combustion. Performed by all industries analyzed, the use of firewood to start the fire in the furnace can be replaced by continuous briquette cane and fueled with vegetable oil, as both showed low CO2 emissions throughout the study.

CASE STUDY - SOCIAL INTEREST HOUSING

The typologies most commonly found in the state of Pernambuco are performed in ceramic block masonry for sealing - often used with structural function in the dimensions 9 x 19 x 19 cm, with eight holes horizontally, and concrete blocks with dimensions 9 x 19 x 39 cm. and built with area of 40 m². The masonry by ceramic blocks with eight holes horizontally (9 x 19 x 19 cm), settled and grouted with cement mortar and sand in 1:3 ratio. Considering 1 m² of masonry as a functional unit, it is possible to identify CO2 emissions and energy consumption for any building that uses the ceramic block as sealing material. For the construction of a social interest housing with 40 m², a total of 3.125 units of ceramic blocks were necessary.

Therefore, to construct a 40 m² house, it is necessary to consume approximately 139.15 kWh of electricity and 271.50 kg of biomass - which results in the emission of 0.038 kg / Nm ³ of CO2.

FINAL CONSIDERATIONS

Preparation of the inventory from the LCA methodology allowed us to identify the inputs and outputs of the production system to qualify and quantify consumption and CO2 emissions. It is an important tool for the study of environmental impacts for they may enable the realization of a diagnosis to make decisions that can define environmental quality and therefore, the quality of life of the society.

The ceramic block is the most used product in civil construction in Pernambuco characterized by low cost, easy access and use of unskilled labor. However, the intense use of this material affects the environment, either solid or gaseous. The value of CO2 emission may seem meaningless if used for manufacturing 340 ceramic blocks, however, when adapted to every house in housing complex; it is possible to scale its influence on global warming. Experimental research has allowed to identify that the utilization of biomass in the burning of the product may be a feasible alternative if used as a byproduct, such as the cane briquette. Firewood, although appears effective with high calorific value, may be replaced by cane briquette and also by vegetable oil. The use of furniture and vegetation residues may also be a viable alternative to the process of burning, in addition to contributing for the elimination of residues.

ACKNOWLEDGMENTS

We thank the agencies CAPES and FACEPE which funded part of this research. The Polytechnic School of Pernambuco which allowed our participation in this event.

REFERENCES

INDEPENDENT EVALUATION GROUP – IEG, 2008 -*Sustentabilidade Ambiental: uma avaliação do Grupo Banco Mundial (Resumo de Avaliação)*, 28p., Washington D.C. – EUA, in: http://worldbank.org/.

CONFEDERAÇÃO NACIONAL DA INDÚSTRIA – CNI, 2007- *Matriz energética: cenários, oportunidades e desafios*. Brasília, Brazil – in: http://www.cni.org.br.

SOARES, S. R., PEREIRA, S. W., BREITENBACH, F. E.,2002 - *Análise do Ciclo de Vida de Produtos Cerâmicos da Indústria da Construção Civil*. In: CONGRESSO INTERAMERICANO DE INGENIERÍA SANITARIA Y AMBIENTAL, 28., 2002, México. Anais... Santa Catarina: Departamento de Engenharia Sanitária e Ambiental (UFSC), 2002, 8p. http://www.bvsde.paho.org

LIFE CYCLE GLOBAL WARMING POTENTIAL ASSESSMENT OF SEAWEED-BASED BIOETHANOL

Kyung A Jung[1], *Seong-Rin Lim*[2*], *Jong Moon Park*[1**]

[1]*School of Environmental Science and Engineering, POSTECH,* [2]*Department of Environmental Engineering, Kangwon National University*

** 1 Kangwondaehak-gil, Chuncheon 200-701, South Korea,Email: srlim@kangwon.ac.kr*

*** 77 Cheongam-ro, Nam-gu, Pohang 790-784, South Korea, Email: jmpark@postech.ac.kr*

Keywords: bioethanol; global warming potential; macroalgae; LCA; seaweed

ABSTRACT

Bioethanol produced from a brown seaweed, *Laminaria japonica*, could be more sustainable and societally ethical than those for terrestrial biomass in response to increasing demands of biofuels and a requirement for biorefinery with low carbon emission. To achieve sustainable bioethanol production systems based on seaweed, we assessed global warming potentials (GWPs) of seaweed-to-biofuel process by using life cycle assessment (LCA). Bioethanol-producing processes using the seaweed and their GWPs were significantly different from the other land biomasses such as corn grain, corn stover, and switchgrass. This study can provide valuable R&D target information needed to effectively reduce the GWP of seaweed-based bioethanol and develop more sustainable bioenergy.

INTRODUCTION

Biofuels, as the next energy for the future, require stable supply security of feedstocks and lower net greenhouse gases (GHGs) emissions in their production. GHG emissions of bioethanol are originated from the cultivation of biomass feedstocks and bioethanol conversion. Current technologies for bioethanol production have focused on sugary and lignocellulosic biomass, which is based on land cultivation (Sánchez et al., 2008). This land cultivation needs a lot of inputs of energy and materials such as fresh water, fertilizer, and pesticides that can induce significant GHG emissions. Also, agricultural tillage practices to undisturbed ecosystem have caused surprisingly high GHG emissions from the plant and soil (Fargione et al., 2008).

Macroalgae, known as seaweeds, have been considered one of promising alternative bioenergy feedstocks and seem to have the potential to replace existing terrestrial biomass for bioethanol. Compared to terrestrial biomass, seaweed mass-cultivation does not require fertilizer, agrochemicals, fresh water, and land areas because seaweeds grow in seawater. Besides, seaweeds have high carbon contents (i.e. seaweed-specific carbohydrates) that can be biochemically converted to bioethanol (Jung et al., 2013).

The objective of this study was to evaluate the global warming potentials (GWPs) of seaweed (*L. japonica*) bioethanol production to compare to terrestrial biomasses (corn grain, corn stover, and switchgrass). For the comparison, life cycle assessment was used. This study can be used to develop sustainable seaweed-based bioethanol processes and to provide many insights into research and developments for marine biofuel.

MATERIALS AND METHODS

We carried out a life cycle GWP assessment of four bioethanols from a brown seaweed and three terrestrial biomasses. The functional unit was 1000 liters of bioethanol, and the system boundary included cultivation to bioethanol conversion stages based on currently available technology. Data for materials and energy used in the cultivation, transportation, and bioethanol production stages were collected from field survey and literature (Cherubini et al., 2010; Han et al., 2011; Humbird et al., 2011; Liska et al., 2009). The life cycle inventory was built based on the Ecoinvent database v2.2. The GWPs were assessed by using the ReCiPe with the hierarchist perspective. In the cultivation stage, we also considered the potential impacts of land uses including tillage practices. The life cycle stages of bioethanol consist of cultivation and bioethanol conversion stages.

RESULTS AND DISCUSSION

In the cultivation stage, the GWP for seaweed biomass was similar to the corn grains; however, the corn stover and switchgrass were about 60% of the seaweed. Although seaweed cultivation did not need any agrochemicals and fresh water (with contrast to corn grain), seaweed farming needed culture frames, seed strings, and rope made by petrochemical polymers (i.e. plastic materials), which has relatively high GWPs. If these frame materials can be changed from petroleum-based materials to biomaterial-based materials, the GWPs of seaweed biomass could be lower than the terrestrial biomass.

In the bioethanol conversion stage, the corn grain demanded only c.a. 40% of the GWPs for the other biomass feedstocks because of the simple carbon structures of corn grain. Seaweed-based bioethanol had slightly high GWP, which was similar to the corn stover and switchgrass because the seaweed was assumed to be processed in dilute-acid and enzyme saccharification-fermentation system, which are generally used for lignocellulosic biomass. In the bioethanol conversion of these three feedstocks, over 65% of GWPs were derived from the pretreatment system. Another reason for the high GWP of the seaweed is that the ethanol conversion yield of seaweeds was lower than land biomass. The GWP of seaweed-based bioethanol could be reduced by optimizing and customizing terrestrial biomass-based conversion processes to fit into the seaweed bioethanol and/or by developing advanced technology like genetic engineering for improvement of seaweed productivity and bioethanol conversion yields (Wargacki et al., 2012).

CONCLUSIONS

Seaweed biomass like *L. japonica* could become a potential candidate of the next sustainable feedstocks that can replace terrestrial biomass in the bioethanol industry. Seaweeds do not require the large scale of land areas for mass cultivation, additional agrochemicals, and fresh water with significant global warming impacts. Since research and developments for seaweed-based biofuels are relatively in immaturity compared to land biomass-based biofuels, advanced biotechnology should be developed to overcome current obstacles related with seaweed-based bioethanol.

REFERENCES

Cherubini, F., & Jungmeier, G. (2010). Lca of a biorefinery concept producing bioethanol, bioenergy, and chemicals from switchgrass. *The International Journal of Life Cycle Assessment, 15, 53-66.*

Fargione, J., Hill, J., Tilman, D., Polasky, S., & Hawthorne, P. (2008). Land clearing and the biofuel carbon debt. *Science, 319, 1235-1238.*

Han, J., Elgowainy, A., Palou-Rivera, I., Dunn, J.B., & Wang, M.Q. (2011). Well-to-wheels analysis of fast pyrolysis pathways with greet (no. Anl/esd/11-8, argonne national laboratory, il) *Argonne National Laboratory Report ANL/ESD/11-8.*

Humbird, D., Davis, R., Tao, L., C. Kinchin, Hsu, D., Aden, A., . . . Dudgeon, D. (2011). Process design and economics for biochemical conversion of lignocellulosic biomass to ethanol (no. Nrel/tp-5100-47764, nrel, co, 2011) *Technical Report NREL/TP-5100-47764*: National Renewable Energy Laboratory.

Jung, K.A., Lim, S.-R., Kim, Y., & Park, J.M. (2013). Potentials of macroalgae as feedstocks for biorefinery. *Bioresource Technology, 135, 182-190.*

Liska, A.J., Yang, H.S., Bremer, V.R., Klopfenstein, T.J., Walters, D.T., Erickson, G.E., & Cassman, K.G. (2009). Improvements in life cycle energy efficiency and greenhouse gas emissions of corn-ethanol. *Journal of Industrial Ecology, 13, 58-74.*

Sánchez, Ó.J., & Cardona, C.A. (2008). Trends in biotechnological production of fuel ethanol from different feedstocks. *Bioresource Technology, 99, 5270-5295.*

Wargacki, A.J., Leonard, E., Win, M.N., Regitsky, D.D., Santos, C.N.S., Kim, P.B., . . . Yoshikuni, Y. (2012). An engineered microbial platform for direct biofuel production from brown macroalgae. *Science, 335, 308-313.*

MODELING OF MUNICIPAL SOLID WASTE (MSW) INCINERATION IN SPAIN AND PORTUGAL

María Margallo [(1)], Rubén Aldaco [(1)], Alba Bala [(2)], Pere Fullana [(2)], Angel Irabien [(1)]*

[(1)]Departamento de Ingeniería Química y Química Inorgánica, Universidad de Cantabria, Avda. de Los Castros, s.n., 39005, Santander, Spain

Tel. +34 942 200931, e-mail: margallom@unican.es; fax: +34 942 201591;

[(2)]Escola Superior de Comerç Internacional (ESCI-UPF), Pg. Pujades 1., 08003 Barcelona, Spain

Keywords: incineration, Municipal Solid Waste (MSW), multifunctional process, Portugal, Spain

ABSTRACT

LCA of waste management systems involve the treatment of a waste mixture with different characteristics. So, it was necessary to estimate the impacts associated to each waste fraction using different allocation rules. These types of systems are so called multi-functional process being incineration a clear example. In this paper the Life Cycle Inventory (LCI) and a multi functional model were developed to describe Municipal Solid Waste (MSW) incineration in Spain and Portugal. In the model, whenever possible, physical and chemical causation allocations were applied. When a causation relationship cannot be established, allocation was done based on a physical parameter (energy or mass).

1. INTRODUCTION

In the recent years several LCA studies have been focused in the waste management field. The main difficulty found in these studies was that it involves the treatment of a mixture of waste with different characteristics. So, it was necessary to estimate the impacts associated to each waste fraction using different allocation rules. These types of systems are so called multi-functional being incineration process a clear example, where several inputs and outputs coexist. In this work the Life Cycle Inventory (LCI) and a multi-input/output allocation model were developed to describe Municipal Solid Waste (MSW) incineration in Spain and Portugal. This work was developed within the framework of FENIX-Giving Packaging a New Life, a 3-year European LIFE+ funded project. The aim of this project is to develop a flexible and user-friendly software tool to be used by Spanish and Portuguese municipalities and other territorial organizations, to obtain LCA results for waste management, integrating environmental, economic and social aspects.

2. MUNICIPAL SOLID WASTE INCINERATION IN SPAIN AND PORTUGAL

According to the European Pollutant Release and Transfer Register E-PRTR and Directive 2008/1/EC, the so-called IPPC Directive (that replaced Directive 96/61/EC), there are 10

Spanish facilities and 3 Portuguese plants included in group 5.b; installations for the incineration of non-hazardous waste with a capacity of 3 tonnes per hour (European Parliament and Council, 2006) (Margallo et al., 2012).

Similar technologies are applied in all these plants; they differ on the age, number of lines and incineration capacity. Particularly, two types of thermal treatment technologies, grates and in a less extend fluidized beds are used in the Spanish and Portuguese incinerators. About flue gases treatment, there is not a significant variation in the type of technology used and the reagents consumed. In particular, for particles reduction, electrofilters and bag filter are the most common technologies, and to a less extent cyclones and multicyclones. For acid gases such as HCl, HF and SOx it is common the use of a dry and semi-dry scrubbers with an alkaline reagent such as CaO and $Ca(OH)_2$. To remove NOx two technologies are applied, the Selective Non Catalytic Reduction (SNCR) and the Selective Catalytic Reduction (SCR). In both cases NH_3 or urea is the reagent used to reduce the NOx to N_2. Other important pollutants generated during the combustion are organic compounds like Polycyclic Aromatic Hydrocarbons (PAHs) or dioxins and furans (PCDDD/F). These substances are usually treated by an injection of activated carbon.

The main product and one of the most important environmental benefits of the incineration process is the energy recovery. Energy production is similar in all the plants and in the range of other studies; however, the oldest plant the lower energy recovery. In the Iberian Peninsula 83% of this energy is sold to the grid and the rest is consumed in the incineration plant. During the combustion apart from the energy and flue gases, ashes and slag are generated. 19% wt. of the input waste are transformed in slag. The total weight of inert materials, aluminium, steel and glass, is transferred to slag, whereas burnable materials are transferred in a less extend. Subsequently, slag is subjected to a magnetic separation in order to obtain scrap that will be use in the steel production. In Spain and Portugal about a 9.8% of scrap is recovered from slag. On the other hand, about 4.3% of ashes are generated. Basically ashes are composed of non inert materials, HDPE, LDPE, Beverage carton, plastic mix, organic matter and paper and cardboard. A solidification process is required to stabilize the ashes in order to be landfilled (Margallo et al., 2013).

3. LIFE CYCLE ASSESSMENT METHODOLOGY

3.1 Goal and scope

The aim of the work is to develop the LCI of the incineration process in Spain and Portugal and to model it. As the main function of incineration is to treat waste so as to reduce the volume and hazard of waste, the functional unit has been defined as 1 ton of MSW fractions (PET, HDPE, LDPE, plastic mix, paper and cardboard, beverage carton, glass, steel, Al, rest of materials and organic matter). In this study were included all the material and energy inputs and outputs of the different incineration process stages. Out of system boundaries are the construction of major capital equipment as well as the maintenance and operation of support equipment. The system is divided 4 subsystems: thermal treatment, flue gases treatment, ash solidification with cement, ash landfill and slag landfill.

3.2 Data collection: Life Cycle Inventory

Data inventory is coming from (a) site specific operating data collected from the Spanish

Association of MSW valorisation plants (AEVERSU), the Spanish packaging waste management association (Ecoembes) some incinerators and the European Pollutant Release and Transfer Register (E-PRTR) and, (b) bibliographic data. These data consist of annual material and energy inputs and outputs for the operation of Spanish and Portuguese plants in 2009. The main inputs are the amount of waste incinerated and the consumption of water, air, combustible and reagents. The main outputs are the energy and solid residues generated and the emissions to air.

3.3 Modelling of the multi input/output allocation process

In this section the allocation rules applied are going to be discussed.

- *Combustible, reagents and auxiliary materials consumption*: as there isn't relation between these consumptions and waste composition so non causality criterions such as mass allocation must be applied.
- *Emissions to air:* emissions of CO_2, CH_4, CO, carbon compounds, heavy metals, SOX, HCl and HF depend on the input waste composition. So they are allocated according to causality criterion based on the carbon and fossil carbon, Cl, F, S and heavy metals content of the input waste fraction. On the other hand, the emission of other pollutant such as nitrogen compounds and particles depends on the applied technology rather than waste composition. These pollutants are allocated based on non causality criterions.
- *Energy recovery:* in this case, the heating value of each waste fraction must be used to carry out the energy production allocation.
- *Waste generation:* both solid residues must be allocated to the input waste fraction using mass allocations.

3.4 Life Cycle Impact Assessment

The environmental assessment of the proposed scenarios was carried out following the ISO 14040 and ISO 14044 requirements (ISO 14040, 2006 and ISO 14044, 2006) with the LCA software GaBi 4.4 (PE International, 2011) and the environmental impact method proposed by CML. The selected impact categories were: Acidification Potential (AP) [kg SO_2-Equiv.], Global Warming Potential (GWP 100 years) [kg CO2-Equiv.] and Human Toxicity Potential (HTP inf.) [kg DCB-Equiv.]. Table 1 shows the main results of the impact assessment for a packaging waste fraction divided in the different stages of the process: thermal treatment, flue gases treatment, ash solidification and landfill.

Table 1. Environmental impacts of incineration process.

	Thermal treatment	**Flue gases treatment**	**Ash solidification**	**Ash landfill**	**Slag landfill**
AP [kg SO_2-Eq.]	5.91E-01	1.49E-02	1.75E-02	3.74E-03	2.12E-02
GWP 100 years [kg CO_2-Eq.]	2.31E+03	2.31E+01	9.57E+00	5.31E-01	1.01E+01
HTP [kg DCB-Eq.]	6.80E+00	1.55E-01	3.35E-01	1.27E-02	3.47E-01

According to these results, thermal treatment represents the highest impact in all the categories due to the combustion process, where green house gases (global Warming), acid gases (acidification), dioxins and furans and heavy metals (human toxicity) are generated. In other order of magnitude, are the impacts of ash solidification, flue gases treatment and ash and slag landfill. The impact of flue gases treatment is associated to the reagents production, mainly urea that has a high toxicity. And finally, cement production is the main contributor in the ash solidification impact.

5. CONCLUSIONS

In this work the most relevant technologies applied in MSW incineration in Spain and Portugal were determined. Regarding the thermal stage, grate incinerators, and FB are in the Iberian Peninsula. Specifically, in Spain the application of grate incinerators makes up 80% of incinerators, rising to 100% in Portugal. The majority of the energy produced is used for the self consumption at the plant (83%) and the rest is sold to the public grid. The amount of energy produced differs from one plant to another and depends on the amount of waste incinerated and the heating value.

When incineration is going to be modelled it is important to note that it is a multi-input/output allocation process. To solve this problem several allocation where applied. When a relationship could be established, physical allocation based on waste composition were applied and when this was not possible a mass or energy allocation was used.

Finally, the results of the impact assessment show that the thermal is the stage with a highest impact due to the emissions generated in the combustion.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support of FENIX-Giving packaging a New Life project.

REFERENCES

European Parliament and Council (2006). Regulation (EC) No 166/2006 of the European Parliament and of the Council of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register and amending Council Directives 91/689/EEC and 96/61/EC.

Fullana P. & Puig R. (1997). Análisis de Ciclo de Vida. Ed. Rubes.

ISO 14040. (2006). Environmental management - Life cycle assessment - Principles and framework.

ISO 14044. (2006). Environmental management - Life cycle assessment –Requirements.

Margallo M., Aldaco R., Bala A., Fullana P., & Irabien A. (2012). Best Available Techniques in municipal solid waste incineration: state of the art. Chemical Engineering Translations, 29, 1345-1350.

Margallo M., Aldaco R., Bala A., Fullana P., & Irabien A. (2013). Life Cycle Inventory of Municipal Solid Waste Incineration (MSWI) in Spain and Portugal. Proceedings of the Vth International Conference on Life Cycle Assessment, CILCA 2013. Best Available Techniques in municipal solid waste incineration: state of the art. Chemical Engineering Translations, 29, 1345-1350.

PE International. (2011). GaBi 4.4 Software and Databases for Life Cycle Assessment. Leinfelden-Echterdingen, Germany.

MODELLING RECYCLING, ENERGY RECOVERY AND REUSE IN LCA

Marc-Andree Wolf[1,], Kirana Chomkhamsri[1], Fulvio Ardente[2]*

[1] *maki Consulting, Am Falkenberg 66, 12524 Berlin, Germany. Marc-Andree.Wolf@maki-consulting.com*

[2] *NIA - Network di Ingegneria Ambientale, Via Mazzini 110, 92027 Licata, Italy*

Keywords: LCA, method, end-of-life, multifunctionality, ILCD

ABSTRACT

This paper guides the application of ISO 14044 for closed- and open-loop recycling (including for multi-material products), energy recovery, and reuse/further use, based on the provisions of the "ILCD Handbook – General guide on LCA" [EC 2010] and converted into a quantitative formula for the first time. This "ILCD Recyclability substitution" approach takes into account both the input of recycled material into the product (recycled content) and the quantity and quality of recycled material generated at the end-of-life of the product (recyclability, multi-functionality of the material), via "expansion of the system boundary to avoid allocation". It captures both physical reality and market-based effects.

INTRODUCTION

One of the most widely disputed topics in LCA is the modeling of the end-of-life (EoL) of products, especially open-loop modeling. The suggested approaches differ considerably, leading in many cases to substantially deviating results [NCASI 2012, EC 2010]. Some of the frequently used EoL methods are briefly presented in the following section and extensively discussed in [NCASI 2012]. In relation to recycling, the ISO 14044 standard describes two technical situations: closed-loop product systems and open-loop product systems [ISO 14044:2006]. However, often the distinction is unclear and in most cases true closed loop situations do not exist - a joint, consistent approach is beneficial.

Drawing on the wealth of previously suggested and tested approaches, the ILCD Handbook's General guide for LCA [EC 2010] presents in chapter 14.5 an integrated "Recyclability substitution" approach and gives specific provisions for EoL modeling in line with the ISO 14044 hierarchy to solve cases of multi-functionality. No formula had been provided in the ILCD Handbook for this approach, other than the formula to model allocation cases ([EC, 2010], chapter 14.4) that is however the subordinate choice in the ISO hierarchy.

METHODS

The cut-off method (100/0) considers that environmental impacts of a product should be directly assigned only to the product that causes them. Hence, the primary material burden is assigned to the life cycle burden for the first product [Nicholson et al. 2009]. It accounts for the environmental impacts at the time they occur: if a product is made e.g. of primary metal, the environmental impacts of primary metal production are attributed to this product. Avoided burdens - in case the metal in the product is recycled when its service life ends – are not accounted for, discouraging design for good recyclability.

The 50/50 method distributes the burdens of virgin material production and waste treatment to the first and last products in equal proportions [Ekvall 1994], without considering however the specific causes for material loss at design or end-of-life treatment.

In the Substitution method (0/100), the environmental burdens of avoided primary production are credited for the amount of recyclate that is produced at the end-of- life of a product. The use of recycled materials is not considered [Ekvall 1994], hence discouraged.

The ILCD Recyclability substitution method captures the actual, physical consequences of using recycled materials in a product and allows to account for benefits and impacts due to EoL processes (e.g. recycling, landfilling, produced recyclate etc.). This includes the downcycling effects on recyclate quantity and quality (i.e. changes in inherent properties of materials) and also energy recovery [EC 2010]. It can, in fact, also capture upcycling. The impacts (E) can be calculated as the sum of four components: E = Production + Recycling + Disposal – Credits (or impacts). The formula for this method reads as follows (for parameter definitions see Table 1 and the poster for more details):

$$E = (E_{Pu}*C_P + E_{Pu}*C_R*P_{Su}/P_{Pu}) + (E_{Rg}*R_g + E_{Rg2}*R_{g2}) + E_D*(R_g – S_g + Wg) – (E_{Pu}*S_g*P_{Sg}/P_{Pu} + E_{Pg2}*S_{g2}*P_{Sg2}/P_{Pg2})$$

RESULTS

The ILCD Recyclability substitution formula is illustrated with an exemplary case-study: a polyethylene (PE) chair. Due to restrictions on the article’s length, results related to other approaches can be presented only in the poster; please contact authors to receive a copy.

Table 1 shows the results of different settings of recycled content and recyclability at a given degree of downcycling (represented by the ratio of the market prices of secondary material to primary material), and referring to the impact category “Climate change” (no ‘real’ data, but methodological demonstration only).

DISCUSSION

The results of Table 1 show that the ILCD Recyclability substitution formula rewards both the provision of recyclable products at the EoL (recyclability) and the use of the recyclates (recycled content), depending on what is more relevant in the analysed case: Whenever the market price for the recyclate is high, close to that of the primary material, the market is readily absorbing more recyclates, i.e. there is a real benefit to provide more recyclate as it avoids to provide these materials from primary production. In this setting, the loss of material at the product’s end-of-life is discouraged - lost material is modeled as additional primary material production plus waste deposit efforts for the lost material.

Table 1. Results of the illustration of the ILCD Recyclability substitution formula to an exemplary case in five scenarios, and using electricity production next to material recycling to illustrate multiple recycling/recovery/reuses of a material. Common parameters (white), varied parameters (blue), results (green).

Parameter / LC-step	**Para-meter in formula**	**Base case (1)**	**Increase recycla-bility (2)**	**Increase recycled content (3)**	**Increase recycled content and recycla-bility (4)**	**Increase recycla-bility to high quality recyclate (5)**	**Unit**
Primary PE	E_{pu}	2	2	2	2	2	Impact/kg produced
Electricity grid mix	E_{Pg2}	0,15	0,15	0,15	0,15	0,15	Impact/MJ produced
PE recycling process	E_{rg}	0,05	0,05	0,05	0,05	0,1	Impact/kg treated
Waste-to-energy plant	E_{Rg2}	0,01	0,01	0,01	0,01	0,01	Impact/kg treated
Sanitary landfill	E_{D}	0,01	0,01	0,01	0,01	0,01	Impact/kg disposed
Electricity price from waste-to-energy	P_{Sg2}	0,005	0,005	0,005	0,005	0,005	Euro/MJ
Electricity grid mix price	P_{Pg2}	0,005	0,005	0,005	0,005	0,005	Euro/MJ
Primary PE content	C_{P}	1	1	0,2	0,2	1	Share
Seconary PE content	C_{R}	0	0	0,8	0,8	0	Share
PE mix control value		1	1	1	1	1	Share
Recycling to sec. PE	R_{g}	0,2	0,8	0,2	0,8	0,8	Share
Produced sec. PE (consid. losses)	S_{g}	0,18	0,72	0,18	0,72	0,72	Share
Energy recovery	R_{g2}	0,8	0,2	0,8	0,2	0,2	Share
Primary PE price	P_{Pu}	0,9	0,9	0,9	0,9	0,9	Euro/kg
Used sec. PE price	P_{Su}	0,14	0,14	0,14	0,14	0,14	Euro/kg
Gen. sec. PE price	P_{Sg}	0,14	0,14	0,14	0,14	0,8	Euro/kg
Electricity produced from waste	S_{g2}	*3,2*	*0,8*	*3,2*	*0,8*	*0,8*	*MJ/kg analysed material*
Waste landfilled	W_{g}	*0,02*	*0,08*	*0,02*	*0,08*	*0,08*	*kg/kg analysed material*
PE-chair mat production	*Production*	*2,00*	*2,00*	*0,65*	*0,65*	*2,00*	*Impact*
PE chair recycling/en. recovery efforts	*Recycling/ recovery*	*0,018*	*0,042*	*0,018*	*0,042*	*0,082*	*Impact*
PE chair waste disposal	*Disposal*	*0,000*	*0,002*	*0,000*	*0,002*	*0,002*	*Impact*
PE chair credit	*Credit/mali*	*0,54*	*0,34*	*0,54*	*0,34*	*1,40*	*Impact*
PE-chair EoL inventory	***E (Final results)***	***1,48***	***1,70***	***0,13***	***0,35***	***0,68***	***Impact/kg***

If the material is kept in the loop, it is only handed over to the next user (or in other words, it is temporary "stored" in the product): in the extreme case of 100% recycling at EoL, only the burdens due to the recycling processes have to be inventoried. On the other hand, when there is a lack of use/demand for the recyclates - indicated by a low price for the recyclate compared to the primary material price - stimulation is needed to use a higher recycled content. In this case, the production of additional low quality recyclate will not solve the problem of lack of it's uses and more recycling can even increase the overall impact (Scenario

2). Products that are better designed to be recycled at the EoL and/or use of better recycling technologies that are effectively resulting in higher quality recyclates, are however encouraged (Scen. 5), as well as is the use of low quality recyclates as input material (Scen. 3). Note that the benefit of energy recovery from the incineration of not recycled materials is included in all scenarios. This yields a self-adapting, balanced methodology and formula. Starting from the Base case (Scen. 1) with 0% recycled content and low recyclability, all interim cases are continuously and smoothly calculated (e.g. Scen. 4 with both increased recycled content and recyclability, however to a low quality recyclate, and less material incineration at EoL). The formula can be applied also to multi-material products with one formula per material (or using an expanded formula).

CONCLUSIONS

This article illustrates the ILCD Recyclability substitution approach, summarized in a reference formula, to model the whole range of possible EoL and other waste situations, including open- und closed loop recycling, energy recovery (and analogously reuse and further use), which are methodologically all the same. Importantly, the formula is practical, as no information is needed on subsequent uses or previous uses of the secondary material; type of materials, recycled content, obtained recyclate amount / material losses at the EoL, and market prices are sufficient. The approach is recommended for use in LCA studies that refer to product-level LCA and Ecodesign-type studies, e.g. in the Situation A (micro-level decision support) and C1 (accounting) of the ILCD Handbook, i.e. the vast majority of cases. The method should be further tested for various materials and cases for a representative range of products.

REFERENCES

European Commission (EC) - Joint Research Centre - Institute for Environment and Sustainability. (2010). International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. First edition March 2010. *EUR 24708 EN. Luxembourg. Publications Office of the European Union; 2010.*

ISO 14044:2006. (2006). Environmental management – Life cycle assessment – Requirements and guidelines. *International Standard Organisation, Geneva, Switzerland*

Nicholson, A.L.; Olivetti, E.A.; Gregory, J.R.; Field, F.R.; and Kirchain, R.E. (2009). End-of-life LCA allocation methods: open loop recycling impacts on robustness of material selection decisions. *URL http://hdl.handle.net/1721.1/60047, retrieved 13.05.2013*

Ekvall T. (1994). Principles for Allocation at Multi-Output Processes and Cascade Recycling. *Leiden, February 1994. SETAC-Europe. In Proceedings of the European workshop on allocation in LCA. (ISBN 90-5191-078-9), Leiden, 1994,*

National Council for Air and Stream Improvement, Inc. (NCASI). (2012). Methods for open-loop recycling allocation in life cycle assessment and carbon footprint studies of paper products. *Technical Bulletin No. 1003. URL* http://www.ciraig.org/Calendrier/document/methods_open_loop_caroline_gaudreault.pdf; retrieved 13.05.2013.

PREDICTION OF GREEN HOUSE GASES IN DEVELOPMENT OF TIDAL POWER AND IGCC USING LEAP MODEL IN KOREA

Jindo Chung, Euiwoo Lee, Taeksung Lee, Yoonjung Jung, Keunghak Oh*

Department of Environmental Engineering, Hoseo University.

165, Sechul-ri, Baebang-myun, Asan, Chungnam, 336-795, S. Korea

jdchung@hoseo.edu

Keywords: green house gass; LEAP Model; IGCC; tidal power; CO_2.

ABSTRACT

We targeted power plants in Chungnam area in which most bituminous coal thermoelectric power plants which accounts for 25 percent of the gross generation in Korea and most emits greenhouse gases are located.

Based on LEAP, we conducted a quantitative analysis on the change of generation for each installment and change of greenhouse gas emissions caused when replacing generation produced in existing bituminous coal thermoelectric power plants with generation produced when the establishment of tidal power and IGCC generation facilities and installment of new renewable energy generation facilities will be increasingly expanded from 2010 to 2030.

According to the result of this study, we expect that when IGCC generation and new renewable energy generation which can replace existing thermoelectric power plants are widely distributed, it will be a great help in reducing greenhouse gas emissions from power plants in Chungnam.

INTRODUCTION

About 52% of carbon dioxide emission of the world comes from thermal plants and petrochemical industries. International Energy Agency (IEA) estimated that the demand for energy should increase by 50% in two decades. Consumption of primary energy in Korea as of 1990 was 93,192 million TOEs (Ton of Oil Equivalent) and increased in 2005 to become 228,622 million TOE, indicating an annual average increase of 6.17%. Also, in proportion to energy consumption, greenhouse gas emission as of 1990 was 297,5 million tCO_2eq.(Ton of CO_2 equivalent). In 2005, it was 591.1 million tCO_2eq., indicating an annual average increase of 4.7% and the increase will be continued.

In 2010, Ministry of Knowledge and Economy announced “the Fifth Basic Plan for Power Supply” with an aim to reduce the amount of fossil fuel that generates greenhouse gases. The aim is to increase nuclear power generation up to 50% by 2024 in order to supplement the reduction of fossil fuel. However, nuclear power generation involves difficulties to dispose of wastes and select sites and the base units shall always operate. Considering these problems, fossil fuel-based power generation shall be considered, too, for stable supply in relation to long-term power supply facilities and variable loads.

This study segmented power areas into details, surveyed consumption of each energy type, identified accurate amounts of emission, and used LEAP (Long-range Energy Alternatives Planning model) as one of the 14 greenhouse gas emission policies suggested by United Nations Framework Convention on Climate Change (UNFCCC) as well as energy consumption and VAT prospective in 2010. This was to provide basic data to establish strategies of climate change in Chungcheongnam-do where large-scale power generation facilities are located. This was followed by an analysis of potential amounts of greenhouse gas reduction from long-term greenhouse gas emission as well as introduction and expansion of tidal power, IGCC, and new and renewable facility.

METHODS (WHICHEVER APPLICABLE)

LEAP model

LEAP model is one of the 14 representative reduction policy analyses introduced by UNFCCC Technology Information Clearing House. LEAP model is largely divided into economic, energy, and environment modules. This is a sequential module of a series of processes that decide greenhouse gas emission such as energy consumption-designing exogenous variables, energy consumption, conversion, and supply, and greenhouse gas and air pollutants emission.

LEAP system is modeled through economic and accounting model scenario making. Analysis of reduction policies begins with the base scenario which is divided into BAU (Business as usual), BC (Best case), and Policy Case.

This study used BAU scenarios to analyze future energy consumption with the current trends continued, followed by estimation of energy consumption and analysis of reduction policies.

Scenario-making Method in LEAP Model

LEAP applied in this study was the 2010 version. The study analyzed impacts of replacement of power generation facilities between 2010 and 2030.

In order to use energy economy models, it is necessary to establish a similar current power supply system, necessitating the 2010 “Fifth Power Supply Plan” of Ministry of Knowledge and Economy and the 2011 Korea Power Statistics of Korean electric power corporation (KEPCO). This led to a check of the estimation of capacity, facility life, efficiency, and demand for power of each power generation facility in Chungcheongnam-do.

BAU (Business As Usual) Scenario Making

This study covered power generation facilities in Chungcheongnam-do where most of the bituminous coal power generators that generate greenhouse gases mostly and take up 25% of domestic power generation are located with an aim to estimate greenhouse gas emission. Based on an assumption of power generation arising from construction of tidal power, IGCC, and new and renewable energy facilities to between 2010 and 2030 replaced with existing bituminous coal power generation, changes of power generation by facility as well as greenhouse gases emission was quantitatively analyzed based on LEAP.

Power capacity, amount, and demand for power of this region for BAU estimation were derived based on the annual local energy statistics of Ministry of Knowledge and Economy in 2011 and KEPCO's statistics. In order to write BAU scenarios of this region, estimation up to 2022 was carried out based on "the Fifth Basic Plan for Power Supply" of the Ministry and it was assumed that between 2023 and 2030, the data will remain the same after 2022.

Power generation in BAU scenarios changes according to energy demand and economic and social trends and the basic prospective of the data necessary to write BAU scenarios will be set up departmentally. Socioeconomic indices presented by the government and major professional agencies and demands for energy in various areas were applied.

Providing Alternative Scenario

Alternatives presented in this study analyzed potential reduction of greenhouse gas emission according to replacement of coal and complex power facilities in this region with the construction of tidal power and IGCC facilities.

Scenarios Ⅰ and Ⅱ provided an assumption of replacement of bituminous coal with tidal and IGCC power without any change of the total power generation. Scenarios Ⅲ reflected the government's 2030 power supply plan with an assumption of replacement of 10% of power generation with IGCC and analyzed potential reduction of greenhouse gas emission.

RESULTS

Existing Scenario Analysis

Table. 1 shows the results of greenhouse gas emission based on a BAU scenario. In 2010, the emission was 234.5 million tCO_2eq and in 2030, it was 407.9 million tCO_2eq, an increase by 73.94% from 2010. This comes from an increase of power generation using coal in this area.

Table1. Potential of Greenhouse Gas Emissions

Year / GHGs	2010	2012	2014	2016	2018	2020	2030
BAU(Million tCO2eq)	234.5	237.9	237.2	317.5	407.9	407.9	407.9
Comparison with 2010 GHGs Emission (Increasing rate (%))	-	1.45	1.15	35.39	73.94	73.94	73.94

Alternative Scenario Analysis

Table 2 is the results of greenhouse gas emission of each alternative scenario.

Table 2. Potential of Greenhouse Gas Emissions by Alternative Scenarios

(Units: Million Tonnes CO2 Equivalents)

Year / GHGs	2010	2014	2018	2022	2026	2030
BAU	234.5	237.2	407.9	407.9	407.9	407.9
ScenarioO	234.5	236.2	402.2	402.2	402.2	402.2
Comparison with BAU GHGs (%)	-	0.42	1.4	1.4	1.4	1.4

ScenarioO	234.5	237.2	403.1	389.5	383.1	383.1
Comparison with BAU GHGs (%)	-	0	1.18	4.51	6.08	6.08
ScenarioO	234.5	236.2	397.2	384	368.7	340.8
Comparison with BAU GHGs (%)	-	0.42	2.55	5.86	9.61	16.45

CONCLUSIONS

Without a change to total power generation of each scenario, the amount of existing power generation facilities (bituminous coal) was replaced with that of tidal power and IGCC facilities. Reduction of greenhouse gas emission by scenario, as of 2030, in Scenario Ⅰ, it was 402.2 Million tCO2eq, a decrease of 1.4% from the comparison with BAU. As for Scenario Ⅱ, it was 383.1 Million tCO_2eq, a reduction of 6.1% from BAU. In Scenario Ⅲ, it was 340.8 Million tCO_2eq, a reduction by 16.45% from BAU.

Based on results of this study, it will be difficult to expand the current national energy plan. If we develop and expand IGCC and new and renewable energy which can replace the existing fossil fuel energy, it will be greatly contributory to reduction of greenhouse gas emission.

Currently, the government aims to increase the distribution of new and renewable energy until 2030 but the distribution rate is lower than in other countries. Therefore, it is necessary to ensure more studies from the perspectives of geographic conditions and economic aspects. We will need environment-friendly power generation that makes fuel supply convenient such as IGCC.

However, based on the characteristics of LEAP model, the values are the results of an analysis of the past forms and prospects of future. In the event of replacement of the technologies based on each scenario assumption rather than accuracy in results, it will be appropriate to approach from the perspective of analysis of the impacts.

REFERENCES

Cho Hyeong-hee and Kim Gyeong-min.(2011). A Study to Reduce CO2 and Improve Energy Efficiency in Power Generation Facilities. *Journal of Machines, Vol. 51, No. 5, pp.30* .

Hwang Wook.(2007). [The Fourth IPCC Report] Humans Pinpointed as A Subject Behind Global Warming. *Korea Freedom Federation. pp. 5.*

Kim Hyeon-jin.(2010). Greenhouse Gas Regulation and Corporate DML Carbon Strategies: Examples of the EU and Japan. *Professional Manager Studies, Vol. 14, No. 3, pp.346,*

Lim Jae-kyu et al..(2004). A Study on Foundation of the Third National Report on Climate Change Agreements (Gyeonggi: Korea Energy Economics Institute). *pp. 95-226.*

Park Jae-chan.(2009). An Explorative Study on Sustainable Consumption in the Area of Energy. Sustainable Management Studies, No. 5, pp.73.

SUSTAINABLE ASSESSMENT OF PRODUCTS / BIOMASS MATERIALS

Kenji Ohashi

SHISEIDO CO., LTD.

1-6-2 Higashi-shimbashi, Minatoku, Tokyo 105-8310, Japan

Keywords: CO_2 emissions; water consumption; shampoo; bio-plastics; data management

ABSTRACT

We launched new shampoo series, which bottle is made from Green-Polyethylene (sugarcane-derived PE), in Oct. 2011. In order to confirm the contribution to reduction of CO_2 emissions and increment of water consumption because of using Green-PE, we carried out life cycle CO_2 and water assessment of this shampoo and some bio-plastics. Green-PE can decrease 0.13 kg of CO_2 emissions instead of increasing 0.13 m^3 of water consumption compared to the fossil-derived PE bottle. We have to consider the increase in other environmental impacts as well as climate change issue in economic activities.

INTRODUCTION

Using the biomass materials to suppress the CO_2 emissions is now spreading all over the industries in recent years. On the other hand, it would increase other environmental burden, for example fresh water consumption, to cultivate the feedstock crops. How much water can we use in order to decrease CO_2 emissions? In this study, we carried out life cycle analysis of our product ── Super-Mild Shampoo ── and bio-plastics about CO_2 emissions and water consumption.

Figure 1. Super-Mild Series, which packaging are made from sugarcane-derived polyethylene

RESULTS

1. Life cycle CO_2 and water assessment of shampoo

We launched new shampoo series, which bottle is made from Green-PE, in Oct. 2011. We carried out calculating life cycle CO_2 emissions and water consumption of this shampoo. As a result, the shampoo emits 14.5 kg CO_2eq, and consumes 2.0 m^3 of fresh water through its life cycle. Green-PE can decrease 0.13 kg of CO_2 emissions instead of increasing 0.13 m^3 of water consumption compared to the fossil-derived PE bottle.

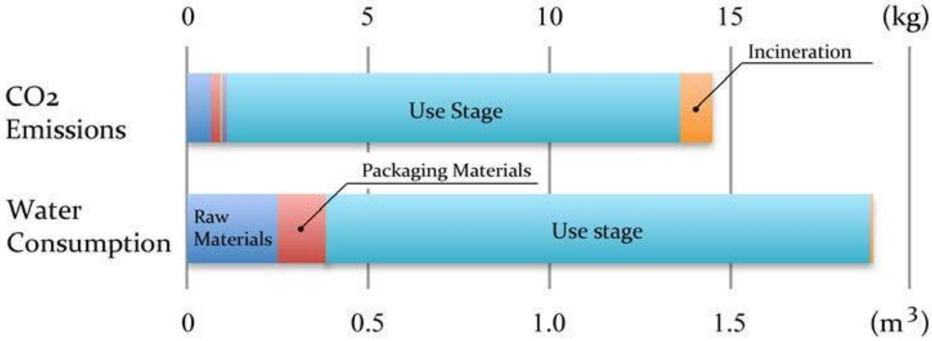


Figure 2. CO_2 emissions and water consumption of Super-Mild shampoo (600mL)

2. Life cycle CO_2 and water assessment of bio-plastics

When we use the biomass materials in order to reduce CO_2 emissions, the water consumption would increase as a trade-off. So we defined "*Water Efficiency*" as following equation and tried to estimate *Water Efficiency* of some bio-plastics, PLA (U.S., Maize, Plant ratio: 100%), PET-1 (India, Sugarcane, Plant ratio: 20%), PET-2 (Brazil, Sugarcane, Plant ratio: 20%) and PE (Brazil, Sugarcane, Plant ratio: 100%).

Water Efficiency = Increment of water consumption [m^3] * Water stress index

/ Decrement of CO_2 emissions [kgCO_2e]

As a result, Green-PE which is adopted in the bottle of Super-Mild Shampoo consumes 1.0 m^3 of fresh water instead of reducing 1.0 kg of CO_2 emissions. Furthermore, the *Water Efficiency* index, that takes into account the water stress of growing area, showed the fact that there is a big difference due to the growing area even in the same kind of bio-plastic. This result indicates the importance of geographic data management on sustainable water use.

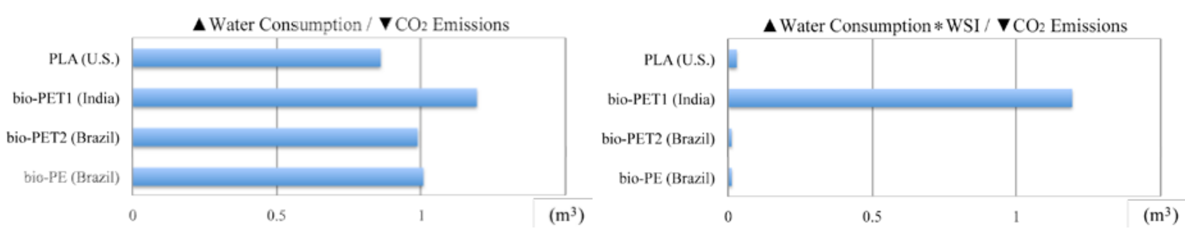


Figure 3. Increment of water consumption and *Water Efficiency* of bio-plastics

DISCUSSION

Using the biomass materials can suppress the CO_2 emissions effectively. However, it leads to an increase in fresh water consumption as a trade-off. We defined a new environmental indicator, *Water Efficiency*, and tried a comparative study about some kinds of plant-derived plastics. As a result, the fact that there is a significant difference in *Water Efficiency* score depends on its cultivation area has come out. This indicator suggests the importance of geographic data management, and it can be easier for us to select more environmental-friendly materials. We will apply it in developing the environmental-friendly products. However, environmental impact that increases as a trade-off to reduce CO_2 emissions is not limited to water consumption. We should consider whether we choose other environmental categories depending on the purpose of the assessment.

Meanwhile, it’s necessary to have a sophisticated data management method to calculate the product life cycle environmental burden. Therefore, we designed a new relational database, named CLIC (Calculator of Life cycle Inventory for Cosmetics), on FileMaker Pro. CLIC can powerfully support us not only product life cycle analysis but also corporate value-chain analysis, with only a few clicks. In these years, the global standards based on LCA method, have been vigorously discussed and developed against the backdrop of heightened concerns over global environmental problems. It’s an essential requirement for all companies to collect, measure, manage and disclose the environmental information. We should accumulate the knowledge and experience about product sustainability assessment, and seek for a way to make a sustainable society.

CONCLUSIONS

In economic activities, it is necessary to consider also the increase in other environmental impacts as well as climate change issue. In addition, we should aim balanced and optimized environmental performance of products. To reach for this goal, it would be extremely important to have an efficient and laborsaving solution for environmental data management.

REFERENCES

Erwin T.H. Vink et al. (2003) Applications of life cycle assessment to NatureWorks polylactide (PLA) production: Polymer Degradation and Stability, 80, 403-419

Satomi Yagihashi, et al. (2012) LCA of polyethylene terephthalate from biomass: The 7th Meeting of the Institute of Life cycle Assessment, Japan

Stephan Pfister et al. (2009) Assessing the environmental impacts of freshwater consumption in LCA: Environ. Sci. Tech., 43 (11) 4098-4104

Winnie Gerbens-Leenesa et al. (2009) The water footprint of bioenergy: Proc. Natl. Acad. Sci. USA, 106 (25): 10219-23

Yasunori Kikuchi, et al. (2011) Life cycle Assessment of Biomass-Derived Polyethylene: The 6th Meeting of the Institute of Life cycle Assessment, Japan

Yuya ONO et al. (2013) Development of Water Footprint Inventory Database Using input-output Analysis in Japan: Journal of Life cycle Assessment, Japan, Vol.9 (2) 108-115

THE EFFECTIVENESS OF WATER FOOTPRINT REDUCTION AND TRADE-OFF AMONG ENVIRONMENTAL CATEGORIES IN THE INTRODUCTION OF INNOVATIVE PACKAGING SYSTEM FOR READY MEAL

Masaharu Motoshita[1], Kiyotaka Tahara[1], Norihiro Itsubo[2], Atsushi Inaba[3]*

1 National Institute of Advanced Industrial Science and Technology, Japan

2 Tokyo City University, Japan

3 Kogakuin University, Japan

** 16-1, Onogawa, Tsukuba, Ibaraki, Japan, 305-0035; m-motoshita@aist.go.jp*

Keywords: Water footprint; Food loss; Impact assessment; Trade-off among environmental categories; Packaging system

ABSTRACT

Food loss may results in significant water availability loss. A new innovative packaging system (MicVac) for ready meals can make it possible to preserve ready meal at maximum 45 days in chilled storage by applying vaccum-sealed package. Water footprint and other whole impacts relevant to ready meals made in conventional way and MicVac were assessed and compared. The results showed predominance of ready meal by MicVac system in both water footprint and full impact assessment mainly due to saving food ingredient input related to unsold meal loss. It could be quantitatively verified that the effects of the increase in power consumption for microwave cooking and chilled storage in MicVac system were relatively smaller compared to the advantage of saving food loss in the perspectives of both water and other relevant environmental issues.

INTRODUCTION

Agriculture is a large user of freshwater. Thus, water footprint of food is generally significant factor in the perspective of water resource management. In Japan, 5-8 million ton of food is wasted annually. In other words, large amount water is lost accompanying with food loss. Reducing food loss is of highly importance in the context of water footprint.

An innovative technology of cooking and pasteurization system for ready meals (MicVac) has firstly developed by the Swedish company, Micvac. In the system, food ingredients and seasoning liguid are filled and sealed in a container and then cooked and pasteurized simultaneously using microwaves whereby MicVac can be preserved for long-term (at the maximum 45 days in chilled storage). Thus, the extension of expiration date can be expected to contribute water footprint reduction of ready meals by reducing food loss at retail stores and households. This technology also practically implemented in Japan by the collaboration of a packaging company (Dai Nippon Printing Co., Ltd.) and a food processing company (Fujicco Co., Ltd.).

The main scope of this study was to verify the effectiveness of the innovative packaging technology on reducing water footprint based on the actually collected foreground data. Additionally, the effectiveness was also assessed from the viewpoint of comprehensive impacts on relevant categories.

METHODS

Scope and system boundary

Both conventional ready meal and MicVac were selected as targets of the assessment. Functional unit was set as 1 package of ready meal, Japanese meat and stew (main content: 250g). Whole life cycle from food ingredient/package/seasoning liquid production to waste disposal (only packages excluding leftover foods) by households including retail and cooking at households was defined as the system boundary for the assessment (Fig.1).

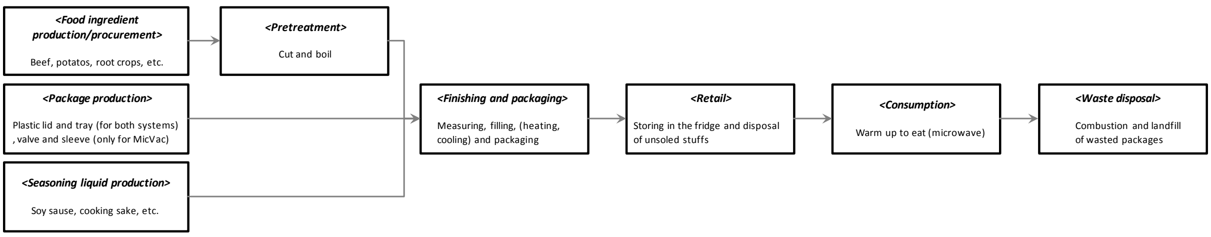


Fig.1 System boundary for the assessment of a conventional ready meal

Data collection

Foreground data on ready meal production was collected by surveying actual input/output amounts of energy and materials on-site. Energy consumption at retail stores was estimated by average power consumption rate of refrigerators and the investigated average term for storing ready meals at retail stores. Unsold loss rates of both ready meals were also surveyed on-site, respectively. At the consumption stage, the conventional ready meal should be consumed within a day cooked, while MicVac was assumed to be stored during three days on average. Based on this assumption, energy consumption of a microwave for warming up and refrigerator at households was calculated.

Inventory analysis and impact assessment

Japanese LCI database (IDEA: Tahara et al., 2012) was adopted for the inventory analysis and relevant impact categories to the items of elementary flow of IDEA were selected as targets of the impact assessment. For water availability footprint, only water consumption (excluding return flow) was accounted as inventory data and characterization factor of water consumption on human health (Motoshita et al., 2010; Motoshita et al., 2011) was applied. Concerning on water footprint profile (including quality degradation effects on water availability), aquatic acidification, eutrophication, human toxicity (aquatic) and eco-toxicity (aquatic) were evaluated by applying characterization factors of LIME2 method (Itsubo & Inaba, 2012). Applied characterization factors on four endpoints (human health, social asset, biodiversity, primary production) were aggregated into a single metric (economic value: willingness to pay for protecting endpoints) by using the weighting factors in LIME2. All relevant other categories were also assessed in the same way by applying the weighted characterization factors of LIME2 (Global warming, ozone layer depletion, photochemical oxidant, urban air pollution (respiratory diseases), resource consumption, waste disposal).

RESULTS

The results of water availability footprint (assessed in the perspective of water consumption) for both conventional ready meal and MicVac are shown in Fig.2. In both systems, significant processes in the context of water consumption were food ingredient production and seasoning liquid production. However, MicVac system can save unsold goods at retail stores and subsequently reduce the net amount of food ingredient input for 1 package production. Water footprint profile in Fig.3 shows integrated impacts on water consumption, acidification, eutrophication, human toxicity (aquatic) and eco-toxicity (aquatic). Physical availability loss by water consumption was dominant compared to other impacts on water availability loss relevant to quality degradation for both conventional ready meal and MicVac. The effectiveness on water footprint reduction by introducing MicVac system could be estimated as around 7.7 % (water availability footprint) and 8.2 % (water footprint profile).

In addition to impacts on water issues, the result of aggregated impacts on relevant categories is shown in Fig.4. Most dominant impact was water consumption in both systems and accompanied with global warming, urban air pollution, and resource consumption. Reduction of whole environmental impacts by introducing MicVac system could be accounted for 13.8 % compared to conventional ready meal.

DISCUSSION

Basically, major differences between both ready meals in their life cycle can be determined as follows.

- Unsold meal loss (advantage in MicVac; disadvantage in conventional ready meal)
- Pretreatment boiling (advantage in MicVac; disadvantage in conventional ready meal)
- Power consumption of microwave cooking and pasteurization at production stage (advantage in conventional ready meal; disadvantage in MicVac)
- Power consumption at retail and household (advantage in conventional ready meal; disadvantage in MicVac)

Above advantages in MicVac could contribute to the reduction of water footprint as shown in Fig.2 and 3. Even though energy consumption for microwave cooking at production stage and storage at consumption stage would increase in MicVac system, saving unsold meal loss seemed to be more critical in the context of water footprint. In other categories like global warming, urban air pollution and resource consumption, additional energy consumption in MicVac system may result in the increase of impacts. However, net impacts on these categories could be reduced in MicVac system compared to conventional system (Fig.4). It indicates that the decrease of unsold meal loss and energy consumption for pretreatment can overcome the impacts of energy consumption increase for microwave cooking and storage term in refrigerators.

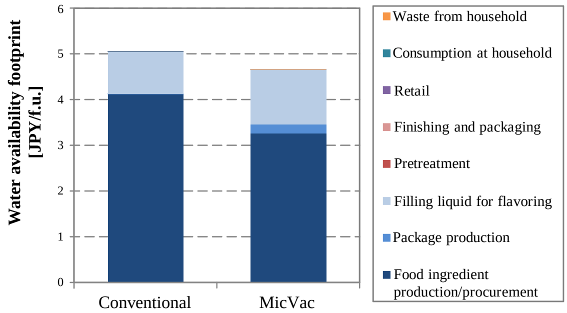


Fig. 2 The result of water availability footprint of ready meals

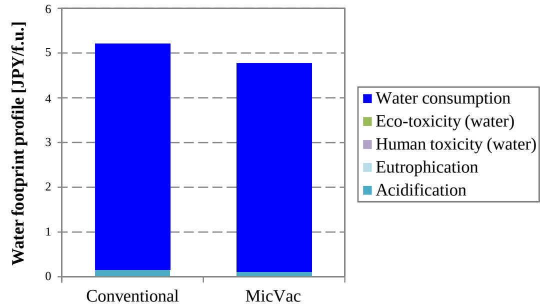


Fig. 3 The result of water footprint profile of ready meals

On the other hand, the effect on water footprint was mainly caused by beef and potato production. Thus, the results may be different in case of other ready meal menu.

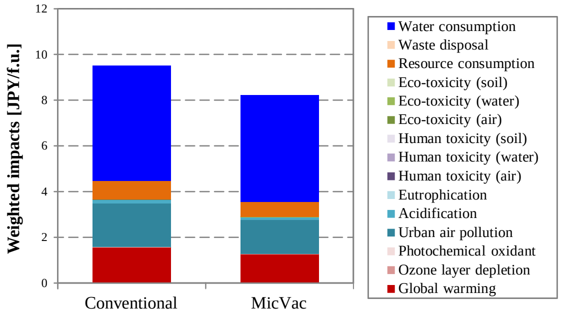


Fig. 4 The full impact assessment profile of ready meals

CONCLUSIONS

It could be verified that the innovative technology for cooking and pasteurization of ready meals can contribute to reduce water footprint of meals by reducing unsold meal loss. The increase of energy demand for microwave cooking and chilled storage in the new system can be fully offset by saving input food ingredient in the perspective of not only water footprint but also full impacts relevant to the system.

ACKNOWLEDGEMENT

Foreground data collection for the analysis were supported by Dai Nippon Printing Co., Ltd. and Fujicco Co., Ltd. The authors sincerely acknowledge their great assistances and meaningful comments.

REFERENCES

Itsubo, N., & Inaba, A. (2012) LIME2 Life-cycle Impact assessment Method Based on Endpoint modeling. *JLCA news English edition*, *14*, Retrived from http://lca-forum.org/english/pdf/No14_C1_Outline.pdf

Motoshita, M., Itsubo, N., & Inaba, A. (2011). Development of impact factors on damage to health by infectious diseases caused by domestic water scarcity. *International Journal of Life Cycle Assessment, 16(1), 65-73.* doi:10.1007/s11367-010-0236-8

Motoshita, M., Itsubo, N., & Inaba, A. (2010) Damage assessment of water scarcity for agricultural use. *Proceedings of 9th International Conference on EcoBalance, D1-1410.*

Tahara, K., Onoye, T., Kobayashi, K., Yamagishi, K., Tsuruta, S., & Nakano, K. (2010) Development of Inventory Database for Environmental Analysis (IDEA). *Proceedings of 9th International Conference on EcoBalance, P-119.*

TOWARD A STRUCTURED FUNCTIONAL UNIT DEFINITION FRAMEWORK TO LIMIT LCA RESULTS VARIABILITY

François Cluzel[1], Yann Leroy[1], Bernard Yannou[1]*

*[1]Laboratoire Genie Industriel, Ecole Centrale Paris
Grande Voie des Vignes, 92290 Chatenay-Malabry, France.*

**E-mail: francois.cluzel@ecp.fr*

Keywords: Life Cycle Assessment (LCA), Goal and Scope definition, Functional Unit, Variability.

ABSTRACT

Functional Unit (FU) ensures the consideration of comparable product quantities to provide reliable Life Cycle Assessment (LCA) results. Although the definition of this FU is essential, it receives only a few attention in the normative texts. A high part of subjectivity is let to the LCA practitioner. In this paper variability sources of the FU definition are identified to propose a more structured and adapted approach. Literature references and data collected among 8 LCA experts on 5 case studies allow us to draw first recommendations towards a more structured FU definition framework.

INTRODUCTION

Life Cycle Assessment (LCA) is performed in product design to measure the environmental performance. In order to ensure the consideration of comparable product quantities to provide reliable LCA results, the concept of Functional Unit (FU) has been introduced. It is well known that LCA is extremely dependent on this FU. It needs to be carefully defined in relation with the objectives of the study. However only a few attention is given in the normative texts to the definition of the FU, which lets a high part of subjectivity to the LCA practitioner. No clear rule is given to define the right FU for a particular study. For this reason, the survey of unresolved problems in LCA proposed by Reap et al. (2008) brings to attention the importance of the definition of the FU as it is a frequent cause of uncertainty.

In the ISO 14040:2006 standard, the FU is defined as the *"quantified performance of a product system for use as a reference unit"* (ISO 14040:2006). This standard, as well as ISO 14044:2006 highlights the FU importance to provide reliable LCA results in comparative assessments. ISO 14044:2006 states that the FU should be clearly defined and measurable (ISO 14044:2006), but no guideline is given to structure it. The ILCD Handbook goes a step further by proposing to define the FU by answering four questions: *"What ?"*, *"How much ?"*, *"How well ?"*, and *"For how long ?"* (Joint Research Center - Institute for Environment and Sustainability, 2010). Cooper also proposes to standardise the FU by considering three factors: magnitude of service, duration of service and expected level of quality (Cooper, 2003). No special attention is given to the function itself. Esterman et al. adopt a Functional

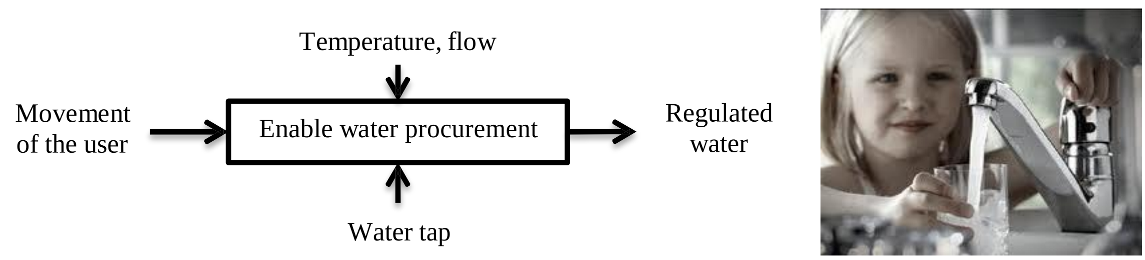
Analysis-based approach to help standardising the FU. They particularly recommend using an active verb-noun pair as the first step to a rigorous FU definition (Esterman, Fumagalli, Thorn, & Babbitt, 2012). Finally, Collado-Ruiz and Ostad-Ahmad-Ghorabi (2010a) introduce the Fuon theory to standardise FUs. *Fuon* stands for Functional Icon and it is defined as *"an abstraction of a product, based on its essential function and representing the whole set of products that share the parameters for this function's flow"*. By identifying the Fuons associated to a product, it is thus easier to define a valid FU and to compare the environmental performance of products sharing same Fuons. However if this framework seems promising to ensure the consideration of comparable products functions, it does not focus on how to identify FU components and how to express the FU itself. In this paper some of these literature findings are tested thanks to FUs provided by 8 experts on different case studies. Then first directions towards a more standardised approach are introduced.

METHOD

The objectives of our research are: (1) To identify among the literature propositions of what are the expected variability sources for the FU; (2) To test on case studies if the consideration of such sources allows a better FU standardisation between different users; (3) To test on case studies what are among these expected variability sources the real ones, i.e. the sources that have a real influence on LCA results; (4) And finally to propose a unified framework to define reliable FUs. In the preliminary research presented in this paper, the gap existing between different FUs is illustrated on a case study by considering the expected variability sources issued from the studies presented in the previous section, and to make first propositions toward a more structured approach. We have asked 8 French LCA experts to define a FU for 5 case studies: a coffee maker, a smartphone, a camera, an electrical motor, and a water tap. Results concerning the water tap are presented in this paper. Five parameters are supervised: *presence of an infinitive verb*, and the four ILCD parameters (*What?*, *How much?*, *How well?*, and *For how long?*).

RESULTS

Figure 1. Simple SADT representation of the water tap



The case study is a mixer water tap for domestic use. A simple SADT is presented in Figure 1 to illustrate the product. 8 FUs were collected from the experts. Examples of answers are *"Allow the flow of cold and hot water to clean the dishes and any other cleaning activity (in litres per day)"*, *"Lifecycle of a mixer tap"*, or *"Enable to obtain water at a given temperature"*. They are qualitatively very different. Table 1 shows the presence or the absence of the five supervised FU parameters. If the two first ones (*Verb* and *What?*) are well represented, it is highly different for the three other parameters. This result shows a high variability of the FU on a same case study for different users.

Table 1. Presence or Absence of the main FU parameters for the 8 water tap FUs

Parameter	Verb	What?	How much?	How well?	For how long?
FU1	Yes	Yes	No	Yes	No
FU2	No	No	No	No	No
FU3	Yes	Yes	Yes	Yes	Yes
FU4	Yes	Yes	No	No	Yes
FU5	Yes	Yes	Yes	No	Yes
FU6	Yes	Yes	Yes	Yes	No
FU7	No	No	No	No	No
FU8	Yes	Yes	No	Yes	No

However, it does not show if the FUs sharing the same elements are similar or not. Going a step further, Table 2 proposes a similarity matrix to analyse the distance between the FUs. The scale used for this assessment is adapted from (Collado-Ruiz & Ostad-Ahmad-Ghorabi, 2010b) and linked with Functional Analysis terminology. *"I"* means *Identical* (same primary and complementary functions even if the quantitative elements are different), *"S"* means *Similar* (same primary functions), *"C"* means *Close* (at least one common primary function) and *"D"* means *Different* (no common primary function). This table shows that even if the same parameters are included in two FUs, they may not be similar.

Table 2. Similarity matrix of the 8 water tap FUs

	FU 1	FU 2	FU 3	FU 4	FU 5	FU 6	FU 7	FU 8
FU 1	I	D	S	D	C	S	D	C
FU 2	D	I	D	D	D	D	D	D
FU 3	S	D	I	D	C	S	D	C
FU 4	C	D	D	I	D	D	D	D
FU 5	C	D	C	D	I	C	D	S
FU 6	S	D	S	D	C	I	D	C
FU 7	D	D	D	D	D	D	I	D
FU 8	C	D	C	D	S	C	D	I

Another analysis that may be performed is to study the LCA perimeter variability associated with each of these FUs. Graphical results are not presented in this paper, but the technical elements (heating system, pipes, sink…) or even the user may be easily included or excluded from the study perimeter by considering the FUs. So 5 different perimeters are obtained with the 8 FUs, which may probably conduct to different LCA results.

DISCUSSION

At this point, first recommendations to standardise FU definition may be formulated. Even if LCA results associated with our case studies are not yet available, it is evident that the lack of accurate guidelines or formal elements to compose a FU leads to a high variability of FU on a same case study. With 8 FUs sharing some elements or functions, 5 different LCA perimeter potentially associated with contradictory conclusions and decisions are obtained. Starting from the existing literature, our first recommendations are to gain experience from the Functional Analysis field, which permits rigorously defining primary and complementary functions as well as constraints based on a verb-noun structure. We also propose to structure each of these functions around the four elements of the ILCD Handbook : the form of the output (*What?*), the magnitude (*How much?*), the performance (*How well?*) and the duration (*For how long?*). Moreover the results presented in the previous section raise some issues that need to be further analysed in future studies. The first one consists in analysing using appropriate LCA simulations the contribution of each of these formal elements to assess if they are really necessary to define a valid FU or not. The second one is to work on guidelines or methods to limit the variability in the content of each formal element. A complementary study has been started to assess FU variability for the same user according to the level of information and training he has.

CONCLUSIONS

We have proposed in this paper a synthesis of existing studies concerning Functional Unit definition in LCA. Starting from these literature references, some expected sources of variability have been highlighted and tested on case studies. Results show the importance of structuring the FU with such elements, but also the need to offer clear guidelines concerning the content of these elements themselves. Future work will deal with the realisation of LCAs to precisely determine the contribution of each element to the LCA results, and thus to go a step further toward a more structured FU definition framework. The contribution of Functional Analysis seems promising.

REFERENCES

Collado-Ruiz, D., & Ostad-Ahmad-Ghorabi, H. (2010a). Fuon theory: Standardizing functional units for product design. *Resources, Conservation and Recycling*, *54*(10), 683–691. doi:10.1016/j.resconrec.2009.11.009

Collado-Ruiz, D., & Ostad-Ahmad-Ghorabi, H. (2010b). Comparing LCA results out of competing products: developing reference ranges from a product family approach. *Journal of Cleaner Production*, *18*(4), 355–364. doi:10.1016/j.jclepro.2009.11.003

Cooper, J. (2003). Specifying functional units and reference flows for comparable alternatives. *The International Journal of Life Cycle Assessment*, *8*(6), 337–349. doi:10.1007/BF02978507

Esterman, M., Fumagalli, M. E., Thorn, B., & Babbitt, C. (2012). Towards parametric environmental profiles of complex industrial systems in preliminary design stage. In *Proceedings of the ASME 2012 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, IDETC/CIE 2012*. Chicago, Illinois, USA.

International Organization for Standardization. (2006a). *ISO 14040:2006 - Environmental management - Life cycle assessment - Principles and framework* (ISO Standard).

International Organization for Standardization. (2006b). *ISO 14044:2006 - Environmental management - Life cycle assessment - Requirements and guidelines* (ISO Standard).

Joint Research Center - Institute for Environment and Sustainability. (2010). *ILCD Handbook - General guide for Life Cycle Assessment - Detailed guidance v1.0* (No. EUR 24708 EN). European Commission.

Reap, J., Roman, F., Duncan, S., & Bras, B. (2008). A survey of unresolved problems in life cycle assessment - Part 1: goal and scope and inventory analysis. *The International Journal of Life Cycle Assessment*, *13*(4), 290–300. doi:10.1007/s11367-008-0008-x

EXPLORING CHALLENGES AND OPPORTUNITIES OF LCM AND LCA FOR THE INDUSTRY: PANEL

Wednesday, Aug 28:	10:30 am - 12:00 pm
Session chairs:	Martina Prox, ifu Hamburg GmbH, Germany Mieke Klein, ifu Hamburg GmbH, Germany

A FRAMEWORK VISUALISING CHALLENGES AND ENABLERS TO SUCCESSFUL LCM UPTAKE IN PRIMARY INDUSTRY SECTORS

Helene Sterzik[1,2,3], Sarah J McLaren[1,2], Anthony Hume[2,3], Elena Garnevska[1] and James E McDevitt[2,4]*

[1] Massey University, New Zealand
[2]New Zealand Life Cycle Management Centre
[3]Landcare Research, Wellington, New Zealand
[4]Scion, Wellington, New Zealand
**H.Sterzik@massey.ac.nz*

Keywords: Life cycle management; sector-based approach; New Zealand kiwifruit industry.

ABSTRACT

There is a rising awareness of environmental problems amongst organisations in the primary industries as these businesses rely heavily on natural resources. So far, research has focused on LCM implementation in individual companies to reduce environmental impacts. However, this research explores the sector-based approach as an opportunity to successfully implement LCM in primary industry sectors. A generic framework has been developed that describes the barriers and enablers to successful LCM uptake in primary industry sectors, based on the bodies of literature on LCM, SMEs, supply chain management and technology transfer. These aspects have been tested and verified through face-to-face interviews and a large scale survey with the main decision makers in the kiwifruit industry in New Zealand.

INTRODUCTION

There is a rising awareness of environmental problems and wider sustainability issues amongst governments, industries and consumers (Green Growth Advisory Group, 2011; McLaren, 2008). Due to the growing relevance of the topic, there are an increasing number of drivers for companies to integrate LCM initiatives into their business practices.

New Zealand is an exporting country and the economy relies heavily on primary products: according to Statistics New Zealand, in 2010, nearly 70% of all export products were primary products. At the same time, New Zealand has a reputation for being 'green and clean' but in order to maintain and reinforce this positive reputation in global markets there is a need to implement strategies and develop management systems to back it up.

However, the progression towards more environmentally benign practices represents a challenge for many businesses in the primary industry. Most of them can be classified as SMEs, and SMEs are known to find it particularly difficult to integrate sustainability strategies effectively into their operations due to their specific characteristics, such as limited financial and human resources and lack of expertise in sustainability (Hillary, 2000; Seidel, 2011). So far, only a small number of SMEs have actually integrated a life cycle approach into their business operations and decision-making processes. Current initiatives are ad hoc and limited to individual companies within sectors.

The focus of this research is on the uptake of LCM initiatives in the New Zealand primary industry. In particular, it examines the sector-based approach to implementation of LCM in the New Zealand kiwifruit industry as an effective way of driving change in an industry and reinforcing New Zealand's clean and green image. By applying a sector-based approach rather than an approach that focuses on individual organisations, arguably there is greater potential for reducing environmental impacts associated with an industry sector – and this will lead to competitive advantages in the marketplace.

APPROACH

This research can be divided into two parts. Firstly, a generic framework has been developed showing diagrammatically the major aspects faced by an industry sector during the uptake of LCM initiatives (Figure 1). These aspects have been compiled based on the literature on SMEs, supply chain management and technology transfer.

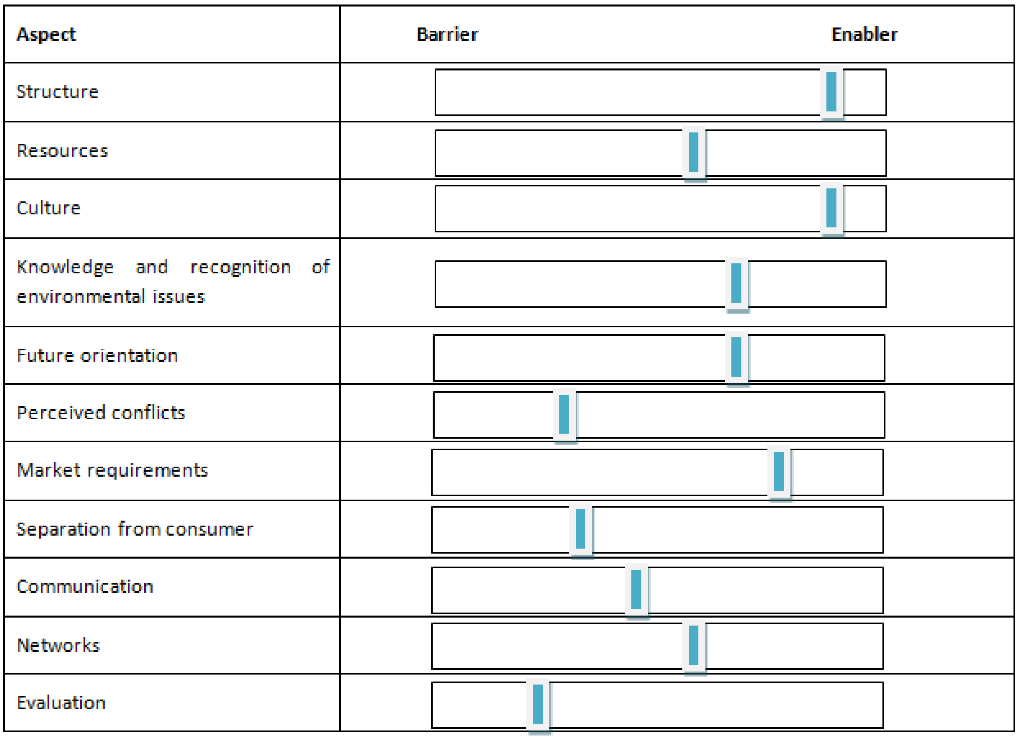


Figure 1: Analysis of Enablers and Barriers for the Kiwifruit Sector to LCM uptake

The second part of the research involves a study in the New Zealand kiwifruit industry to test the framework. This industry has been chosen because it is New Zealand's largest single horticultural export by volume and value, exceeding $1billion of exports in 2012 (New Zealand Horticulture Export Authority, 2012). Furthermore, due to the restructuring Act 1999, Zespri Group Ltd is a single desk exporter with the exclusive rights to export and market New Zealand kiwifruit to countries other than Australia.

Methods being used to test the framework but also to get a deeper insight into the kiwifruit supply chain structure; and to determine whether the New Zealand kiwifruit sector experiences the same barriers and enablers to implementing LCM as those identified in the international academic literature, were semi-structured face-to-face interviews as well as an online survey with the main supply chain entities in the industry.

During this research, seven organic growers (four small businesses, one medium sized business and two large businesses) and 13 conventional kiwifruit growers (three small businesses, two medium sized and eight large businesses) have been interviewed. The researcher also interviewed ten employees from post-harvest operators and two employees from Zespri. The interviews took place in the The Bay of Plenty as this is the focus of kiwifruit growing (principally Katikati, Te Puke, Tauranga and Opotiki); it produces 81% of the total New Zealand kiwifruit crop.

RESULTS

Industry sectors operate in a very complex and dynamic environment. The framework described in this paper analyses and summarises the major barriers and enablers faced by industry sectors during the uptake of LCM initiatives. These are a combination of factors affecting individual companies, in particular SMEs, and factors related to supply chains and technology transfer processes.

The list of barriers and enablers to sector-wide uptake of LCM can be summarised as: fragmented industry structure; limited resources (financial, human, technical); unsupportive culture; limited knowledge and recognition of environmental issues; lack of future orientation; perceived conflicts between environmentally friendly practices and other business objectives; lack of demonstrable market requirements/pressure from supply chain partners; geographical separation of production and consumption; communication barriers; and weak networks.

Structure refers to structure within an organisation as well as the structure along the supply chain. It includes criteria such as division of labour as well as hierarchies of decision making, coordination and communication. Structure is closely related to the culture within an organisation and supply chain.

LCM uptake can only be successful if these barriers can be overcome. In many cases, the individual companies face difficulties due to their limited financial **resources**, which directly impacts human and technical resources. But resources are also pivotal at sector level in order to successfully network with other supply chain parties and the external environment. Thereby, knowledge and experiences can be shared in order to facilitate LCM uptake in individual companies and the entire industry sector. The **culture** of individual companies and a sector also plays a significant role in the success of LCM uptake. Culture incorporates values and beliefs and if these interfere with the belief that sustainability plays an important role for a company and an industry sector, then change of attitudes and behavior within the sector can be very difficult. On the other hand, a culture that supports the concept of environmental responsibility can facilitate the uptake of LCM.

Limited knowledge and recognition of environmental issues also impede successful LCM uptake in sectors and companies. It shows that education and awareness of environmental issues need to be improved through successful knowledge transfer from companies with success stories, as well as from researchers who develop tools and processes to facilitate LCM uptake. Limited knowledge is closely related to the **lack of future orientation** and **lack of market requirements**. If companies and sectors do not experience pressure to incorporate LCM into their operations they might prioritise other projects that do not incorporate sustainability initiatives. One barrier for organizations in LCM uptake is the perceived **trade-off between sustainability objectives and other business objectives**. Usually, businesses prioritise projects according to time and cost. If projects are vague in their financial return in the short term, SMEs in particular are unlikely to start them. Another aspect is the **separation of production and consumption**, which leads to diffused responsibility for the environmental impacts of products. **Communication and networking** is important for successful LCM uptake across a sector. It is important to develop a structure and culture that allows open and honest communication in order to develop a vision that is shared by all supply chain parties and develop and keep track of short- and long-term objectives. Communication then allows each supply chain party to see where the individual initiative fits in the bigger picture. Effective networks and contacts can facilitate knowledge management amongst supply chain parties and external environment and pool knowledge from different perspectives in order to respond appropriately to stakeholder requirements.

CONCLUSION

In conclusion, the main enablers for the kiwifruit sector are their specific monopoly structure, the culture, the knowledge and recognition of environmental issues as well as the future orientation and awareness of market requirements.

Lack of financial resources as well as appropriate technical resources create a barrier for this industry in the successful uptake of LCM. This is closely related to the perceived conflicts between business objectives which do not lead to priorisation of LCM initiatives at the moment. The separation from consumers is particularly a barrier for growers and post-harvest operators. Communication, networks and evaluation should also be improved in order to serve as enablers for successful LCM implementation sector-wide.

REFERENCES

Green Growth Advisory Group. (2011). *Greening New Zealand's Growth.*

Hillary, R. (2000). *Small and medium-sized enterprises and the environment: business imperatives:* Greenleaf Publishing.

McLaren, S. J. (2008). *Defining a role for sustainable consumption initiatives in New Zealand.*

New Zealand Horticulture Export Authority. (2012). *Kiwifruit industry profile*, from http://www.hea.co.nz/index.php/2012-05-11-03-05-28/kiwifruit-trade

Seidel, M. (2011). *Towards Environmentally Sustainable Manufacturing: A Strategic Framework for Small and Medium sized Enterprises.* PhD, The University of Auckland.

CHANGES IN ENVIRONMENTAL IMPACTS OVER TIME IN THE FAST DEVELOPING ICT INDUSTRY

Dag Lundén* and Jens Malmodin**
*TeliaSonera AB, Broadband Services, SE-123 86 Farsta, Sweden (Corresponding author).
**Ericsson AB, Ericsson Research, SE-164 83 Stockholm, Sweden.
daglunden@teliasonera.com and jens.malmodin@ericsson.com

Keywords: LCA; ICT; Carbon footprint; Electricity; Energy

ABSTRACT

The information and communication technology (ICT) sector is changing: Data volumes and ICT usage is growing exponentially, ICT infrastructure is shared by many services instead of used only by voice, the volume of end user (customer) devices is increasing but at the same time the telecom operator's internal electricity consumption remains almost constant. This paper elaborate on identified trends during the period 1990 to 2010 using data from several LCA studies over time to conclude what implications can be drawn on the estimated environmental impact.

INTRODUCTION

The ICT sector has since Alexander Bell invented the telephone in 1876 (Whether Mr. Bell invented the telephone or not is another story) been under constant development. However the resent years rapid data volume increase in combination with increased mobility, new technical solutions and services have changed business models, energy consumption patterns as well as ICT's environmental impact. In this paper environmental impact is based on LCA and exemplified by energy consumption and CO2e emissions. In the early age of voice communication electricity was centrally distributed via the copper wire, i.e. the phone was passive and powered from a centralized exchange. Without the wire the phone was dead. When TeliaSonera (Telia up to 2003) performed the first LCA of a fixed telephony subscription service (Lindroth 1999) the result showed that the main environmental impact originated from powering the local exchange sites. The end user equipment had a minor part from an LCA perspective even when manufacturing was included.

But the situation has changed dramatically and the largest change has occurred during the last 10 years despite the sectors 130 year of history. An increased mobility in the society (Always connected!), streamed video services and growing numbers of personal ICT devices is increasing transported data volumes. In 1990th the mobile phone was limited to a few, in 2011 the situation was the opposite and there's almost one "smart phone" per person plus personal Tablet's, Laptops etc. in addition to the increased use of other connected devices (M2M). The usage of ICT based services has increased and the total data volumes is at least doubled every third year. Simultaneously information storage and processing have been moved in to "the cloud". Or to be more precise, in to one or more of the growing large data centers that have emerged during the last couple of years. Google and Facebook are probably the most known but there are other actors as well, not the least traditional telecom operators.

MATERIALS AND METHODS

TeliaSonera operates a large part of Sweden's core and access networks and has about 40% of all ICT subscriptions (PTS 2011). Figure 1 shows a summary of 10 years of operational data.

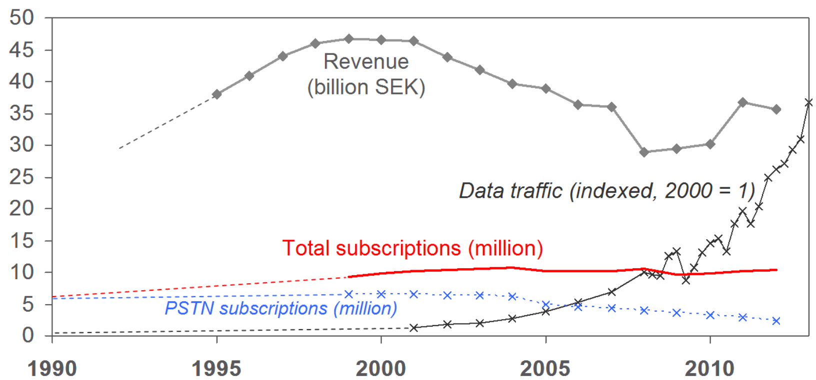


Figure 1. Revenue, total number of subscriptions, fixed telephony (PSTN) subscriptions and data traffic (indexed) for TeliaSonera operations in Sweden 1990-2011. Units shown in graph.

The total volume of subscriptions has grown from about 6 million fixed telephony subscriptions to about 10 million ICT subscriptions (fixed, mobile and IP telephony, mobile and fixed broadband and IPTV) in addition to TeliaSonera's core network traffic that today carries a large part of Sweden's enterprise data. Total data traffic including voice expressed as data has increased about 100 times and is still growing with approximately 30% per year. Revenue was higher in 2000 but is now on par with the revenue in 1995. The number of employees has decreased from more than 40000 to less than 10000. From energy consumption perspective a holistic approach has been applied and in this study all ICT connected user and network equipment have been included. The connected devices electricity consumption has increased substantially and is now about 4 times larger than the energy used by TeliaSonera's network, which used to be the main consumer in the past, see Figure 2. The Networks electricity consumption has been almost flat despite the growth in subscriptions, data rates and data traffic due to overall better network performance.

There are some data gaps due to the fact that the first thoroughly energy assessment was performed as late as in 1996 however existing data have been extrapolated to close these.The total ICT energy includes historical estimates of IT equipment based on energy investigations of buildings in 1990 (a) and in 2005 (b) (Swedish Energy Agency 2009) together with estimates of offline/modem connected PCs. The year 2010 (c) is based on the most recent study of ICT in Sweden (Malmodin et al 2013). Note that network energy (d) represents the primary energy content in fuel consumed while all other parts represent electricity consumption (secondary energy).

Figure 2 shows the convergence of IT and telecom into ICT. Connected IT equipment (data centers, LANs, PCs) has not been modeled in detail besides for recent years. The historical connectivity towards the Swedish ICT network has been modeled from 0% in 1995 to 100% in 2010. The increase in electricity consumption is mainly related to user equipment and data centers. The impact from fixed telephony equipment (office and cordless phones, answering machines etc.) that used to have high stand-by consumption is decreasing due to lower usage.

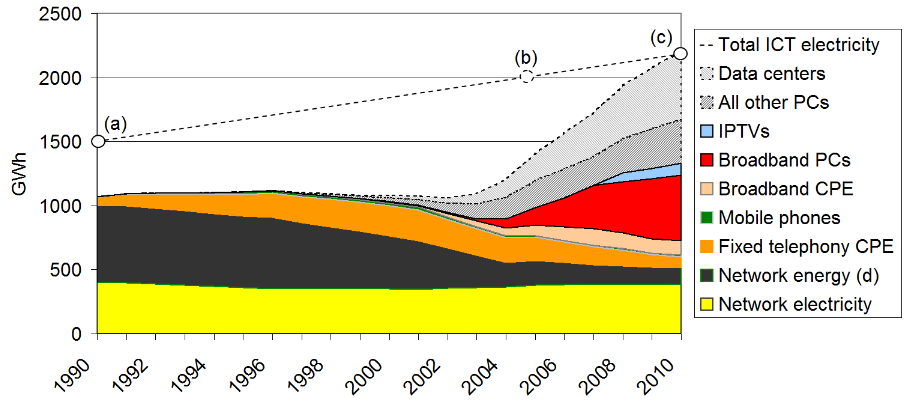


Figure 2.Electricity consumption of connected user and network equipment to TeliaSonera networks 1990-2010.

The performance of connected business related IT equipment is in control of business customers. The energy performance of private user equipment is mainly controlled by private customers but TeliaSonera as service provider is partly able to influence the actual performance on these in relation to energy and environmental impact.

RESULTS

The total carbon footprint for TeliaSonera operations in Sweden including all connected user and network equipment as described in Materials and Methods are shown in Figure 3.

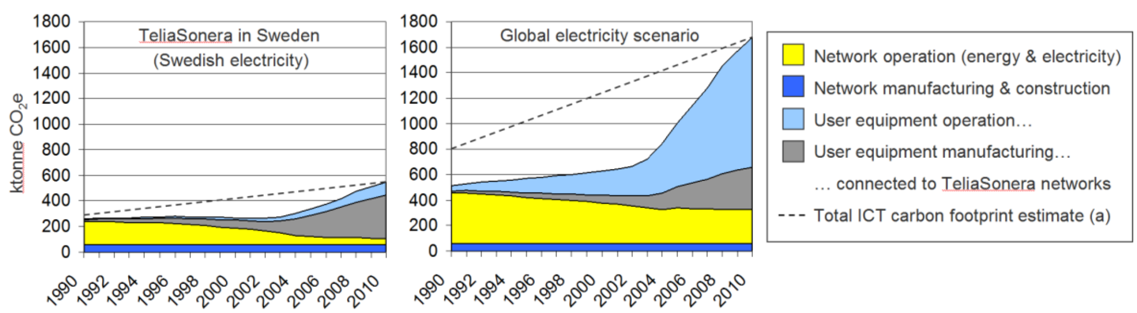


Figure 3. Total GWP (Global Warming Potential) results expressed as CO_2e (carbon dioxide equivalents) for TeliaSonera operations in Sweden 1990-2010. Including all (a) connected user and network equipment (data centers, LANs, PCs) as described in Materials and Methods also including all related manufacturing (embodied emissions).

If Swedish electricity mix is used manufacturing of user equipment (mainly PCs) abroad becomes the largest source of CO_2e emissions. Import of ICT products is also the reason why the absolute footprint has doubled since 1990. But if Swedish electricity mix is replaced by a global average the operation of user equipment becomes the main source for the growth and the main source of absolute carbon footprint (4 times larger than the actual footprint in Sweden in 2010). The global electricity scenario is similar to an average ICT scenario in developed countries. The average footprint in Sweden is 70 kg CO_2e per subscription, 160 kg CO_2e per person. On a global perspective this would be about 2-3 times higher per subscription or person with equal ICT use as in Sweden (Malmodin 2011).

DISCUSSION

The presented data shows that the ICT industry is expanding, the volume of connected devices is increasing and ICT is reaching more people, not the least via wireless communication. The number of fixed connections is increasing steadily but with a lower phase. In addition "cupper line" access in the past only used for PSTN is now shared by new fixed services. From a user perspective traditional voice communication is replaced by instant messaging services (IMS) such as SMS and chat.

TeliaSonera's core network energy consumption has been constant despite the huge data volume increase. However since end user devices requires local powering as well as " cloud data" and since the total number of devices is exploding the total ICT electricity consumption and the total environmental impact is increasing. But since the total impact is shared by more subscriptions the impact per subscription remains the same or decreases, the later one related to mobile services. The impact per data bit has been reduced by more than a factor of 10 since 2000 despite the growth in the ICT sector.

From a LCA perspective the large impact from end user equipment's embodied footprint is uncertain and especially in Sweden with low carbon electricity the embodied carbon footprint will have a larger relative impact. However in a global perspective with fossil based electricity the usage will have a larger share and by this the uncertainty is reduced.

CONCLUSIONS

Based on the change in ICT usage, the data volume increase in combination with changed usage behaviors it's obvious that it makes little sense comparing ICT studies from 1990ths with studies from 2012. The few conclusions that can be drawn are:

- The environmental impact per connected device and data volume are lower than in the past due to increased shared infrastructure.
- End user equipment's total share of ICT's environmental impact including the impact from shared data centers is increasing.
- To decrease ICT's total environmental footprint efforts should be focused on reducing electricity consumption in core sites, data centers as well as in end user devices.

REFERENCES

Lindroth, M. 1999. Livscykelanalys av telefoniabonnemang (In English: Life cycle assessment of fixed telephone subscription services). TeliaSonera internal report, externally verified by IVL2000.

Malmodin, J. and D. Lunden. 2011. Life-cycle assessment of ICT networks and primary subscription services in Sweden. Abstract & presentation. NorLCA, 15-16 September 2011, Helsinki. www.dtu.dk/upload/norlca/malmodin%20&%20lunden.pdf

Malmodin, J., D. Lunden.,Å. Moberg., M. Nilsson and G. Andersson. 2013. .Life cycle assessment of ICT networks – carbon footprint and operational electricity use from the operator, national and subscriber perspective. Submitted article, not yet accepted.

PTS. 2011. The Swedish telecommunications market 2011. The Swedish Post and Telecom Authority: statistik.pts.se/pts2011e/download/The%20Swedish%20Telecommunications%20Market%202011.pdf

Swedish Energy Agency. 2009. Energy statistics for non-residential premises 2007. ES 2009:05. www.energimyndigheten.se/stil2

INCORPORATION OF LIFE CYCLE MANAGEMENT IN PRODUCING DICALCIUM PHOSPHATE: A BRAZILIAN EXPERIENCE

Martinho, Henrique Miguel , Kulay, Luiz, Polytechnic School of the University of Sao Paulo, Av. Luciano Gualberto, 308, tr.3 – 05508-900, Sao Paulo, Brazil, henrique.martinho@usp.br*

Keywords: dicalcium phosphate, sulfur, Life Cycle Management, LCA, Continuous Improvement

ABSTRACT

An organization within the Brazilian fertilizer sector is proposing to search for alternatives towards environmental performance improvement for the dicalcium phosphate's production process. This analysis comprised an LCA within an approach of cradle-to-gate, for obtaining 1 ton of the product. The main environmental impacts were associated with the extraction of sulfur - a resource fully acquired via importation - and its logistics. So it was decided to follow using the Life Cycle Management in the decision-making process related to the selection of suppliers of sulfur, performing an analysis based on Eco-efficiency, relating the costs of obtaining and shipping sulfur with the environmental impacts associated, allowing suppliers classification from an economic and environmental criterion.

INTRODUCTION

Dicalcium phosphate ($CaHPO_4.2H_2O$, DF) is used in the composition of dog food, mineral salts, and other products and other products spread with the livestock sector. Nevertheless, its manufacture is not absent from causing impacts on its surroundings. This occurs not only by way of the inexorable consumption of phosphate rock – a natural resource considered by many as the strategic reserve of a nation – but also because of the demand for water, sulfur, additives, energy, other processing agents. Also negatively affect the environment the liquid effluents, gaseous emissions, solid residues, land transformation and vegetation suppression originating from the mining activities.

Features like these have motivated an important organization within the fertilizer industry in Brazil to assess the environmental performance of the technological route practiced by it in the manufacture of DF. The organization expects with this effort, not only to reduce costs related to the process, but also to present itself in the market as a proactive company in terms of environmental sustainability. In terms of working method for the study was structured in three phases.

Phase 1 comprises conducting a LCA to identify opportunities of environmental performance improvement. This diagnosis makes it possible that in Phase 2 be structured specific scenarios in which problem previously identified can be evaluated in more detail in terms of its causes and consequences.

Phase 3 of the project performs an analysis in which economic and environmental variables are reconciled to provide subsidies for management decision-making of the executive team of the company.

To be carried out Phase 1 of the method for production of 1.0 ton DF were identified different potential sources for the implementation of improvement actions. Among these stood out the impacts associated with the obtaining and transport of sulfur, an essential asset to the production of dicalcium phosphate. This article describes and discusses in more detail this case.

PHASE 1: LCA FOR DICALCIUM PHOSPHATE

LCA for DF was carried out to comply with the patterns defined in ISO standards 14040:2006 and 14044:2006. The goal of the study consisted in identify environmental impacts occurred along its production. In this frame, a methodological approach of cradle-to-gate used. Regarding to Scope Definition it was established as Reference Flow: "*to produce 1 ton DF*". the product system under analysis considered the elementary processes of phosphate rock treatment – which are made up of the washing, crushing and classification operations –; obtaining the phosphate concentrate; the importing of sulfur; H_2SO_4 and H_3PO_4 productions; the extraction of limestone (calcium carbonate) and the production of dicalcium phosphate. In addition, the unit processes of industrial water and effluents treatments, the production of electricity by cogeneration and the electricity acquired from the Brazilian grid were included.

The application of cut-off criteria followed the guidelines given in NBR ISO 14044 (2006). Stood by exclusion limit 1.0% of cumulative contributions. Resource consumption and waste generation from DF manufacture were modeled by primary data. The same occurred with transports and the industrial utilities production. Other product systems – the production and transport of sulfur and of electrical energy acquired from the grid – were modeled by using secondary exhaustively adapted for the process conditions (Althus et. al. 2009).

Temporal Dimension comprised a continuous historical series of twelve months along 2011. Geographical Dimension selected the State of Sao Paulo because this is the region in which the DF manufacturing unit is installed. For the specific case of sulfur, the productive regions within countries from which importation occurs, were identified, namely: Germany, Canada, United Arab Emirates, the United States, Italy, Qatar and Russia.

Technology Coverage considered the average technology practiced by the organization at the time of data collection. Energy content was applied as the allocation criteria between vapor and H_2SO_4. In whatever other situation mass criteria was employed. Life Cycle Impact Assessment (LCIA) was carry out by the method ReCiPe – midpoint (H) v 1.07. Only impact categories of interest for analysis were taking into account. Thus, no longer were considered Urban Land Occupation, Marine Eutrophication and Ecotoxicity, Ionization Radiation, Metal Depletion and Natural Land Transformation (Goedkoop, et al. 2012).

This LCA allowed for the identification of the H_3PO_4 and electricity cogeneration processes as the stages with the greatest impact in obtaining of 1.0 ton DF. Together with the electricity acquired from the concessionaire, such unit processes figured as major contributors in twelve of the thirteen categories analyzed.

However, must to be highlighted common influence upon both processes for the production of H_2SO_4. In this context, the importation of sulfur – whose logistic reformulation could be carried out, taking into account the environmental variable as a benchmark – would become the target of potential improvement actions, as well as the losses of SO_x to the atmosphere.

If such effects were to be damped down, one could then think of increasing cogeneration already in operation at the unit, to levels that would allow for no longer having dependence on energy supplied by the Brazilian grid. Such non-compatibility must occur, only and merely, after taking care of the rationalization of the raw materials of the process itself.

PHASE 2: LCA FOR DICALCIUM PHOSPHATE

In Phase 2 the diagnosis made in the previous step was taken in order to investigated in more detail the problems identified. Three scenarios of analysis were defined: Scenario A: *Sulfur import*, Scenario B: *Phosphoric acid production* and Scenario C: *Rationalization of energy consumption*.

The team responsible for the evaluation of scenario A made a survey of parameters associated with origin and logistics sulfur acquired by the company. Table 1 present these data.

Table 1: Logistical information about the supply of sulfur

Country	Extraction technology	Local of extraction	Modal transportation Facility-Port	Port of departure	Modal transportation Port-Port	Port of arrival
Russia	Natural gas sweetening	Astrakhan	Barge + Rail	Kavkas, Kerch, Ust Luga	Transoceanic	Santos-SP
Germany	Petroleum refining	Brake	Rail	Brake	Transoceanic	Santos-SP
United Arab Emirates	Natural gas sweetening	Abu Dhabi	Road by truck	Ruwaiss	Transoceanic	Santos-SP
Canada	Natural gas sweetening	Edmonton + Calgary	Rail	Vancouver	Transoceanic	Santos-SP
Italy	Petroleum refining	Genoa	Road by truck	Genoa	Transoceanic	Santos-SP
United States of America	Petroleum refining	Texas City + Beaumont	Rail	Beaumont + Long Beach	Transoceanic	Santos-SP
Qatar	Natural gas sweetening	Ras Laffan	Road by truck	Ras Laffan	Transoceanic	Santos-SP

This information allowed the construction of individual models of product systems for the sulfur acquired at each location. Apart from the transoceanic displacement, also terrestrial distances were identified in accordance with each specific modal of transport.

After being completed this intermediate step LCIA method ReCiPe – endpoint (H) v 1.07 with normalization model World H / H was applied to each of the situations. Once again, there were considered only the impact categories selected for the Phase 1. The application of the method led to development of single scores for each transport logistics and obtaining of sulfur.

Table 2: Environmental Performance and Unitary Costs of production and transport of sulfur

Countrv	Unitary Cost (C) (US$/ton)	Environmental Performance (E) (Pt)	F = (C * E) ^ 0.5
Russia	227	107	155.85
Germany	227	94.2	146.23
United Arab Emirates	228	102	152.50
Canada	227	103	152.91
Italy	227	92.4	144.83
United States of America	217	102	148.77
Qatar	228	100	151.00

Parallel to that the team in charge of analyzing collected data on the costs associated with these operations. The result of this survey and the application of the recipe - Endpoint as single score for each scenario under study appear in Table 2.

PHASE 3: ENVIRONMENTAL – ECONOMIC PERFORMANCE: JOINT ANALYSIS

The F factor represents the geometrical means between E and C. Considering this indicator the sulfur provided by Russia presents the worst environmental-economic performance among the alternatives under analysis (155.85). At the other end of a possible ranking of suppliers are located respectively products imported from Italy and Germany. The derivative shows German environmental performance but slightly higher than its counterpart (1.9%). Another aspect that should be highlighted is the profile similarity between sulfur imported from North America, with that originating from the Middle East. Considering that the transoceanic distances are greater from Asia, the product originating at that location was able to compensate for this deficiency with lower impacts on terrestrial and displacements in the extraction process.

CONCLUSIONS

LCA technique supported the decision-making process for selection of suppliers of sulfur answered adequately the expectations of the company. From this approach, it was possible to assess the environmental performance of discretized way of alternatives. Income generated from this analysis can then be appropriately harmonized with economic indicator.

REFERENCES

ABNT – Associação Brasileira de Normas Técnicas, 14.044, (2009). *Gestão ambiental - Avaliação do ciclo de vida - Requisitos e orientações.* Rio de Janeiro. 44p.

Althaus, H.J.; Hischier, R.; Osses, M. (2007). *Life Cycle Inventories of Chemicals. Ecoinvent report. N^{o}. 08.* Ecoinvent Centre. Dübendorf. pp 541- 542.

Goedkoop, M., Heijungs, R., Huijbregts, M., de Schryver, A., Struijs J, (2012). *Description of the ReCiPe methodology for Life Assessment Impact Assessment.* retrieved from http://www.lcia-recipe.net

The 6th International Conference on Life Cycle Management in Gothenburg 2013

PROMOTING ENERGY SAVINGS AND GHG MITIGATION THROUGH INDUSTRIAL SUPPLY CHAIN INITIATIVES

Amelie Goldberg, Julia Reinaud*, Giel Linthorst***

**Institute for Industrial Productivity, 5 rue du Helder, 75009, Paris, France, amelie.goldberg@iipnetwork.org, julia.reinaud@iipnetwork.org*

*** Ecofys, Kanaalweg 15G, 3526 KL Utrecht, The Netherlands, g.linthorst@ecofys.com*

Keywords: Supply chain initiative, effectiveness, case study, success factors

ABSTRACT

Supply chain initiatives (SCIs) are structured interventions by companies that are able to exert significant leverage with their suppliers. SCIs targeting energy and GHG performance can result in tangible benefits for buyers and suppliers including cost-savings, higher product quality and reduced exposure to climate policy-related risks. This paper provides an analysis of ten SCI case studies from across a range of industrial sub-sectors and geographical regions. It examines the benefits of the different approaches employed, the effectiveness of these initiatives, and the lessons learned by the organisations leading their implementation. It concludes with success factors for consideration by buyers or organisations seeking to reduce supply chain GHG emissions by implementing SCIs.

INTRODUCTION

As awareness grows of the impact of human activities on the planet, there is an increasing expectation from consumers and investors for companies to be visibly operating in a responsible and sustainable manner. While global surveys of corporate leadership (Blackhurst et al. 2012) show that executives believe sustainability has and will continue to have a material impact on their business, many state that they are still not exploiting opportunities fully. To date, companies have focused largely on actions within the boundaries of their own company. Now extending sustainability across the supply chain, which can be done through supply chain initiatives (SCIs), is becoming increasingly important.

This conference paper provides an analysis of ten SCI case studies, which was carried out in May 2012 by the Institute for Industrial Productivity (IIP) and Ecofys[1]. It explores the range of different SCI approaches employed, examines the effectiveness of these initiatives, and the lessons learned by companies leading their implementation. Finally a number of success factors are extracted to provide guidance on developing SCIs.

[1] Full report Goldberg, A., J. Reinaud, E. Holdaway and S. O'Keeffe (2012). Promoting Energy Savings and GHG Mitigation through Industrial Supply Chain Initiatives, available through: http://www.iipnetwork.org/sites/iipnetwork.org/files/file_attachments/resources/IIP-EcofysSupplyChain.pdf

WHY ENGAGE IN SUPPLY CHAIN INITIATIVES?

Benefits for buyers - On average, 40% to 60% of a manufacturing company's carbon footprint is from its supply chain (CERES, 2010), rather than its own operations, and this can be much greater for retailers. A company that wants to control risks related to corporate reputation and protect its value will work to ensure it is adequately managing its supply chain (UN GCNS, 2009). Many downstream consumer-facing companies now consider sustainability as a key competitive differentiator. An energy efficient supply chain can result in benefits for buyers by reducing their exposure to climate policy and energy risks passed through from their supply chain. In addition, improved energy or GHG practices by suppliers may also see improved quality and management of other resources by the supplier, resulting in a potentially better product and pass-through of cost savings.

Benefits for suppliers - Suppliers that are driven by buyers to reduce GHG emissions or make energy savings are also likely to find synergies between efficiency and other resource-productivity issues (e.g. process quality and throughput, and reduced downtime and maintenance costs) (BSR, 2010). Suppliers may be able to demonstrate their performance improvements to other potential buyers. Companies partaking in SCIs may be best placed to create long-term contractual relationships with their buyers

CHALLENGES TO ENGAGE IN SUPPLY CHAIN INITIATIVES

Engaging with suppliers to reduce energy or emissions presents a number of challenges. Globalisation has led to increasingly complex, global and decentralised supply chains (UN GCNS, 2009), which can hamper efforts to coordinate supply chain initiatives and monitor their impact. Also, the value chain position of the buyer company that initiates the SCI influences the leverage the company has and thus its direct ability to mitigate overall supply chain impacts. Before setting up a SCI, the buyer must have a general understanding of the overall emissions impact of their supply chain in order to most effectively guide their suppliers' emissions reductions activities. Lastly, SCIs can give rise to competiveness issues for suppliers active in regions with lower sustainability standards (Sherman et al., 2012), as well as confidentiality issues for suppliers unwilling to share their energy and GHG performance outside their company.

METHODOLOGY AND APPROACH

The case studies selected comprise the following ten organisations: BASF (chemical company), British Gypsum (plaster and plasterboard manufacturer), Ford (automobile manufacturer), General Electric (providing a wide range of energy, industrial and technology solutions), IKEA (furnishings and home ware), Home Depot (hardware store), Prorail (construction and maintenance of the Netherlands rail network), SKF (manufacturer of bearings, seals and engineering solutions), Walmart (grocery and general store) and China's city government-led Suzhou Energy Efficiency Star Scheme.

Desktop research and interviews were undertaken to collect the required data. The desktop research served to collect the main components of each SCI, such as region, SCI activity types, length and overview of the initiative, partnership or programme linkages. For a more in-depth analysis and to gain insights into the implementation experiences of each buyer company, interviews were conducted. The interviews also sought to obtain information on the specific sectors the suppliers comprised, impacts of the SCIs within individual suppliers, the bottlenecks that were encountered, and what were the key design features of the SCI that made the initiative successful or not.

RESULTS AND CONCLUSIONS

SCI categorization

A SCI categorization was made to show the diversity of approaches that were found to be used. Assessed ten SCIs could be categorized according to the following types or combination of types:

- Mandatory performance requirements - The buyer requires the supplier to comply with set performance criteria;
- Purchasing approaches - Supplier performance leads to advantages or disadvantages in procurement process;
- Reporting and monitoring - Suppliers must report their emissions or energy use to their buyers;
- Subsidised audits - On-site audits to determine a supplier's GHG/energy performance and identify improvement options;
- Capacity building and implementation support – Training/workshops and other measures to improve suppliers' ability to improve their energy and GHG performance;
- Supplier forums or coalitions - Conferences, meetings, webinars and online forums where buyers and suppliers can communicate;
- Labelling - Labelling of energy performance as an informational tool for buyers;
- External facilitation tools - Platforms that help connect or match GHG/energy performance of suppliers with buyers' interests or criteria.

SCI impacts

There was a general lack of supplier data on costs savings and GHG reductions. This may be partially explained by the newness of the SCIs and the reluctance of suppliers to share data on cost savings associated with implemented SCI measures (in case the buyer then expects to see that saving reflected in a lower product/service price). In spite of this, multiple benefits to both suppliers and buyers were found among the ten case studies. These benefits include cost savings through increased energy efficiency, marketing and reputation benefits, improved business relationships and reduced risks related to climate policy, energy costs and reliability. Examples include CO_2 reductions of 19% (GE supplier), 35% (IKEA supplier) over approximately two years; and on average 2-3% annual energy efficiency improvements (Prorail suppliers). The cost of identifying energy saving measures is generally met by the supplier. Costs typically range from $5,000 - $10,000 per audit. However, there are instances where personnel directly from buyer companies conducted audits and paid for the verification or the audits themselves (GE, Walmart). It is notable that the examples reported demonstrated reasonably attractive payback periods for suppliers.

SCI success factors

Based on the findings from the case studies seven success factors for strong and effective strong SCI can be identified. The success factors are summarized in Table 1.

Supplier selection	Focusing on a select group of suppliers rather than the buyer company's entire supplier base.
Partnership and Fostering Trust	Working in partnership with suppliers on specific programs to foster trust and build capacity so that suppliers are comfortable working on sensitive topics such as energy or GHG management and achieve GHG reductions, rather than imposing mandatory requirements without support to suppliers to reach those goals.
Multi-pronged elements	Combining several complementary elements within an initiative, such as external platforms, auditing, capacity building and direct financial support and expertise to reduce supplier GHG emissions.
Cumulative approaches	Cumulative, stepwise approaches with increasing ambition.
Third party involvement and internationally-recognised tools	Third-party involvement, i.e. partnering with external organisations such as non-governmental organisations to provide additional expertise and credibility, using external tools such as energy management systems (EnMS) or environmental management systems (EMS) standards (ISO 14001 and ISO 50001), or Scope 3 Value Chain Standard.
Leadership commitment	Executive or board-level support and engagement within the supplier to participate with the supply chain initiative.
Tailored to local and sectoral conditions	Understanding of local conditions and points of leverage.

Table 1: Success factors for SCIs

REFERENCES

Blackhurst, J., D. Cantor and M. O'Donnell (2012). Sustainable Supply Chains: a guide for small and medium-sized manufacturers. Center for Industrial Research and Service (CIRAS), Iowa State University. Retrieved 4 April 2012 from http://www.ciras.iastate.edu/publications/CIRAS_Supply_Chain_Sustainability-2012.02.29.pdf

BSR, Business for Social Responsibility (2010). Unlocking Energy Efficiency in China, A guide to partnering with suppliers, May 2010, BSR. Available at: http://www.bsr.org/reports/BSR_Unlocking_Energy_Efficiency_in_China.pdf

CERES (2010). The 21st Century Corporation: The Ceres Roadmap for Sustainability. San Francisco: CERES.

Sherman, R., K. Chen, M. Terada, R. Kawahara, K. Ishimaru (forthcoming, 2012). China Sustainable Retail Supply Chain Report. Washington D.C: Efficiency Exchange.

United Nations Global Compact Network Spain (2009) Local Network Report, Red Pacto Mundial España. Retrieved 8 March 2012 from: http://www.unglobalcompact.org/docs/networks_around_world_doc/communication/network_reports/2009/ES_2009.pdf

CURRENT DEVELOPMENTS IN LIFE CYCLE BASED LABELING

Tuesday, Aug 27: 8:30 am - 10:00 am

Session chairs: Jeppe Frydendal, Ecolabelling Denmark, Denmark
Michele Galatola, European Commission, Belgium

COMBINING TYPE I AND TYPE III ECO-LABELS: A SUCCESSFUL EXPERIENCE IN THE WINE SECTOR

Dr. Cristina Gazulla UNESCO Chair in Life Cycle and Climate Change (ESCI-UPF), V. Carrillo, F. D'Souza and A. Liedke (PE International); Dr. Y. Núnez, L. Pereda, R. Clemente and M. López (Fundación Centro Tecnológico de Miranda de Ebro); and J.A. Díez, S. Gómez and M. Cano (Fundación del Patrimonio Natural de Castilla y León).*Passeig Pujades 1, 08003 Barcelona. Spain. cristina.gazulla@esci.upf.edu*

Keywords: eco-labels, wine, environmental product declaration

ABSTRACT

In the framework of the European project LIFE HAproWINE, the authors suggest that the award of Type I eco-labels should be based on certified environmental product declarations and which are based on quantitative environmental information obtained from specific products (through an LCA study). This approach is currently being tested within the wine sector with the cooperation of a number of wineries of the Spanish region of Castilla y León. To this end, a combination of Type I and Type III eco-labels types is suggested, including the definition of thresholds for awarding the best products with a life cycle perspective.

INTRODUCTION

Eco-labels are used by manufacturers and distributors to provide information about the environmental performance of their goods on a voluntary basis. When accurate and relevant, this information should help consumers to identify those products and services of the market with lower environmental impacts. In order to avoid impact shifts between different categories or life cycle stages, a life cycle approach should be applied when defining the rules for awarding eco-labels. Currently, only Type III eco-labels (or Environmental Product Declarations, EPDs) require that a LCA study of the product is undertaken following specific pre-defined calculation rules (named Product Category Rules, PCR). However, the technical and detailed contents of EPDs make them better suited for professional purchasers rather than final consumers, which may have the time and competence to understand their contents. On the other hand, Type I eco-labels are easier to understand, however the extent in which LCA methodology is followed in the definition of awarding criteria varies from one Type I scheme to another.

Within this context, the European project LIFE HAproWINE (LIFE08/ENV/E/000143) suggests that wine producers first develop an EPD of their products and then, by comparison to average market reference values of the different environmental impact categories (without aggregation), companies award an Eco-label Type I for their wines if they satisfy the threshold values. Such scheme, which may be applied to other product sectors, implies that the Eco-label Type I criteria should be based on LCA results of individual products. To this end, average environmental impacts of product categories should be known in advance.

Therefore, LCA studies developed for a number of wines of the Spanish region of Castilla y León have been used in combination with scientific literature in order to define the thresholds values for the Type I eco-label.

METHODS

Product Category Rules for development of Environmental Product Declarations of wine

Type III environmental declarations, also known as "environmental product declarations" (EPDs), present relevant and quantitative environmental information about the life cycle of products. The information declared is based on an independently verified Life Cycle Assessment (LCA) study undertaken according to specific rules (i.e. Product Category Rules, PCR) developed in the framework of ISO 14040-44 and ISO 14025 standards.

Up to date, the only EPD programme which has published a PCR document for wine is the *International EPD® System.* However, no published EPDs produced applying this PCR are available. On the other hand, the project partners considered that some specific contents of this PCR, such as the functional unit or the impact categories to be declared, needed further discussion. For this reason, within the HAproWINE project a new PCR document for wine has been prepared.

As stated in ISO 14025, the previous PCR document has been taken into account, as well as previously published LCA studies on wine. However, it has been the development of a number of detailed LCA studies of the products of local wineries and the consultation with additional wineries and stakeholders of the region of Castilla y León that allowed gaining the required in-depth knowledge to develop a PCR document suitable for the wine produced in Spain.

Definition of the environmental thresholds for the Type I eco-label

The Type I eco-label requires a benchmark against which each applicant wine can be measured. For each impact category, average values can be defined based on the results declared through EPDs. These values should be updated periodically in order to foster the continuous reduction of the environmental footprint of wine.

Within the HAproWINE project, pilot EPDs and LCA studies have been developed in collaboration with wineries of Castilla y León. In addition, and considering the results of the complete LCA studies, key inventory data have been collected for additional wineries. Finally, a comprehensive literature review of LCA studies of wine in different parts of the world has been undertaken. Based on this available information, benchmarks have been identified for wine for the following impact categories and indicators: global warming, water use, (fossil) primary energy consumption and eutrophication.

RESULTS

EPDs of Spanish wines will be produced as pilot case studies within the HAproWINE project. In addition, a PCR document will be available for its application in further cases. In this sense, conversations with EPD program holders are in progress in order to facilitate the use of this outcome of the project in already existing EPD systems in Spain and abroad. Finally, environmental benchmarks on the production of wine for the Castilla y León region and/or the global market will be available.

DISCUSSION

The development of the Product Category Rules and the definition of the environmental thresholds have been subject to external review by wineries and other stakeholders belonging to the advisory group of the HAproWINE project. A number of seminars were held with them to discuss key assumptions and methodological decisions, so as to achieve the widest possible agreement and contribute to the advancement of the state of the art in the LCA of wine.

Both the developed Product Category Rules and environmental thresholds for awarding the Type I eco-label have been tested for a reduced number of wines of the region of Castilla y León. It is considered that PCR could be applied to wines produced in other regions of the world, whereas environmental thresholds would need further revisions.

CONCLUSIONS

Once the HAproWINE project will be closed (December 2013), a tested scheme for combining Type III declarations with Type I eco-labels will be available for wines, including Product Category Rules and environmental benchmarks for distinguishing those wines with better environmental performance in comparison to average products. With minor adaptations, the outcomes of the project could be transferred to other wine producing regions of Spain and abroad.

REFERENCES

EPD® System. Product Category Rules (PCR) for wine of fresh grapes, except sparkling wine; grape must. Version1.0.: http://www.environdec.com/en/Product-Category-Rules/Detail/?Pcr=5850 (last access: May, 2013)

ISO 14025:2006 Environmental labels and declarations – type III environmental declarations – Principles and procedures.

ISO 14040:2006 Environmental management – Life cycle assessment – Principles and framework

ISO 14044:2006 Environmental management – Life cycle assessment – Requirements and guidelines

Liedke A., D'Souza F., Carrillo V., Deimling S. (2013). Definition of Environmental Quality Criteria. 2013, May. Internal Report of the HAproWINE project (LIFE08 ENV/E/000143).

ENVIRONMENTAL LABELLING OF ABSORBENT HYGIENE PRODUCTS: INSIGHTS AND PRELIMINARY OUTCOMES FROM THE EU ECOLABEL CRITERIA DEVELOPMENT PROCESS

M. Cordella – European Commission's Joint Research Centre,*
I. Bauer – PE International,
A. Lehmann – PE International,
M. Schulz – DEKRA Consulting GmbH,
O. Wolf – European Commission's Joint Research Centre

** Institute for Prospective Technological Studies, C/ Inca Garcilaso, 3. Edificio Expo, 41092 Seville, Spain, e-mail: mauro.cordella@eceuropa.eu*

Keywords: absorbent hygiene products; environmental criteria areas; EU Ecolabel; LCA.

ABSTRACT

This contribution describes the state of play of the process setting the ground for the development of EU Ecolabel criteria for absorbent hygiene products (AHPs), which include baby diapers, feminine care products, tampons and breast pads. Criteria areas for the selection of environmentally friendly AHPs have been identified based on the analysis of techno-economic and environmental aspects through the products´ life cycle and on the critical revision of legislation, technical procedures and environmental programs of relevance. The continuous engagement of stakeholders plays a key role in the process. Environmental criteria for AHPs could potentially cover: fitness-for-use, use of materials and substances, manufacturing and end-of-life. Consumer information and social criteria can be relevant as well for this product group.

INTRODUCTION

Promoting and following sustainable practices of production and consumption is one of the key challenges of modern society. Among the policy instruments that tackle this issue, Environmental Labels Type I [ISO 14024:1999] are a voluntary multi-criteria tool aiming at awarding environmentally preferable products based on life cycle considerations. A large group of products are included within the scope of existing environmental labeling programs available worldwide [Global Ecolabelling Network]. In particular, the EU Ecolabel [Regulation (EC) No 66/2010] is the instrument with which the European Commission intends to promote leading products on the market in terms of environmental performance and protection of human health and natural resources.

This contribution describes key results of a preparatory study setting the ground for the development of EU Ecolabel criteria for absorbent hygiene products (AHPs) and the preliminary identification of criteria areas of potential interest for this product group [JRC-IPTS et al., 2013]. The two main elements of this work have been an extensive analysis of

Disclaimer: *The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.*

AHPs with focus on techno-economic and environmental aspects and the direct interaction with stakeholders. The following products have been included within the scope: baby diapers, feminine care pads, tampons and breast pads.

MATERIALS AND METHODS

The development of selection criteria should follow a coherent, broad and transparent approach. Information relevant for the development of EU Ecolabel criteria for AHPs has been gathered through the following activities:

Task 1: A critical review of existing legislation, standards and testing procedures, environmental labels and green public procurement schemes has allowed the screening of rules and requirements potentially relevant for AHPs.

Task 2: The European market for AHPs has been analyzed to understand the economic weight of the products included within the scope and to ensure focusing on those most significant from an economic point of view . Information on sales, consumption, import/export figures as well as market growth rates has been collected with the support of EDANA, the international association for the nonwovens and related industries. No relevant data has been found for breast pads, but their market is expected to be significantly smaller.

Task 3: The technical description of AHPs and the further identification of potential sources of hazard and environmental hot-spots throughout the products' life cycle have provided the basis for understanding the significance of specific potential requirements for this product group. For the purposes of this task, existing Life Cycle Assessment (LCA) studies have been reviewed and new models developed and assessed for each AHP. LCA models have taken into account the environmental performance of average products on the European market from cradle to grave. Bills of materials and further production data have been derived from industry. Life cycle inventory data of relevant background processes have been obtained from the GaBi database [PE International, 2011]. Environmental impacts of relevance for this product group have been assessed through the CML 2001 method. The following indicators have been considered: Abiotic Depletion Potential, Acidification Potential, Eutrophication Potential, Global Warming Potential and Photochemical Ozone Creation Potential. Demand of renewable and non-renewable primary energy has been also quantified.

Further information about materials and methods can be found in [JRC-IPTS et al., 2013].

The insights gained from these steps have allowed for the identification of areas where environmental criteria for AHPs could be developed. Interaction with stakeholders along the process has been fundamental in order to gain technical information and to solve critical issues that could undermine coherency and practical feasibility of requirements.

RESULTS AND DISCUSSION

Task 1: Analysis of legislation, technical procedures and environmental schemes of relevance
The EU Ecolabel promotes, whenever possible, the harmonization between labels. The definition of requirements for AHPs could be inspired by some elements contained in existing labeling and green public procurement programs. At the current state of the art, the most significant references for this product group are represented by the Nordic Swan's criteria for

Disclaimer: *The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.*

sanitary products and by the guidelines developed by EDANA and by the Swedish Environmental Management Council [JRC-IPTS et al., 2013]. In addition, some environmental claims, e.g. sourcing of organic cotton, could be of potential interest. Consistency and feasibility of each requirement, however, must be evaluated critically before being proposed for inclusion in the EU Ecolabel. The development of EU Ecolabel criteria for AHPs is further influenced by existing criteria for other product groups (e.g. certification of wood and pulp production). In accordance with the EU Ecolabel regulation, requirements must also ensure that the use of hazardous substances is restricted.

Furthermore, criteria such as fitness-for-use and product quality are important elements to ensure that AHPs have desired product performance characteristics. However, product classification and test methods are not harmonized within industry and user tests seem to be the only widely-accepted method for assessing the technical performance of AHPs.

Task 2: Market analysis
In Europe, the production volume of AHPs in 2011 added up to ~8.6 billion € (58% diapers, 32% feminine care pads, 10% tampons), which equals approximately 0.8 million tons (84% diapers, 14% feminine care pads, 2% tampons) [JRC-IPTS et al., 2013]. A slight increase of production volumes could be observed over the past few years. 90% of the products are consumed in Europe and export sales are much higher than the amount of imported products, which are usually less expensive and heavier. The trend towards product differentiation and decrease of product weights can be observed

Task 3: Technical and environmental analysis
LCA results are reported in [JRC-IPTS et al., 2013] and for all AHPs within the project scope show a clear dependence between life cycle impacts and weight of the products, that could not be the case on a general basis. For each of the environmental impacts assessed, materials contribute to 53-98% of the total impacts. The end-of-life stage is relevant for Eutrophication Potential (16-25%), Global Warming Potential (27-33%) and Photochemical Ozone Creation Potential (9-19%) while contribution from production process, packaging and transport appears of secondary importance. Results for diapers are consistent with the information available in the literature, while information published for the other three case studies appears scarce. Results highlight that use of materials, i.e. natural resources (fluff pulp, cotton, viscose) and synthetic polymers (super absorbent polymers, polypropylene, polyethylene), is the key environmental issue for this product group. The technical analysis of the main materials has allowed the preliminary identification of actions that could lead to an improvement of the environmental performance. The analysis has also shown that some inherently hazardous substances could potentially enter into the product (e.g. with adhesives, inks and dyes), even if consumers can be reinsured that the use of the product is safe.

Identification of potential criteria areas
Based on the results presented, the development of criteria for AHPs could encompass different environmental areas. However, financial implications should be also taken into account in order to avoid prohibitively high costs for manufactures.

Fitness-for-use and quality characteristics of AHPs are considered of key importance to ensure that criteria for AHPs do not negatively influence the product performance.

Disclaimer: *The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.*

In addition, LCA evidence suggests that the main area for environmental improvement and, therefore, criteria development should be related to the use of materials. Requirements influencing the design of the product would be probably the most effective measure to promote more eco-friendly products on the market. However, from a practical point of view, following this direction is complicated by the lack of harmonized classification for AHPs, the limited information available for setting environmental thresholds, and the costs that SMEs would have to afford. Other key issues related to the materials used for AHPs (e.g. fluff pulp, viscose, cotton) are their sustainable sourcing and production as well as declaring the avoidance of inherently hazardous components in the product. The end-of-life stage is another critical element in the products' life cycle. However, possibilities of influencing disposal practices are limited. Due to the relatively low contribution to the life cycle impacts of the product, packaging is not considered a key issue. This applies similarly to the manufacturing process itself, however, since it is under the companies' direct influence, it is considered feasible to achieve some environmental improvements in this life cycle stage.

Setting criteria in these areas should assist in the reduction of negative impacts due to production and consumption of AHPs. Other issues of potential interest include the information of consumers and the consideration of social aspects.

CONCLUSIONS

This contribution describes the work carried out for building a basis of information that can be used to address the development of EU Ecolabel criteria for AHPs (i.e. baby diapers, feminine care pads, tampons and breast pads). The following steps have been followed: scoping phase, analysis of legislation technical procedures and environmental schemes of relevance, market analysis, technical and environmental assessment, identification of criteria areas. Preliminary criteria areas of potential interest for AHPs relate to: fitness-for-use, use of materials and substances, manufacturing and end-of-life. The continuous engagement of stakeholders plays a key role for the definition of a set of coherent and feasible requirements. Further discussion is ongoing and a final set of criteria is planned to be drafted by 2014.

REFERENCES

Global Ecolabelling Network (GEN). http://www.globalecolabelling.net/

ISO 14024:1999. Environmental labels and declarations - Type I environmental labelling - Principles and procedures. http://www.iso.org/iso/catalogue_detail?csnumber=23145

JRC-IPTS, DEKRA Consulting and PE International (2013). Development of EU Ecolabel Criteria for Absorbent Hygiene Products - Preliminary Report – Draft v.5. http://susproc.jrc.ec.europa.eu/sanitaryproducts/stakeholders.html

PE International (2011). GaBi 5 - Software-System and Databases for Life Cycle Engineering. Copyright, TM. Stuttgart, Echterdingen. 1992-2011

Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:027:0001:0019:EN:PDF

Disclaimer: *The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.*

"GREEN POWER" PURCHASE APPLIED FOR ENVIRONMENTAL REPORTING AND MARKETING

Hanne Lerche Raadal
Ostfold Research, Gamle Beddingvei 2B, N-1671 Kråkerøy, Norway.
E-mail contact: hlr@ostfoldforskning.no

Keywords: environmental reporting, electricity, Guarantee of Origin, green power

ABSTRACT

Electricity consumption represents an important input to almost all environmental analyses and reports. When introducing Guarantees of Origin (GO) and Electricity Disclosure according to the European Renewable Energy Directive (2009/26/EC) and Electricity Market Directive (2009/72/EC), respectively, a system allowing informed consumer choice was established. A GO represents both a tracking instrument and a contractual obligation between suppliers and customers, and can therefore be used to allocate specific electricity generation to specific end-user. An important precondition is the calculation of corresponding Residual Mixes.

There is a need for reaching an internationally common understanding regarding the principle of whether GOs should be allowed, or not, for environmental reporting in order to make fair comparisons between products/companies.

INTRODUCTION

When introducing Guarantees of Origin (GO) and Electricity Disclosure according to the European Renewable Energy Directive (2009/26/EC) and Electricity Market Directive (2009/72/EC), respectively, a system allowing informed consumer choice was established.

A GO is defined as a means of proving the origin of electricity, while the objective of Electricity Disclosure is to provide consumers with relevant information about power generation and to allow for informed consumer choice, not only based on electricity prices. The Electricity Market Directive requires all suppliers of electricity to disclose their electricity portfolio with regard to energy source and environmental impacts, specifying the emissions of CO_2 and the amount of radioactive waste.

The European Energy Certification System (EECS) constitutes a commercially funded, integrated European framework for the international trade of energy certificates, such as GOs. The EECS has been developed by the Association of Issuing Bodies (AIB n.d.), which is a membership-based non-profit organisation. It currently has members from 14 EU member states plus Norway and Switzerland. The EECS offers a set of agreed standards, known as the Principles and Rules of Operation (PRO), to ensure that the systems of its member organisations are compatible with one another. As seen in Figure 1, the EECS market has increased significantly since 2000, when the market was established.

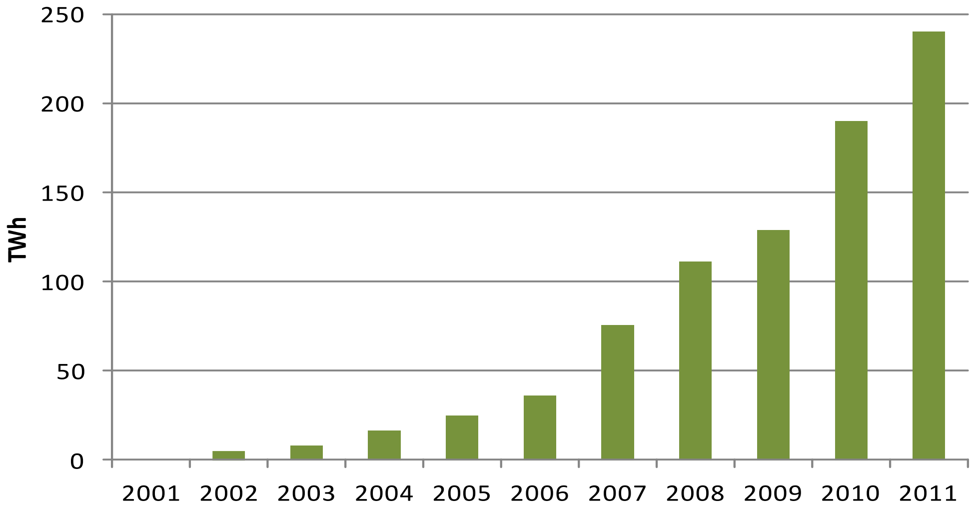


Figure 1. Cancelled GOs (and similar products) using the EECS system (AIB, 2012).

As seen from the figure, about 240 TWh GOs and similar products were traded in Europe in 2011, accounting for 30% of the European renewable electricity generation. However, despite the relatively rapid growth in this market, the knowledge and interest with regard to the application of such products in environmental reporting have been relatively modest within the LCA community.

MATERIALS AND METHODS

Environmental reporting (such as Carbon footprint calculations of companies, products etc.) clearly takes the attributional LCA modeling approach (European Commission, 2010, Frischknecht & Stucki 2010). Hence, the data required for the analyses relate to the value chain of the product/object under study. In accordance with relevant literature (International Standard ISO 2006, European Commission 2010, The International EPD System 2010, The GHG Protocol 2011, European Commission Joint Research Centre 2013, Frischknecht & Stucki 2010), for electricity consumption, the general recommendation is to use technology-specific data, specified variously by the terms “supplier-specific production mix”, “specific electricity technology”, “specific, contracted electricity”, etc. In addition, some standards/guidelines require the avoidance of double counting of electricity. Thus, it can be concluded that there is a general preference for the use of specific data. There is, however, a general lack of harmonisation in the guidelines as to how this “specific electricity” should be defined and determined.

With regard to electricity, which is delivered through a common electricity grid, there is a particularity in that the electrons are indistinguishable. Thus, the implementation of GOs, which represent both a tracking instrument for proving the origin of electricity and a contractual obligation between electricity generators/suppliers and customers, opens up possibilities for the allocation of specific electricity generation to a specific end-user. The tracking mechanism and contractual relationship, however, do not automatically qualify GOs to be claimed. An important presupposition for this is the avoidance of double counting of the environmental attributes (which are sold as GOs). The electricity covered by GOs must therefore be separated from the average consumption mix. On this basis, a methodology for calculating the Residual Mix, representing the consumption mix for all the customers who do not purchase GOs in the related country or region has been developed (RE-DISS, n.d.). The traditional way of determining electricity mixes in environmental inventories has been to use “fixed” average national or regional grid mixes, based on production mixes corrected by physical import and export figures.

As no clear recommendation regarding the determination of “specific electricity” exists, two different principles for the calculation of relevant electricity mixes are available for environmental reporting: the traditional use of average electricity grid mixes and the specific use of GOs/Residual Mixes.

RESULTS

Based on the two different principles for determining electricity mixes, relevant electricity mixes and related CO_2-emissions have been calculated and exemplified by a Norwegian consumer who can voluntarily choose to purchase GOs. These are shown in Table 1.

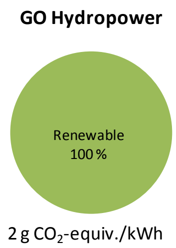
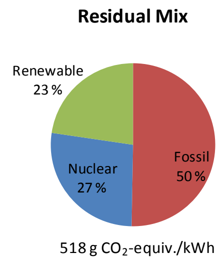
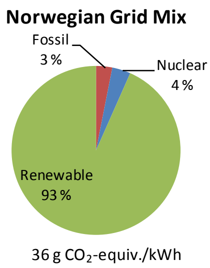
GOs allowed to be claimed		GOs not allowed to be claimed
Customers purchasing GOs	**Customers not purchasing GOs**	**Customers purchasing or not purchasing GOs**
Contractual purchased electricity	Residual Mix for the country/region	Grid mix for the country/region
		

Table 1. Relevant electricity mixes for environmental reporting, depending on whether or not GOs are allowed to be claimed.

The table shows that the different electricity mixes represent a large variety of CO_2-emissions, varying from 2 to 518 g CO_2-equivalents/kWh. If GOs are allowed to be claimed in the environmental report, the purchase of GOs will lead to an improvement in the inventory of the product in question, since the CO_2-emissions are significantly lower when compared with the Residual Mix’ emissions. This improvement will occur to the detriment of the “ordinary” electricity customers (not purchasing GOs), as it makes the Residual Mix more “dirty”. If GOs are not allowed to be claimed, the relevant electricity mix for electricity consumption relating to the product in question is based on the national or regional Grid Mix. In that case, customers would have no possibility of influencing the energy source of their own electricity.

DISCUSSION AND CONCLUSIONS

Environmental reporting takes the attributional modelling approach. Hence, the inventory model is based on the value chain of the product under study and that specific data relating to the value chain should be applied. Since electrons are indistinguishable, a tracking mechanism is needed to distinguish between electricity originating from different electricity plants. A GO, which represents both a tracking instrument for proving the origin of electricity and a contractual obligation between suppliers and customers, could therefore be used as an instrument for allocating specific electricity generation to specific end-users. Important preconditions in this case are the avoidance of double counting of attributes and the availability of reliable electricity data. When these requirements are fulfilled, the GO system makes it possible for consumers to, in a reliable way, choose purchased electricity on the basis of environmental preference, thus treating purchased electricity just like the purchase of any other product chosen by a company. The environmental attributes relating to the specifically purchased electricity (influenced by the consumer) should therefore be included in the inventory. On this basis, voluntarily purchased renewable electricity products may represent an "environmental liberalisation" of the electricity market's relationship with its customers, moving from "fixed" average grid mixes, based on geographical locations of facilities and grid, to specific electricity mixes based on the customer's demand and choices.

There is a need for reaching an internationally common understanding regarding the principle of whether GOs should be allowed, or not, for environmental reporting in order to make fair comparisons between products/companies.

REFERENCES

AIB (Association of Issuing Bodies) HOME http://www.aib-net.org/portal/page/portal/AIB_HOME

AIB, 2012. AIB - Market Activity. http://www.aib-net.org/portal/page/portal/AIB_HOME/AIB_OPE/MARKET_INFORMATION/MARKET_ACTIVITY

European Commission Joint Research Centre, 2013. Product Environmental Footprint (PEF) Guide, Available at: http://ec.europa.eu/environment/eussd/product_footprint.htm.

European Commission, 2010. *International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed Guidance*. First edition March 2010. EUR 24708 EN. European Commission, Joint Research Centre, Institute for Environment and Sustainability. Publications Office of the European Union, Luxemburg.

Frischknecht, R. & Stucki, M., 2010. *Scope-dependent modelling of electricity supply in life cycle assessments*. The International Journal of Life Cycle Assessment, 15(8), pp 806-816.

International Standard ISO, 2006. International Standard ISO 14044:2006 Environmental management - Life cycle assessment - Requirements and guidelines

RE-DISS. The RE-DISS (Reliable Disclosure Systems for Europe) Project Homepage. Available at: http://www.reliable-disclosure.org/.

The GHG Protocol, 2011b. Product Life Cycle Accounting and Reporting Standard. http://www.ghgprotocol.org/files/ghgp/Product%20Life%20Cycle%20Accounting%20and%20Reporting%20Standard.pdf

The International EPD System, 2010. Basic Module CPC Division 17 Electricity, town gas, steam and hot water. http://environdec.com/en/Product-Category-Rules/Detail/?Pcr=7059#.US35d6IXLTo.

LABELLING IN THE ELECTRONICS SECTOR – IS EPEAT THE ANSWER?

Christina Bocher[1], Sean Nicholson[2]*

[1]DEKRA Consulting GmbH, Handwerkstr. 15, 70565 Stuttgart, Germany

[2]Microsoft Ltd., Microsoft Campus, Thames Valley Park, Reading RG6 1WG, UK

**Corresponding author: christina.bocher@dekra.com*

Keywords: green electronics; EPEAT; IEEE 1680; green purchasing; eco-label.

ABSTRACT

Recognising and rewarding electronics that have a high environmental performance is challenging. The rapid evolution of electronic products stands in stark contrast to the glacial evolution of product standards. Electronics are constantly redesigned and improved to provide ever new functions to users, and hence use a variety of materials. While product standards, created to define and measure environmental performance, evolve over years. In particular if they are to become accepted by the global market place as credible and scientific. To date, EPEAT occupies a unique space in the world of standards and eco-labels, connecting a product standard to an online registry to support services for purchasers wishing to specify EPEAT products. With its strengths and weaknesses, EPEAT presents an insightful case for study.

THE ELECTRONICS SECTOR

The worldwide market for computers is more than 350 billion US dollars or 350 million PCs and laptops, over 70% of which are purchased for business use (Gartner 2012). Overall, the electronics sector is characterized by rapid product turn-over, high complexity and high configurability. Regulatory requirements are increasing, thinking of the EU RoHS or WEEE Directives, focusing on hazardous substances and the product end-of-life. Customers are demanding products that go beyond legal requirements (Wendschlag 2012) and purchasers are increasingly choosing greener products. A 2012 study of 50 national governments revealed over half have mandates or guidelines for office IT equipment, as well as for food, lighting, furniture, construction, cleaning products, transportation and electricity (O'Rourke et al. 2013). As a consequence, eco-labelling and rating schemes have been developed in an attempt to give market recognition to products that attain higher levels of environmental performance. The Electronic Products Environmental Assessment Tool (EPEAT) is one of them.

THE EPEAT RATING SCHEME

EPEAT is a product rating scheme, which has become the one of the most widely used by purchasers and manufacturers alike. Over 120 million EPEAT registered products were sold in 2011 (GEC 2012). Launched in 2006, it now comprises more than 3,500 products from more than 50 manufacturers registered in 42 countries, which can be publicly accessed and searched for online (EPEAT 2013). EPEAT provides a tool for both manufacturers and purchasers of ICT hardware to assess the environmental impact of electronic products along their life cycle. This voluntary scheme has become adopted as large institutional buyers, such as governments, universities and enterprises, use it to specify electronics.

The EPEAT rating system is based on voluntary consensus standards, the IEEE 1680 family, which builds on international requirements and standards including Energy Star, the EU RoHS Directive, and Blue Angel. The IEEE 1680 series standards were developed by a multi-stakeholder group including manufacturers, recyclers, technical experts, purchasers, environmental advocates and governments. There are standards for three different product categories: computers and displays (IEEE 1680.1), imaging equipment (IEEE 1680.2) and TVs (IEEE 1680.3) – the latter two only released in late 2012. Each standard contains a set of required and optional criteria (s. Table 1), covering specific environmental impacts throughout the product life cycle and the supply chain. The products are rated in progressive tiers: Bronze for products meeting all required criteria and showing a high environmental performance; Silver for products meeting additionally at least 50% of the optional criteria; and Gold for products meeting all required criteria plus at least 75% of the optional criteria.

Table 1. IEEE 1680 Standards – Summary of Environmental Criteria

		Computers 1680.1		**Imaging Eq. 1680.2**		**TVs 1680.3**	
Performance category	**Examples**	Req.	Opt.	Req.	Opt	Req.	Opt
Product Specific Criteria							
Environm. sensitive materials	RoHS and beyond	3	8	4	7	3	9
Materials selection	Recycled content	3	3	4	3	3	3
Design for end-of-life	Ease of recycling	6	5	7	2	5	6
Product longevity/ LC extension	Warranties, spare parts	2	2	2	1	3	0
Energy conservation	Energy Star and beyond	1	3	2	4	1	4
Packaging	Recyclable, recycled cont.	3	4	5	2	5	2
Consumables	Paper, cartridges	-	-	4	2	-	-
Indoor air quality	Emission rates	-	-	1	0	-	-
Corporate Criteria							
End-of-life Mgt.	Take-back and recycling	2	1	2	2	2	2
Corporate performance	EMS, env. policy, report	3	2	2	3	2	3
Overall total number of criteria		**23**	**28**	**33**	**26**	**24**	**29**

In order to register products under EPEAT, manufacturers claim the criteria each product meets, confirming that they possess and are able to provide the supporting evidence at any time upon request. Initial registrations are accompanied by a process called Desk Review, whereby the registering organisation working with the manufacturer verifies their comprehension of the standard requirements and capacity to support declared criteria. Based on this self-declaration the rating is granted. In addition, EPEAT conducts independent and ongoing verification to assure the accuracy of the declarations and thus secure the quality of the registry for purchasers. The verification results are publicly disclosed, revealing any non-conformances.

THE PC INDUSTRY'S PERSPECTIVE

The EPEAT rating scheme impacts businesses in the electronics industry in different ways and the awareness about it varies. This can be seen in the approaches to EPEAT, which are as versatile as the original equipment manufacturers (OEMs) themselves. Some large OEMs strive to register as many of their products in as many countries. Other OEMs chose to go for the high end performance and design all their products in compliance with Gold, but only register in few countries. Such goals are difficult to achieve for the smaller, local OEMs with less knowledge and capacity. Even awareness of the standard is not widespread with 75% of smaller “single country” OEMs knowing little or nothing about EPEAT (Microsoft 2012). Since governments are increasingly incorporating EPEAT requirements into their procurement specifications, EPEAT is decisive for the OEMs to qualify for public tenders. This leads to hotspots of local OEM commitment to EPEAT, so in Brazil of the 11 OEMs with EPEAT registered PCs, 7 are local to just Brazil (EPEAT 2013). Contrast that with Germany that has 8 OEMs registering PCs but all are multinational companies. Informal feedback from local OEMs shows some view the EPEAT standard as another challenge when competing for business competition with multinational OEMs.

EPEAT is an international standard with a global scope. However its origin in the US and its availability in English only means it is sometime perceived as an American standard. This perception is one barrier to its geographic expansion and to date large developing markets, such as India, are still absent in the registry. EPEAT is focused on the commercial rather than consumer space, and manufacturers focus their efforts on commercial products. For example HP's recent citizenship report announced that in 2012, 43.7% of commercial PCs shipped by HP were EPEAT Gold qualified, and an additional 10.9% were EPEAT Silver qualified (HP 2013). With the new certification for printers and imaging devices, and some online retailers such as Amazon (Amazon 2013) promoting EPEAT it may start to become recognised by more consumers. EPEAT is an open model with a publically searchable database of registered devices, enabling consumer access. However, in practise, consumer products may have a product identifier that differs from the product identifiers used in the public technical specifications, making it difficult for consumers to locate EPEAT-qualifying products in the EPEAT registry.

The recent explosion of new form factors, such as tablets, has highlighted the dilemma between offering a stable standard that OEMs can plan with, and the rapid product changes that can make a standard less relevant. The market questions, for example, whether tablets qualify within the standard EPEAT, and new notebook designs are pushing the boundaries of interpretation of the standard on questions on ease of disassembly and repair. Both OEMs and their customers are keen to evolve the standards to reflect this change, and EPEAT has an update process underway for the PC standard, but convening the relevant stakeholders and agreeing on public standards is not a fast process.

CONCLUSIONS

Despite shortcomings, EPEAT remains unique in the market place. Relative ease for purchasers is one key behind the rate of uptake of EPEAT. Specifically, purchasers can easily search for products online, there are a very large number of qualifying products which is key to the competitive bidding requirements in many organisations and the EPEAT organisation provides text that would-be green purchasers can add to their own purchasing contracts. The ongoing verification process is in place to assure purchasers they are selecting high performing products, and to advise manufacturers when a product falls out of conformance or needs updating.

For manufacturers, the intent is to enable fast registration and hence fast recognition in the market which is in contrast to the slow verification procedure behind other traditional eco-labels. The criteria within the EPEAT standards affect manufacturers in the design of products and services, but also recyclers and management of the product at the end of its use. For environmental and advocacy groups, the fact that the EPEAT standards cover multiple phases of the product life cycle and are tiered to promote ongoing improvement, also sets the standard apart.

REFERENCES

Amazon (2013). What is EPEAT. http://www.amazon.com/gp/feature.html?ie=UTF8&docId=1000405461.

Electronic Products Environmental Assessment Tool (EPEAT) (2013). The EPEAT Registry. Search Options. http://ww2.epeat.net/searchoptions.aspx.

Gartner (2012). International Data Corporation. August 24, 2012.

Green Electronics Council (GEC) (2012). Environmental Benefits of 2011 EPEAT® Purchasing. http://www.epeat.net/wp-content/uploads/2012/11/Report2012_R6_Full.pdf.

Hewlett-Packard (HP) (2013): HP 2012 Global Citizenship Report. http://h20195.www2.hp.com/V2/GetPDF.aspx/c03742928.pdf.

Institute of Electrical and Electronic Engineers (IEEE) (2010). IEEE Standard for Environmental Assessment of Personal Computer Products, Including Notebook Personal Computers, Desktop Personal Computers, and Personal Computer Displays. IEEE Std. 1680.1™-2009, New York.

Institute of Electrical and Electronic Engineers (IEEE) (2012a). IEEE Standard for Environmental Assessment of Imaging Equipment. IEEE Std. 1680.2 ™-2012, New York.

Institute of Electrical and Electronic Engineers (IEEE) (2012b). IEEE Standard for Environmental Assessment of Televisions. IEEE Std. 1680.3 ™-2012, New York.

Microsoft (2012): Microsoft survey: Smaller OEM survey n=93, May 2012, London.

O'Rourke, A., Leire, C. & T. Bowden (2013). A study of national governments' sustainable purchasing practices. *Forthcoming*, UNEP DTIE, Paris.

Wendschlag, H. (2012): Customer demand for 'green' product information: What customer request to make informed purchase decisions. *Electronics Goes Green 2012+ Conference Proceedings.* https://www.conftool.com/egg2012/index.php?page=browseSessions&form_session=33.

METRICS BEHIND THE MANAGEMENT OF SUPPLY CHAINS

Tuesday, Aug 27: 8:30 am - 10:00 am

Session chairs: Mark Goedkoop, PRe Consultants BV, The Netherlands
Nicole Unger, Unilever, United Kingdom

ONE TWO WE: AN LCM PROGRAMME FOR ENVIRONMENTALLY FRIENDLY CANTEEN MEALS

Jungbluth, N., Doublet, G., Flury, K.,*
** jungbluth@esu-services.ch, ESU-services Ltd., Margrit-Rainer-Str. 11c, CH-8050 Zürich,*
www.esu-services.ch/projects/lcafood/meals/
Keywords: canteen; meal, supply chain; gastronomy, food

ABSTRACT

The environmental impacts of all food purchases of the Swiss canteen operator SV Group were analysed within an LCA study. Improvement potentials were identified, which include measures in the canteen operation (e.g. reduction of food waste), measures in the supply chain (e.g. a reduction of vegetables grown in heated greenhouses) and dietary measures such as a reduction of the average amount of meat per meal. The results have been used to initiate the programme "ONE TWO WE" together with the WWF Switzerland. It assists the customers (companies who commission the SV Group with the operation of canteens in their premises) to reach improved levels of environmental performance e.g. a 20% cut on GHG emissions in the supply chain.

INTRODUCTION

Nutrition accounts for 30 % of environmental impacts caused due to the final consumption of Swiss households. It is the most important consumption sector from an environmental point of view with high reduction potentials (Jungbluth, Flury, & Doublet, 2013; Jungbluth, Nathani, Stucki, & Leuenberger, 2011). This was the starting point for the collaboration between the LCA consultancy ESU-services Ltd., the canteen operator SV Group and the WWF in Switzerland in order to improve the sustainability in the gastronomy sector.

METHODS

The environmental impacts of all food purchases in several hundred canteens of the SV Group were analysed within an LCA study. The SV group provided a detailed list of purchases. In the next step, LCI data for several thousand of food items available within the ESU food database (Jungbluth et al., 2013) were linked to the purchased amounts. The objectives were twofold. In a first step, the most important ingredients were identified and the impacts of the food supply were compared with the impacts of the canteen operation. In the second stage of the project, improvement potentials were identified in the supply chain and the operation of the canteen. In the original study, the results are analysed across a representative range of impact categories with the ecological scarcity method (Frischknecht, Steiner, & Jungbluth, 2009). Presented in this short article is the Global Warming Potential (GWP).

RESULTS

The food purchases include meat, fish, dairy products, eggs, vegetables, fruits, bread, sweets, beverages and convenience products. The contribution of each life cycle stage to the GWP of all food purchases is shown in Figure 1. The GWP is expressed per meal, which means that the GWP of all food purchases were divided by the total amount of meals delivered per year. The life cycle includes the production, the processing, the packaging, the transport to the canteen and the operation (meal preparation at the canteen).

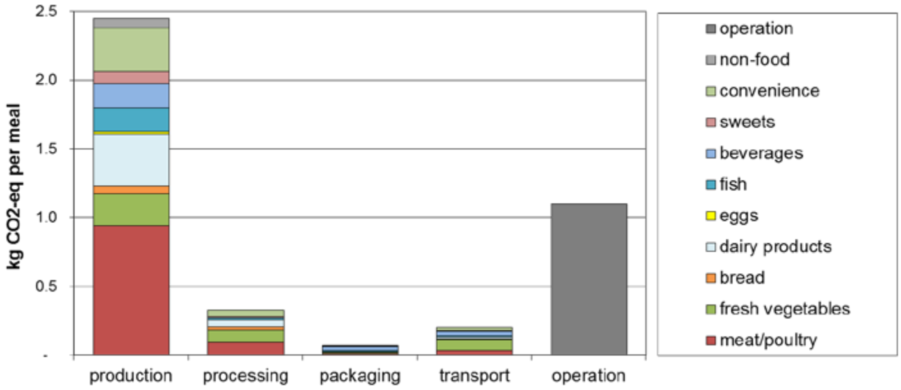


Figure 1 Global warming potential per meal of food purchases and canteen operation

A meal served in a canteen operated by the SV group has an average GWP of 4.1 kg CO2-eq. The agricultural production step is responsible for 60% of the emissions, the processing 8%, the packaging 2%, the transport 5% and the operation of the canteens (cooling, cooking, etc.) 25%. The overall GWP of the food supply is dominated by the meat and poultry products (35%), the dairy products (15%), the fresh vegetables (14%) and convenience products (14%).

The environmental impacts of vegetable and fruit purchases depend on the production period, the origin and the means of transport. For a given fruit or vegetable, all monthly supply routes were assessed in order to provide better guidance for purchases. For example, fresh broccoli is supplied from Switzerland, Spain and Italy. The fresh broccoli from Switzerland is only supplied from May to October and its GWP is 0.6 kg CO2-eq per kg. From January to May and from November to December, fresh broccoli is transported in truck from Spain and Italy. The fresh broccoli is produced in heated greenhouses and its GWP is 7.2 kg CO2-eq per kg in January, February and December. The production of fresh broccoli that is deep-frozen in order to maintain a supply during the off-season generates a GWP of 0.7 kg CO2-eq per kg. Deep-frozen vegetables are an interesting alternative to fresh vegetables cultivated in heated greenhouses. Another relevant example is the supply of green asparagus. From July to February, green asparagus cultivated in Peru and transported by air cause a GWP of 12.8 kg CO2-eq per kg. Green asparagus cultivated in Switzerland or Spain and supplied from April to June have an average GWP of 1.6 kg CO2-eq per kg. These two examples are illustrated in Figure 2.

kg CO2-eq per kg good		Jan	Feb	March	April	Mai	June	July	Aug	Sept	Oct	Nov	Dec
Broccoli	CH-truck												
	ES-truck												
	IT-truck												
Broccoli deep-frozen	CH-LKW												
Green asparagus	CH-truck												
	ES-truck												
	PE-Air												
Low value		below 2.5 kg CO2-eq per kg good											
High value		between 2.5 and 5.0 kg CO2-eq per kg good											
Very high value		above 5.0 kg CO2-eq per kg good											
Exlcusion zone		SV Group does not provide this goods											
Origin - Legend		CH	Swiss		IT	Italy		ES	Spain		PE	Peru	

Figure 2. Example of broccoli and green asparagus for the creation of the Season table

DISCUSSION

The programme "ONE TWO WE" was elaborated based on the results of the LCA and further collaborations. It consists of a set of improvement options in five fields namely the logistic, the canteen operation, the food supply and the food range. Therefore targets on certain key performance indicators have been set. The environmental performance of the logistic shall be improved by reducing the share of air-freight. The optimisation at the canteen includes for example the amount of food waste and energy efficiency (cooling, lighting, cooking and ventilation). The mitigation of the environmental impacts of the food supply relies on the reduction of fruit and vegetables cultivated in heated greenhouses. Another important measure is the reduction of the average quantity of meat per meal by offering attractive vegetarian meals and meals with a lower amount of meat per serving. A good communication with the guest and customers should explain the background of this programme while at the same time allowing the guest to choose from attractive recipes. The programme aims for a reduction of 20% on greenhouse gas emissions in canteens which follow all suggestions for improvements. The achieved reductions shall be documented transparently.

CONCLUSIONS

The programme "ONE TWO WE". started successfully with many customers positively convinced by the proposed changes in the provision of canteen meals. In 2013 the initiative " ONE TWO WE" has been awarded with the Zurich Climate Prize 2013. The future will show whether also the guest in the canteens support the started changes.

REFERENCES

Frischknecht, R., Steiner, R., & Jungbluth, N. (2009). The Ecological Scarcity Method - Eco-Factors 2006: A method for impact assessment in LCA. Zürich und Bern: Federal Office for the Environment FOEN.

Jungbluth, N., Flury, K., & Doublet, G. (2013). *Environmental impacts of food consumption and its reduction potentials.* Paper presented at the 6th International Conference on Life Cycle Management, Gothenburg.

Jungbluth, N., Flury, K., Doublet, G., Leuenberger, M., Steiner, R., Büsser, S., . . . Itten, R. (2013). Life cycle inventory database on demand: EcoSpold LCI database of ESU-services. Zürich, CH: ESU-services Ltd.

Jungbluth, N., Nathani, C., Stucki, M., & Leuenberger, M. (2011). Environmental impacts of Swiss consumption and production: a combination of input-output analysis with life cycle assessment (pp. 171). Bern, CH: ESU-services Ltd. & Rütter+Partner, commissioned by the Swiss Federal Office for the Environment (FOEN).

ROUNDTABLE FOR SOCIAL METRICS: AN INDUSTRY LED INITIATIVE TO HARMONIZE APPROACHES AND IMPROVE SOCIAL SUSTAINABILITY

J. FONTES [1], S. Evitts [2], M. Goedkoop [3]*
[1, 2, 3] PRé Consultants

[*] Printerweg 18, 3821AD Amersfoort, The Netherlands, fontes@pre-sustainability.com

Keywords: harmonization; social impact assessment; social LCA; product sustainability.

ABSTRACT

Seven Companies who were all working on the development of their own methodology for the assessment of social impacts of products got together under a round table initiative from the authors. This has led to the development of a joined but modular approach, allowing companies to adjust the proposed assessment method to their needs. The main achievements are the alignment on common principles, the development of an overall framework and the alignment of social topics and indicators.

INTRODUCTION

Pro-active companies are setting frameworks and developing programs to measure and manage social sustainability at product level both as a driver for innovation as well to mitigate risks. Ultimately this is an opportunity for companies to differentiate as it enables them to improve peoples' lives while doing good businesses with responsible products. At the same time, the pressure on companies for transparency and consistency grows as different stakeholder groups are increasingly questioning the social impacts associated with goods and services. There is therefore an increasing need for companies to improve their internal assessment systems and programs.

While tools are being developed and research continues to support the frontrunners oon organizational social sustainability, workable solutions on product level have not yet been sufficiently addressed. Triggered by practical dilemmas, a group of experts from large companies including DSM, Philips, Goodyear, BASF, Ahold, Reckitt Benckiser and one automotive company have decided to join forces initiating the Roundtable for Social Metrics. This working group started in 2012 aiming at i) consolidating principles for product social sustainability assessment and harmonizing approaches, ii) aligning with other global initiatives and sharing with other companies and iii) developing solutions for cross-cutting implementation issues.

METHODS

Companies have been invited to join the Roundtable. The work at the Roundtable is developed based on participants' experiences, global standards and external references.

Furthermore the Roundtable for Social Metrics is based on stakeholder engagement and literature review, i.e. following a bottom-up and top-down approach.

An important starting point has been the alignment of the guiding principles for social assessment, as these provide a basis for decisions and guidance in the method development:

- Guidance for product social sustainability needs to focus on the feasibility for the companies, allowing businesses to apply and develop it organically, as well as to improve performance based on an aligned and transparent methodology. (New applicability principle)
- The guidance should support companies to implement product social sustainability and to conduct social life cycle impact assessment in a harmonized way, thus also allowing B2B communication. (New application principle)
- The sustainability manager should identify homogenous grop of internal and/or external stakeholders that are affected positively and negatively by the product along its life cycle. . (Adapted from the stakeholder inclusiveness principle of GRI (GRI, 2011))
- The social topics and performance indicators should reflect positive and negative impacts of the product to enable a reasoned assessment of overall performance. (Adapted from the balance principle of the GRI (GRI, 2011))
- The assessment should include the three stakeholder groups: employees, consumers and local communities. In addition, the impact assessment should not be conducted in a way that one stakeholder group is overweighed at the expense of the others. (New stakeholder balance principle)
- Impact assessment should make efficient use of human and financial resources (e.g. by applying a limited, but effective set of indicators) and should have a realistic approach to assessment. (Adapted from the practical focus principle of ISEAL (ISEAL, 2010))
- Data collected to support the assessment should be gathered, recorded, compiled, and eventually disclosed in case of subjective examination in a way that establishes the quality and the relevance of the information. (Adapted from the reliability principle of GRI (GRI, 2011))
- Data should be recorded and the impact assessment should be documented in a way that the assessment can be reproduced within the organization. (New reproducibility principle)
- Information should be made available in a manner that is understandable and accessible to users of the assessment report. (Adapted from the clarity principle of ISEAL (ISEAL, 2010))
- Evaluations and impact assessments should be consistent and credible, allowing for their use by stakeholders to show the contribution of a product towards social well-being. (Adapted from the quality principle of ISEAL (ISEAL, 2010))
- Assessment reports should be relevant, accurate, concise and engaging. (Adapted from the effective communication principle of ISEAL (ISEAL, 2010)

To arrive at such a generic methodology is important to understand the different types of assessment methods used by the Roundtable participants. This not only provides context for the group in order to understand different levels of maturity and cultural approaches, but also served as building blocks from which to synergise a generic; the figure below provides an overview of the steps.

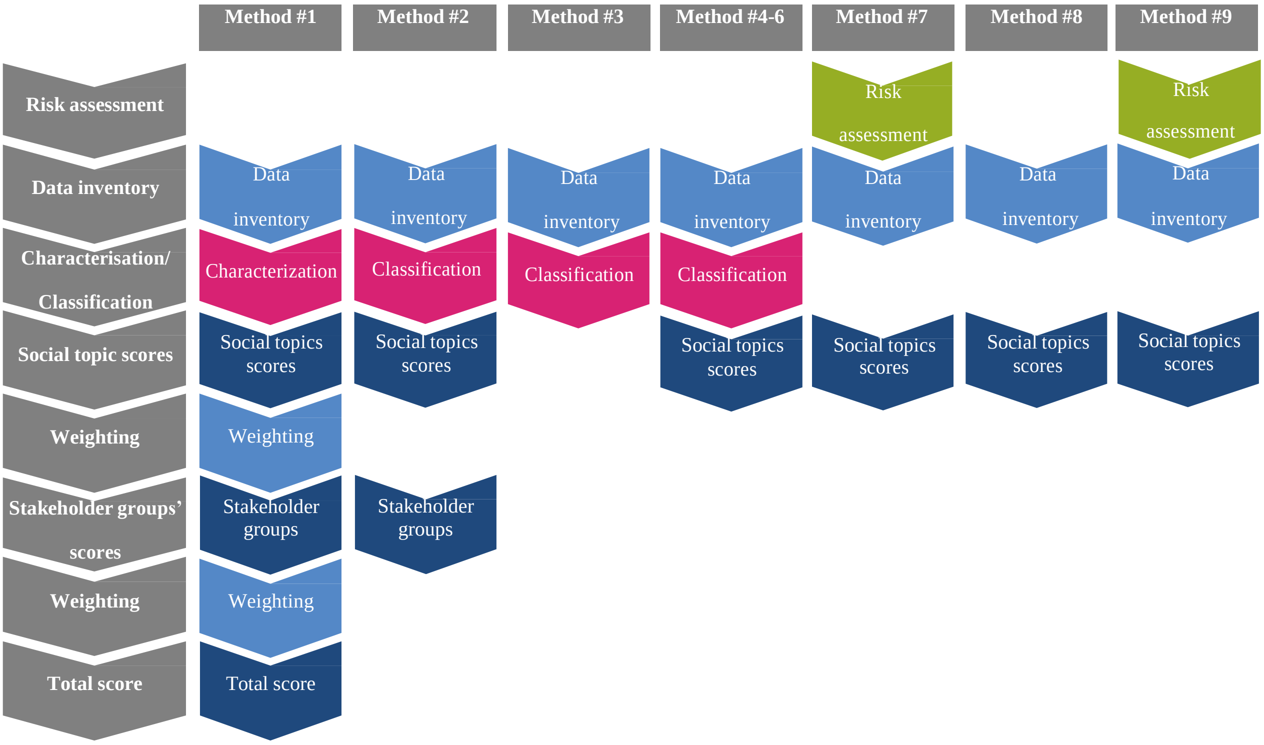


Figure 1: overview of the methodologies used or developed by the member companies.

We identified some other important overarching differences. Some use then methods in a purely quantitative way, some use 5 or three point scales. We also found differences in the normative reference. Some set their own level on what is an acceptable impact, some base the reference on more objective sources like international agreements on working and living.

Interestingly enough there important similarities between company methodologies. An important similarity was the selection of stakeholder groups and topics. We found that three stakeholder groups employees, local communities and consumers cover what most companies need. We analyzed and gathered the social topics used by companies and in external references and we found no less than 110 different social topics, but after eliminating very similar and highly overlapping topics together with the roundtable participants we reduced the number to 20 social topics.

The data inventory has the form of collecting information on predefined social indicators. Initially we identified around 500 indicators that were used by the companies and in literature, but also here many overlaps occur. We developed a procedure with the members to streamline and combine indicators, as this high number is quite unworkable. Having so many indicators and topics also introduces the risk that important issues get drowned among the many not so relevant indicators or topics. The criteria for selecting and adjusting topics we agreed upon, also taking note of the UNEP SETAC, and some other standards are:

- Not overlapping; Each indicator stands alone and no two indicators should cover the same information.

- Non sector specific; The indicator is relevant for all sectors.
- Practicality; Data is currently available from public or private databases, or relatively easy to be obtained.
- Risk oriented; Omission represents a high reputational risk.
- Preferably on product level; The indicator expresses the performance of the product. Otherwise allocation from corporate data to the product level needs to be possible.
- Balanced; The complete set of performance indicators should reflect positive and negative impacts of the product to enable a reasoned assessment of overall performance.
- Completeness; The indicators are complementary to the definition, i.e. all together the set of indicators cover all aspects of the definition.

DISCUSSION AND CONCLUSIONS

The emphasis of this roundtable so far is on getting alignment between the methods used by the members and the available handbooks and procedures already published. The next key challenge is to get the input from stakeholders. The first step is a comment (not really review) round by experts from important international organizations. After this a new project phase will start focusing on intensive stakeholder communication and understanding the level of acceptance by society, and what can be done to increase the level of acceptance..

REFERENCES

GRI (2011). Sustainability Reporting Guidelines, version 3.1, https://www.globalreporting.org/resourcelibrary/G3.1-Guidelines-Incl-Technical-Protocol.pdf, viewed February 2013

ISEAL (2010). Assessing the Impacts of Social and Environmental Standards Systems, version 1.0, http://www.isealalliance.org/sites/default/files/P041_ISEAL_Impacts_Codev1.0.pdf, viewed February 2013

ISO (2010). ISO 26000 Guidance on Social Responsibility, first edition, 2010-11-01

MDGs (2000). The Millennium Development Goals, http://www.undp.org/content/undp/en/home/mdgoverview, viewed February 2013

OECD (2011). Compendium of OECD well-being indicators, http://www.oecd.org/std/47917288.pdf, viewed February 2013

UNEP SETAC (2009). Guidelines for Social Life Cycle Assessment of Products, http://www.unep.fr/shared/publications/pdf/DTIx1164xPA-guidelines_sLCA.pdf, viewed February 2013

UNGC (2004). The UN Global Compact's ten principles, http://www.unglobalcompact.org/AboutTheGC/TheTenPrinciples/index.html, viewed February 2013

SUSTAINABILITY AT TEIJIN ARAMID: PROVIDING AND INCREASING CUSTOMER VALUE THROUGHOUT THE LIFE CYCLE

Heidi (A.M.) Beers, Harrie (H.F.) Bosman, Marjan (M) Kamer, Max (M.J.) Sonnen, Maurits (M) van Kolck.*
Harrie Bosman, Manager Eco Efficiency Services, Teijin Aramid BV
P.O. Box 5153, 6802 ED Arnhem, The Netherlands
T +31 (0)88 26 89145 M +31 (0)6 51825431
E-mail: Harrie.bosman@teijinaramid.com

Keywords: Customer Benefit Model; Eco Efficiency; business case; energy savings; Total Cost of Ownership

ABSTRACT

Since 2008 Teijin Aramid used Eco Efficiency Analysis as a method to compare ecological and economic impacts over the full value chain. Since 2011 Teijin Aramid and Ecomatters developed the Customer Benefit Model (CBM). This model compares specific solutions over the full value chain from the perspective of the user – and is modeled together with the relevant chain partners. All kind of variables can be built into the CBM to adapt to changing circumstances. This way, customer and situational specific calculations can be made for current and future situations. The CBM has proven to be an effective tool in providing the edge in convincing customers and other chain partners of the financial and ecological benefits of our products.

INTRODUCTION

In general, lightweight and long-lasting solutions (so called smart solutions) can lead to resource savings, lower CO_2 emission and a smaller ecological footprint along the whole value chain. In many applications this can be achieved by the use and reuse of Twaron® (an Aramid fiber produced by Teijin Aramid). The comparative impact of smart solutions can be calculated by using the Teijin Aramid Customer Benefit Model.

METHODS

To analyze, quantify and present the performance of our products compared to mainstream in the areas of environmental and economic impact, Teijin Aramid has in co-partnership with Ecomatters, developed a model that uses the principles of an Eco-Efficiency Analysis (EEA). The model shows the added value for every actor throughout the whole life cycle. This identifies potential competitive advantages of our products for every partner in the value chain.

Our model is called the "Customer Benefit Model" or CBM. It is used to support a business case by comparing mainstream products with Twaron® based solutions (products) for the same functional unit. The CBM starts with a mutual qualitative assessment. By using a stage gate process it will potentially result in a quantitative model with three main components:

1) Environmental assessment based on Life Cycle Assessment (LCA), which comprises basic environmental impact data: energy and CO_2 emissions throughout the whole product life cycle.
2) Financial assessment based on the Total Cost of Ownership (TCO). By using the TCO, we analyze the costs structure of the product life cycle and we calculate the payback time, the Net Present Value (NPV) and Internal Rate of Return (IRR)
3) Current and future scenarios can be quantified by changing values of variables.

By building cases together with value chain partners via an interactive and iterative process, the outcomes of the process are shared and accepted by all participants.

RESULTS FROM CASE STUDIES

Two case studies are described below: Steel reinforced conveyor belts in comparison with Twaron® reinforced conveyor belts used in mining operations, and steel gas cylinders compared to Twaron® reinforced composite gas cylinders.

Case study: Conveyor belts

Conveyor belts are used in mining operations to transport ore. These belts can measure up to 10 km in length. As basis for this study, we used the results of Lodewijks (2012) for mines in South Africa as input for our model.

By replacing the steel reinforcement by Twaron® fabric, a weight reduction of the empty belt of 40% is achieved. This is caused by two major drivers; the lower weight of the Twaron® fabric, and less rubber per square meter.

Twaron® reinforcements in conveyor belts can be combined with adding Sulfron® to the rubber. Sulfron®, a Twaron® based product reduces hysteresis in rubber, leading to a reduction in rolling resistance (Van den Hondel, 2012). The reduction in cumulative energy demand for the replacement of steel is 13,5%. Additionally, adding Sulfron® gives another 11,5% reduction. The total effect of lower weight and less rolling resistance leads to a 25% reduction in energy use

Some figures:

Weight reduction	**40%**
Energy savings:	**25%**
CO_2 emissions savings:	**depends on grid**
Payback time:	**some months**

Figure 1: Picture of South African Conveyor belt, with some results of the calculations.

In this case study with the Customer Benefit Model, the variables were the type and price of energy, the energy source (e.g. coal, wind etc.), rubber price and carbon pricing. Energy prices and the type of energy differ per region. Additionally, rubber and energy prices often fluctuate over time. We provided for every customer a tailor-made calculation of the energy and CO_2 emission savings and the yearly financial benefit. The latter was expressed as NPV, IRR and pay-back time, in order to give an easy and understandable evaluation of the results. Financial effects strongly depend on local prices of energy and rubber. Payback time is a few months, and the IRR is far above 200% (Bosman et. al, 2012).

Case study: Gas cylinders

For gas cylinders weight reduction is the main driver for replacement of steel by using Twaron® as reinforcement material whilst assuring intrinsic safety. By comparing both solutions over their lifetime, it became clear that for regions with a tropical climate maintenance is an extra driver. A steel cylinder needs to be repainted several times during the lifetime, whilst for the Twaron® based composite gas cylinder this is not necessary.

We considered the lifetime of both as equal, and both are fully recyclable. A big advantage in the use phase is the lower weight of the cylinder: 16,4 kg for steel compared to 4,3 kg for Twaron® based composite cylinders. Maximizing cost performance in the chain expressed in the financial benefits leads for tropical regions to 40% reduction. Over the lifetime of the gas cylinders at least 33% energy and CO_2 emission savings are realized. The positive effects of less weight during transportation over the total lifetime are expected to be significant; these effects are not taken into account yet.

Case study gas cylinders: some figures

calculated over the total lifetime of 25 years

Weight reduction (empty):	**74%**
Primary energy savings:	**33%**
CO_2 emission savings:	**33%**
Cost reduction (TCO):	**40%**

Note: transport is not included yet.

Figure 2: Case study Gas Cylinders: some figures.

CONCLUSION

The CBM can be used to quantify effects over the whole life cycle of smart solutions. It supports business cases by quantification of financial and ecological advantages of Twaron® based solutions in comparison to the current mainstream. Current and future scenarios can be quantified by changing values of variables. By using the CBM it proves that sustainability can be a driver for business development. It connects environmental performance with sound and sustainable business cases.

REFERENCES

Bosman, H., Beers, H., Ven, H. van der, Bos, H. (2012). Environmental and financial savings for conveyor belts by using aramid as reinforcing material. *Proc. Of the Enermin Conference Salvador Bahia, Brazil, September 11, 2012*

Van den Hondel, G. (2012). Aramids for low weight and low rolling resistance of conveyor belts. *Proc. of the Bulk Solids Europe 2010 conference, Glasgow, United Kingdom, September 9, 2010*

Lodewijks, G. (2012). The next generation low loss conveyor belts**.** *Bulk Solids Handling*, 1, 52-56

ROLES AND RESPONSIBILITIES IN BUILDING AND CONSTRUCTION

Tuesday, Aug 27:	10:30 am - 12:00 pm
Session chairs:	Holger Wallbaum, Chalmers University of Technology, Sweden Michael Scharpf, Holcim Technology Ltd, Switzerland

CHALLENGES FOR THE USE OF LIFE CYCLE ASSESSMENT AS A DECISION-MAKING TOOL IN BUILDING DESIGN – THE WÄLLUDEN CASE STUDY

Diego Peñaloza, SP Technical Research Institute of Sweden*

Per-Erik Eriksson, SP Technical Research Institute of Sweden

Joakim Norén, SP Technical Research Institute of Sweden

**Address correspondence to: Diego F. Peñaloza, SP Wood Technology. Drottning Kristinas väg 67, Box 5609, 11486. Stockholm, Sweden. E-mail: Diego.Penaloza@sp.se*

Keywords: Life Cycle Assessment; Wood Construction; Carbon Footprint

ABSTRACT

The construction sector accounts for almost twenty percent of the global carbon emissions, so measures to decrease the carbon footprint of constructions should be introduced during design. A full LCA was conducted for eight different designs for a four-storey multi-family building. The methodology was tailored for a designer’s perspective to identify challenges for the use of LCA by non-practitioners. Results show that the selection of building system does not influence the results, as does the use phase energy efficiency or the selection of materials. The production phase becomes more influential with increased use phase energy efficiency. Results suggest that either an increased knowledge of sustainability tools among designers or further simplification of the tools, standards and guides available is required.

INTRODUCTION

Society is heavily dependent on fossil fuels, with rising concerns about environmental impacts such as climate change (IPCC, 2007). The construction sector is responsible for a large share of society’s greenhouse gas emissions. Currently, around 33% of the global greenhouse gas emissions from human activities can be attributed to the building sector (UNEP, 2007). Safe housing is a basic need for mankind, which means there is a strong need to decrease these emissions while still building enough housing for the growing world population and contributing to economic growth. All this calls for measures towards a more sustainable built environment. Environmental criteria should be involved in construction projects as early as in the construction stage. In order to do this, designers have different tools such as standards, software tools such as SimaPro, VIP+ or GaBi, ready-made databases such as Ecoinvent or ILCD, and environmental product declarations (EPDs). Life Cycle Assessment (LCA) is a well-accepted tool for analysing the environmental impact of design alternatives using a life-cycle perspective (Baitz et al, 2013; Guinée et al, 2011). It provides a fair idea of the environmental impacts related to each life cycle stage of a building, which is often used to identify the environmental “hot spots” of a product’s life cycle.

METHODOLOGY

A cradle-to-grave LCA was performed. The methodology of the assessment was tailored for a designer's perspective to identify challenges for the use of LCA among non-practitioners by using easily available data. The production of wood materials was modeled using EPDs inventoried by SP Wood Technology (formerly as Trätek) with the Swedish wood industry. For other materials, external EPDs, literature data (Björklund and Tillman, 1997; IISI, 2001) and existing databases such as Ecoinvent and ELCD were used. The use stage energy requirements were modeled by Linnaeus University (as part of the €CO2 project) using the VIP+ dynamic simulation software and environmental data reported by Växjö Energi AB, the local energy supplier. A square meter of living area was assumed as the functional unit, and a service life of one hundred years was used. Only carbon footprint was used as an indicator.

The effects from concrete carbonation phenomena were included in the analysis, following a methodology developed Lagerblad (Lagerblad, 2005). Ecoinvent data was used to model the waste treatment processes, assuming that 70% of the waste is recycled or reused and the remaining waste goes to treatment processes, while 90% of the wood waste is used for energy production. These carbon implications are explored applying a substitution effect, assuming that the energy produced from the wood waste will replace fossil fuels. The storage of carbon dioxide in wood products is displayed to illustrate the possibility of potential additional benefits from the temporal storage of carbon. Further details for the assessed designs are described in SP's research report 2013:07 (Peñaloza et al, 2013).

RESULTS

The results for the greenhouse effect impact category are displayed in figures 1 and 2. The contribution from different kinds of materials to the total carbon footprint of the production phase can be observed in figure 1. Meanwhile, figure 2 shows the carbon footprint for the whole life cycle of each of the analyzed designs. The results are distributed per life cycle stage, a distribution which is aligned with the module division in the EN 15978 standard (CEN, 2011). The results displayed under "Module D" correspond to the environmental benefits from the end-of-life scenario in which all the bio-based products are incinerated to produce energy, and this energy replaces energy from coal described in the previous section.

DISCUSSION

The main differences between the carbon footprints of the evaluated design alternatives come from the selection of materials in the production phase and the use phase energy demand. The completeness of the study ensures that every life cycle stage is included to some extent, and as many processes as possible are included. Identifying these influential aspects is possible during data collection, but this identification requires certain level of expertise in the LCA field. The difference between the evaluated systems is case-specific, as not every decision in the designing process is related with material selection or energy efficiency standards. Other variables such as construction method, selection of suppliers, the level of prefabrication or architectural design may be more important for other cases or circumstances.

Involving every life cycle stage favors the completeness of LCA, but it increases the amount of time and resources required to obtain a result. The evaluation of design alternatives requires often a more practical approach of LCA, a method which provides faster results with minimum input, so as many design alternatives as possible can be evaluated. This is the case especially for buildings, as they are complex systems involving different processes and systems. This is why completeness might not be very relevant for this kind of application of LCA tools. Instead, short and fast LCAs should be applied with focus on the processes and life cycle stages affected by the differences between the evaluated alternatives. Moreover, the use of existing LCA standards in the design process presents a certain challenge, as standards tend to favor completeness over practicality. This is due to the fact that existing standards are made by experts and intended to be used by experts, which excludes designers from using standards as a tool in LCA practice for decision-making.

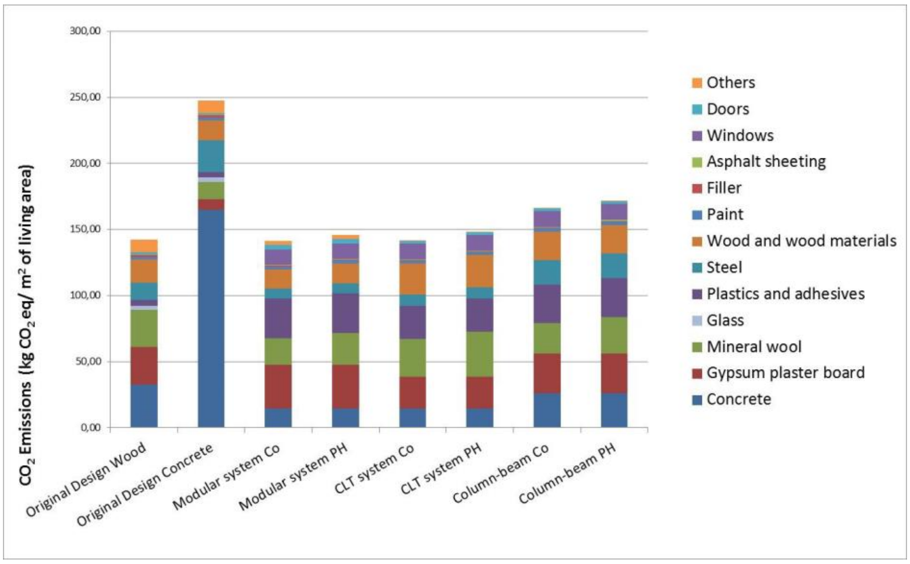


Figure 1. Greenhouse effect for the production phase of the eight design alternatives.

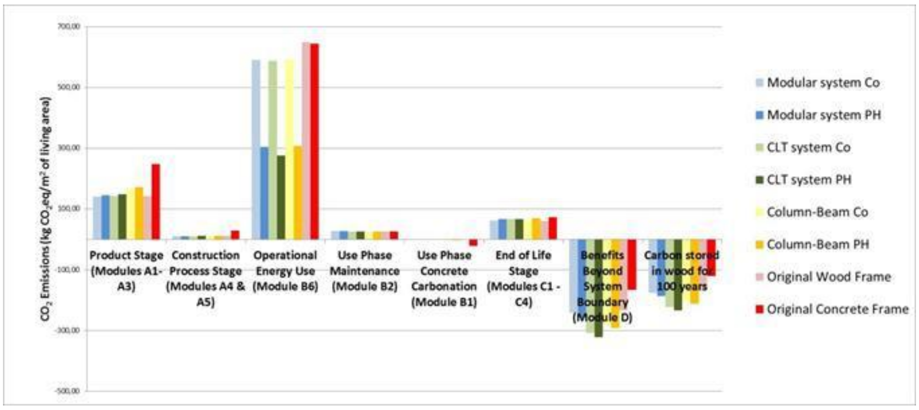


Figure 2. Greenhouse effect for the whole life cycle of the eight design alternatives.

CONCLUSIONS

In order to use LCA tools for decision-making during the design of construction projects, the scope of the assessment should be defined with focus on the differences between the evaluated alternatives rather than the completeness of the evaluated system. There is currently a gap between designers and the use of LCA during design. In order to close this gap, it is required either an increased knowledge of LCA practice among designer teams or further simplification of the tools, standards and frameworks available for them to use in the process. Other challenges identified for designers are product data availability and interpretation, uncertainties over service life of buildings and materials and the interpretation of results from existing ready-made LCA software tools.

Regarding the LCA results, they show that for more energy efficient building designs or buildings supplied from energy systems with lower carbon footprint, the production and end of life stages are highly relevant. The use of wood and bio-based materials can significantly decrease further the carbon footprint of energy-efficient buildings. This potential can be seen in the production stage, the construction activities and the end-of-life stage. Furthermore, buildings with a higher content of wood materials have higher potential environmental benefits beyond the end-of-life from using them for energy recovery. The choice of wood building system does not seem to have a major influence in the results.

ACKNOWLEDGEMENTS

The findings described in this abstract result from the work done as part of the €CO2 project, part of the Wood Wisdom-net ERA-net platform.

REFERENCES

Baitz M, Albretch S, Brauner E, Broadbent C, Castellan G, Conrath P, et al (2013). LCA's theory and practice: like ebony and ivory living in perfect harmony? *International Journal of Life Cycle Assessment 18:5-13*.

Thomas Björklund, Ann-Marie Tillman (1997). LCA of building frame structures. Chalmers University of Technology, Technical Environmental Planning. *Report 1997:2*.

European Committee for Standardization CEN (2011). Sustainability of Construction Works – Assessment of environmental performance of buildings – Calculation methods. *EN 15978*.

International Iron and Steel Institute - IISI (2001). Life cycle inventory data for steel products.

Solomon S, Quin D, Manning M, Chen Z, Marquis M, Averyt KV, Tignor M, Miller HL (2007). Climate change 2007: The Phisical Science basis, contribution of working group I to the fourth assessment report of the IPCC. *Cambridge University Press, Cambridge, UK and New York, USA*.

Guinée JB, Heijungs R, Hupes G, Zamagni A, Masoni P, Buonamici R et al (2011). Life Cycle Assessment: Past, Present and Future. *Environmental Science and Technology 45:90-96*.

Björn Lagerblad (2005). Carbon dioxide uptake during concrete life cycle – state of the art. Swedish Cement and Concrete Research Institute (CBI*). CBI Report 2:2005*.

Diego Peñaloza, Joakim Norén, Per-Erik Eriksson (2013). Life Cycle Assessment of Different Building Systems: The Wälluden Case Study. *SP research report 2013:07*.

United Nations Environmental Programme (2007). Buildings and Climate Change: A Summary for Decision. United Nations Environmental Programme.

EXPLORING THE REGULATIVE DRIVERS AND BARRIERS FOR LOW IMPACT BUILDING MATERIALS IN THE UK

*Natasha Watson, IDC in Systems and Buro Happold Ltd.*Prof. Pete Walker, University of Bath, Andrew Wylie, Buro Happold Ltd., Dr. Celia Way, Buro Happold Ltd.*

**IDC in Systems, University of Bristol, Bristol, BS8 1TH, UK*
Natasha.watson@burohappold.com

Keywords: Low Impact Building Materials, Regulations, Barriers to entry

ABSTRACT

This paper used online questionnaire, interview, and case study data to explore the regulative forces applied to the adoption of low impact building materials in the UK. It was discovered that there are few regulative barriers to their adoption, but there are issues with the conservative nature of UK construction, warranty and insurance, the valuation of sustainable buildings, perceived and real extra costs, and the interpretation of the Building Regulations. There is the need for clear and specific legislative drivers to entry for these materials and greater awareness and education of the construction industry that support the increasing market demand for green buildings and LIBM. The most important change needed is the reassessment of the valuation of green housing.

INTRODUCTION

Low impact building materials (LIBM) are those that have a low negative environmental impact and a potentially high positive social and economic impact. LIBM can range from materials that modestly improve on typical practice (e.g. concrete with cement replacement) to ‘deep green’ materials such as straw bale, rammed earth, and bamboo.

In line with EU and UK directives to reduce carbon emissions as well as the new era of sustainable architecture, the UK construction industry is reducing its carbon footprint. Currently, this is being achieved through changes to the construction process as well as changes to the delivery of buildings and in building design. With these measures, and as we move towards a zero carbon energy supply from nuclear and renewables, the importance of the embodied carbon of our construction materials will increase. This will call for the increased use of local materials from renewable (crop or earth based) or recycled sources (LIBM).

The term ‘regulative’ has been defined as ‘to control or direct according to rule, principle, or law; to adjust to a particular specification or requirement’ and so covers planning and building regulations, as well as warranty, insurance, and aspirational building assessments such as Code for Sustainable Homes (CSH) and British Research Establishment Environmental Assessment Method (BREEAM).

METHOD

This project was undertaken as 'practitioners' research' with the aim to strike a balance between academia and industry; implementing rigour and respectability to the research whilst keeping the topic and findings relevant and credible. Data were collected using a questionnaire that had 81 responses, six semi-structured interviews with industry experts, and chain-referral data sampling of secondary sources. This data was coded using NVivo and processed using a qualitative techniques based on grounded theory (Corbin and Strauss 2008). Previous literature and quotes from the data have been integrated into the discussion to support the findings.

DISCUSSION

Conservative vs. Innovative

The UK construction industry is viewed as "*conservative*" and regulations need to be more "*bullish*" to promote the use of LIBM. This is in keeping with the literature as Derwick and Miozzo (2002) and Pitt et al. (2009) believe steady increases in legislative penalties and economic incentives are needed to promote sustainable buildings, creating a 'level playing field' between sustainable and non-sustainable buildings. Williams and Dair (2007) found that where policies and regulations were clear and enforceable, sustainable objectives are largely met. This suggests that designers want a 'tick-box' exercise to increase the use of LIBM as it is simpler to monitor and enforce; a prescriptive set of regulations. This also suggests that regulation is being viewed as a means of getting the construction industry to change; to artificially stimulate the market into creating low energy housing and offices. This is very different from how the Building Regulations currently stand as a functional performance standard. They "*are written for innovation... we try to say 'yes' first, and… try and meet that minimum standard*". The National House Building Council (NHBC) building standards are similar as there are only five technical requirements and "*everything else is either a performance standard or guidance*." Building regulations currently do not achieve their aim, as the construction industry is too conservative for them i.e. as they are not prescriptive, the construction industry doesn't have the drivers it needs to change its attitude. This disconnect between what needs to change; the construction becoming more innovative, or the regulations becoming more prescriptive, needs to be tackled if LIBM are to be used more in the UK.

Value of Green Buildings

Commercial buildings have added value if they are 'green' due to reputational benefits, fulfillment of CSR mandates and increased employee productivity (Nelson and Rakau 2010 cited by RICS 2011). These benefits have been recognised by commercial developers and so asking them for BREEAM Very Good certification "*has become just completely straight-forward, like default industry standard*".

However with house building, "*the resistance to change is much greater*" as there is a "*cultural difference*" between commercial developers and volume house builders. Further investigation suggests that this is down to how the market is perceived; "*house builders think that buyers are conservative*" and so provide for that market, making it "*self reinforcing*". There is also "*more awareness of running costs in commercial buildings, so [if] people are looking for office space, for example, then they will look quite carefully at what their energy* *bills are*". Yet with increasing fuel prices and fuel poverty in the UK, there is an increasing demand for sustainable housing with low running costs. Climate works (2011) found that "*homes which are smaller, with very much lower running costs, can be particularly desirable*". Also the rise of green consumerism could make LIBM more attractive than standard building products.

Much of a house's value is still on "*traditional indicators such as the number of bedrooms, bathrooms, built-form*." and although developers "*ought to be able to get a premium for this house if [they] put solar panels on the roof*", it is not usually the case. This is a very important point that needs addressing. There are many house builders within the UK and with the demand for low cost housing, developers tend to compete on cost alone. If developers were reimbursed for extra costs they incur from additional work and altering their supply chain to produce greener housing, there is more of an incentive for developers to implement these improvements.

Perceived and Real Extra Costs

Understandably green buildings tend to have extra capital costs due to extra insulation, lack of economies of scale with LIBM etc. However the extent of these extra costs is very difficult to determine. Bristol's policy on achieving Code for Sustainable Homes Level 6 housing by 2016 underwent a consultation written up by Climate works (2011) as developers believed it to be too onerous and costly to achieve. The report stated that the developers were not necessarily concerned with "*the principle of the fact that higher performance standards would mean extra cost*", but more that there was an "*uncertainty about what these costs might be, how to achieve the required standards, the difficulties of amending existing design and procurement processes, and how to sell higher performance buildings to customers*." These concerns call for greater education and guidance for the developers on how to achieve these standards, and for specific and clear legislative drivers for LIBM.

Warranty and Insurance

Building Regulations and NHBC Building Standards may be written for innovation, but their accountability ends when the building is completed. Warranty and insurance consider the long-term performance of a building material and in the case of LIBM the main issue is durability. Conventional materials have proved their reliability over time through empirical data from field performance. This leaves LIBM in a dilemma; field performance data are difficult to collect as few projects use these materials, and only a few projects use LIBM because there concerns with the reliability of these materials due to the lack of data. In the absence of field data, third party assessments on the performance of a particular materials or products are accepted. Testing would not be accepted, as "*tests in isolation don't give us the whole picture*". These assessments under are expensive, and as many LIBM companies are smaller start-ups, undergoing this assessment is a large financial ask. As third party assessment isn't necessary for Building Regulations this issue isn't a critical barrier for the use of LIBM, however third party certification would increase the market available.

Interpretation of Building Regulations

Tir-y-Gafel, an eco village in Pembrokeshire developed by the Lammas Low Impact Living Initiative, became involved in a dispute with Pembrokeshire County Council over Building Regulations. This development follows the 'deep green' philosophy, which calls for such a large departure from mainstream house design that the interpretation of these occupants of 'adequate', 'reasonable' or 'appropriate' within the Building Regulations is very different from those of the mainstream population, including most building inspectors. This included sourcing fresh water from a nearby spring, sourcing hot water from heating it up on a wood stove, skylights made from recycled cellophane, and breathable wall construction.

All charges have been dropped by Pembrokshire County Council (PCC) as it was their interpretation of the regulations, of what is 'adequate', 'reasonable' or 'appropriate', that was the issue, not the regulations themselves (PCC 2011 cited by Dale and Saville 2011). This issue of mainstream interpretation of the Building regulations is a key one, as those with a ‘deep green’ mentality will have a different interpretation of what are acceptable living conditions.

CONCLUSIONS

In conclusion, there are few regulative barriers to the adoption of LIBM, but there are issues with the conservative nature of the UK building industry, warranty and insurance, the valuation of sustainable buildings, perceived and real extra costs, and the interpretation of the Building Regulations. There is the need for clear and specific legislative drivers to entry for these materials and greater awareness and education of the construction industry that support the increasing market demand for green buildings and LIBM. The most important change needed is the reassessment of the valuation of green housing. Through appropriate valuation, developers would then be able to recuperate the extra costs needed to alter their supply chain and install benefits such as micro generation and breathable wall constructions. This will also allow housing developers to compete on criteria other than cost, prompting best practice. An increase in scope would lead to the investigation of the valuation of green housing; interviewing estate agents, house buyers, house builders, and mortgage companies.

REFERENCES

RICS. 2012. Supply, Demand and the Value of Green Buildings. London: RICS.

Pitt, M. et al. 2009. Towards sustainable construction: promotion and best practices. Construction Innovation: Information, Process, Management, 9:2 201-224.

Williams, K. and Dair, C. 2007. What is Stopping Sustainable Building in England? Barriers Experienced by Stakeholders in Delivering Sustainable Developments. Sustainable Development, 15 135-147.

Climate works, 2011. Sustainable building standards evidence base - Bristol. Bristol: Climate works

Corbin, J. and Straus, A. 2008. Basics of qualitative research. 3e Ed. Sage, London.

Dale, S. and Saville, J. 2011. The Compatibility of Building Regulations with Projects under new Low Impact Development and One Planet Development Planning Policies. Lammas.

Dewick, P. and Miozzo, M. 2002. Sustainable technologies and the innovation – regulation paradox. Futures, 34 823–840.

HOW FRANCE'S BOURGOGNE DISTRICT HAS FOSTERED THE DEVELOPMENT OF LIFE-CYCLE OPTIMIZED BUILDINGS INVOLVING ALL STAKEHOLDERS

Sié Marion[1], Payet Jérôme[1], Marie Dominique[2]*

[1]Cycleco, [2]Région Bourgogne

**Cycleco, 1011 avenue Leon Blum, 01500 Ambérieu-en-Bugey, France, marion.sie@cycleco.eu*

Keywords: buildings; ecodesign; LCA; tool; database

ABSTRACT

Bourgogne district have been working for 5 years to bring LCA into general practice in the building field. They began in 2009 to conduct a substantive work which fitted with current needs at that time: a database of environmental impacts of generic building products for French market. The second step of the project was for Bourgogne district to discuss the method with stakeholders. The outcomes of discussion indicate the need to enter a third step (under way) aiming at improving the database. All data are implemented into e-LICCO, a LCA software used by building professionals. This experience shows how a political decision maker, Bourgogne district, succeeds in fostering the development of life-cycle optimized buildings involving stakeholders in the process.

INTRODUCTION

The Construction sector represents about 40% of the total energy consumed in Europe and has a great potential for improvement. Indeed, energy efficiency strategies can reduce a building's energy consumption by 50% to 70% and buildings can be used to raise the share of renewable energy (Zervos, Lins, & Muth, 2010). In addition, the built environment uses 50% of the materials taken from the Earth's crust. The construction and demolition stages are the source of 25% of all waste generated in Europe.

In light of this, Bourgogne district always tried to contribute to the challenge of reducing environmental impacts of building industry, trying to always be one step forward regulation. In 2008 the building team in Bourgogne district launched a call for projects for very low energy buildings (Marie, 2008). In particular, the call included the requirement for building owners to take care about embodied energy of their building. This call constitutes the first step of Bourgogne district into life cycle thinking. They thus state that there were no independent, complete and liable databases of building materials impacts available on the market. Indeed, reliability of French INIES database (Meur, & Ruzin, 2008), which gather EPDs of building products manufacturers, rely on manufacturers' good faith (only 30% of EPD are reviewed) and other available data are not valid for French context. From then on, the Building department of the district, led by Dominique Marie, has worked at the elaboration of an environmental database to allow performing reliable LCA during building conception.

METHOD

Conduct a substantive work which fits with actual needs

The 2008 call for projects for very low energy buildings gather up more than 100 building owners, so the year after Bourgogne district chose Cycleco, a Life Cycle Assessment company, to assist them throughout the issue of embodied energy. During two years, Cycleco developed an ecoinvent-based database of embodied energy of building materials and products. The requirements were to make a complete and well documented database of generic products, i.e. independent from manufacturers. Cycleco build up a first version including 220 items and went beyond project terms and developed of prototype of a LCA web application to go with the database.

Discuss the project with stakeholders

In 2011, interest for embodied energy growing, Bourgogne districts consolidated a steering committee of political decision makers, as people belonging to ADEME (French Environment and Energy Management Agency) and other districts in France, for them to give their recommendations about the tool being developed. On the supervision of the steering committee, Cycleco established a Product Category Rules (PCR)-like for LCA of buildings and completed a first version of the web application called e-LICCO (Sié, & Payet, 2012). At that time Regional Delegation of ADEME in Bourgogne decided to be involved and to support the project. Meanwhile, Cycleco keep on working on the database adding 300 new items, and improving the software. Furthermore, building professionals began to use e-LICCO, mainly in the framework of calls for projects lead by districts in France.

Improve what have been done

In 2012 Bourgogne district decided to involve building professionals in the development of the next version of e-LICCO database. Two architects' and three building engineers' teams have been working along with Cycleco since the beginning of last year on the development of an improved version of the database which allows, once implemented into e-LICCO, starting eco-design at the early stages of a building project. It involved in particular aggregation of data to build environmental impact of constructive systems (wall, floors…) and ratios for technical systems and utilities. In addition, constructive system's cost ranges are estimated and displayed to help designer through conception process. The second version of the software will be available in January 2014.

RESULTS

As a result, around 40 building projects have been life cycle assessed with e-LICCO so far.

Building professionals use it:

- to assess grey energy and carbon footprint
- to know environmental burden of construction or renovation in relation to operation (see figure 1)
- to compare variants

- to study eco-design routes

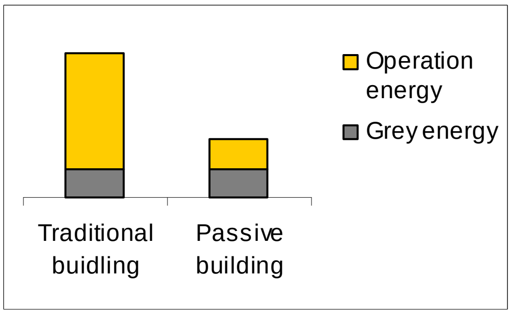


Figure 1. Example of results provided by e-LICCO: comparison of grey impacts and building's operation impacts

Bourgogne district and its partners hope to foster use of LCA for building design with the next version of e-LICCO to be launched in January 2014 and currently under beta test. Using this new version, projects developers can easily and quickly (less than 3 hours) achieve a reliable LCA of their building at the planning stage of their project. They get costs information as a help to design while performing assessment. In addition, ILCD Midpoint impact categories have been added to the set of indicators already in place.

CONCLUSIONS AND PERSPECTIVES

Bourgogne district experience shows how a political decision maker succeeds in fostering the development of life-cycle optimized buildings involving all stakeholders in the process.

Management board of e-LICCO, consisting of of Bourgogne district, Regional Delegation of ADEME in Bourgogne and Cycleco, is currently thinking about actions plan for next years to attract always more and more users and, as a consequence, to get more and more Life Cycle Optimized buildings. This plan includes tasks as: involvement of manufacturers in database elaboration, communication and marketing around the tool, to become closer to environmental certification/labialization schemes, the study BIM (Building Information Model) compatibility…

REFERENCES

Marie, D. (2008). Appel à projets 2008, Bâtiments basse et très basse énergie, bâtiments à énergie positive. http://www.bourgogne-batiment-durable.fr

Meur, A. & Ruzin, S. (2008). Protocole relatif à la structure provisoire de gestion de la base de données sur les déclarations environnementales et sanitaires des produits de construction (INIES), Retrieved from: http://www.inies.fr

Sié, M., Payet, J., (2012) e-LICCO: Evaluation tool for Low Impacts and Costs Constructions, *Proceedings of the 2nd International LCA Conference [avniR]*, 36-38.

Zervos, A., Lins, C. & Muth, J., (2010). Re-thinking 2050: A 100% Renewable Energy Vision for the European Commission. Retrieved from: http://www.erec.org

LCA IN CONSTRUCTION WORKS AS A POWERFUL DECISION MAKING TOOL. ACCIONA INFRASTRUCTURE´S EXPERTISE

Fernández Flores, Rocío; Guedella Bustamante, Edith; Sánchez Rojo, Antonio José; Calvo Herrera, Ignacio. Valportillo Segunda, 8, 28108, Alcobendas, Madrid, Spain. Technological Centre. ACCIONA Infrastructure.* e-mail:rocio.fernandez.flores.ext@acciona.com*

Keywords: LCA; sustainable construction; decision making; tool; GaBi.

ABSTRACT

Construction sector is aware of the need of measuring, avoiding and reducing environmental damage caused by construction materials, processes, services, construction methods and sites.

ACCIONA Infrastructure has the strategy of considering LCA as a tool for both environmental and business management. ACCIONA´s Technology & Innovation Division has applied LCA methodology to building and civil construction. ACCIONA bets on innovative materials and construction processes which help to reduce environmental impacts by replacing traditional ones by them. Some LCA examples highlight encouraging results for innovative materials like fiber reinforced polymers in comparison with traditional ones like concrete and steel.

In conclusion, thanks to life cycle thinking, construction sector has enhanced its processes and products, making them more technically efficient and environmentally sustainable.

INTRODUCTION

The global understanding that natural resources and non-renewable energy sources are not inexhaustible has been growing lately together with the increase of conscientiousness on the consequences that our demanding way of life has on the environment. Global warming, ozone layer depletion, greenhouse effect or acid rain, are some of these consequences, which may reach catastrophic levels if nothing is done to emend the current situation. Lately, society is beginning to consider sustainability not only as a requirement but also as a distinctive value which has to be pursued by the different areas of society such as public administration, companies, engineers and researchers (García, 2011).

As a fundamental part of society, infrastructure and building have utmost importance in sustainable development. Building sector, including housing, constitutes 30–40% of the society's total energy demand and approximately 44% of the total material use (Erlandsson & Borg, 2003). The environmental impact of construction, green buildings, designing of recycling and eco-labeling of building materials have captured the attention of building professionals across the world. Building performance is now a major concern of professionals in the building industry and environmental building performance assessment has emerged as one of the major issues in sustainable construction (Ding, 2008). It is essential making an effort to use all the available tools to apply the best structural design which not only meets technical requirements but also has a good performance to the environment. There is a concern about how to improve construction practices in order to minimize their detrimental effects on the natural environment.

In this context, environmental assessment methodologies provide a valuable tool for helping decision makers and engineers to identify and select the best alternative design regarding environmental issues. It is important to count on a common basis as well as to establish homogeneous criteria with a systematic methodology in order to obtain reliable results to compare alternatives and make right decisions. Designers of buildings, manufacturers of construction products, users of buildings and others actives in the building sector are increasingly demanding information that will enable them to make decisions that will minimize the adverse environmental impacts of buildings and construction assets. They are joining forces to develop a standard and harmonized procedure of reduction and measurement of emissions as well as common and updated databases for using worldwide.

The objective of this paper is presenting ACCIONA´s commitment in its struggle to include sustainability concept into its works and services. ACCIONA mainly uses LCA methodology as a selection criterion in order to make the optimum decision in regard construction technologies, processes and materials with better environmental performance.

METHODS

Life cycle assessment is a methodology to assess the environmental aspects and potential impacts associated with a product, process, or service considering a “cradle-to-grave” approach which begins with the gathering of raw materials from the earth to create the product and ends at the point when all materials are returned to the earth. LCA is a standardized technique (ISO 14040-44) which consists of compiling an inventory of relevant energy consumption and raw material, evaluating the environmental impacts associated with identified inputs and interpreting the results to help decision making process.

LCA becomes an environmental strategy of ACCIONA´s Technology & Innovation Division in accordance with the business line of ACCIONA Infrastructure with the aim of reducing environmental damage as well as generating business value by lowering costs associated with energy consumption and materials. Therefore, it is a tool for both environmental and business management. The main advantage of the proposed methodology is the possibility of assessing the environmental impacts and sustainability of any innovative construction process developed by ACCIONA, and the comparison of its associated environmental impacts with those caused by conventional technologies, processes or materials. ACCIONA has the know-how for applying this methodology to their decisions making processes, helped by GaBi 6.0 software (databases: ELCD, Ecoinvent, PE, updated in 2012). Some examples are LCA of several elements of buildings such as fences, pipes, floors, walls, doors and insulation panels. LCA of civil works such as a Fiber Reinforced Polymer (FRP) bridge (M-111 highway, Madrid, Spain and its comparison with its analogue structure in concrete and steel), railway bridge (Arroyo Valchano, Orense, Spain), excavation and sustaining of a tunnel in a 40MPa rock considering two different procedures, drilling and blasting, roads (Cieza-Fuente de la Higuera Road, Valencia, Spain and N-340 Road, Elche, Alicante, Spain) and structural reinforcement (with concrete, steel or FRP) of beams and columns, among others.

RESULTS

Thanks to the application of LCA methodology it is possible to obtain quantified results regarding not only general emissions (to air, water, soil) of heavy metals, inorganic and organic compounds, particles, radioactive compounds but also the eco-profile (damage caused to human health and ecosystem quality) by adding emission effects to different impact categories (CML 2001 methodology).

Results obtained after applying LCA methodology to a bridge construction will be analyzed below. The goal is the evaluation of the environmental damage caused by the construction of a 30m span and 12m width bridge, comparing the environmental behavior of a FRP bridge and a concrete bridge. Concrete bridge was made with prefabricated concrete troughs beams, precast concrete pre-slabs, steel bars and a concrete slab. FRP Bridge was made with FRP beams (infusion process), glass fiber pre-slabs (pultrusion method), a concrete slab, glass fibers bars (pultrusion method) and glass fiber upper flange (infusion process). Figure 1 details the results related to general emissions (A), emissions to air (B), CO_2 emissions to air (C) and impact categories according to CML methodology (D).

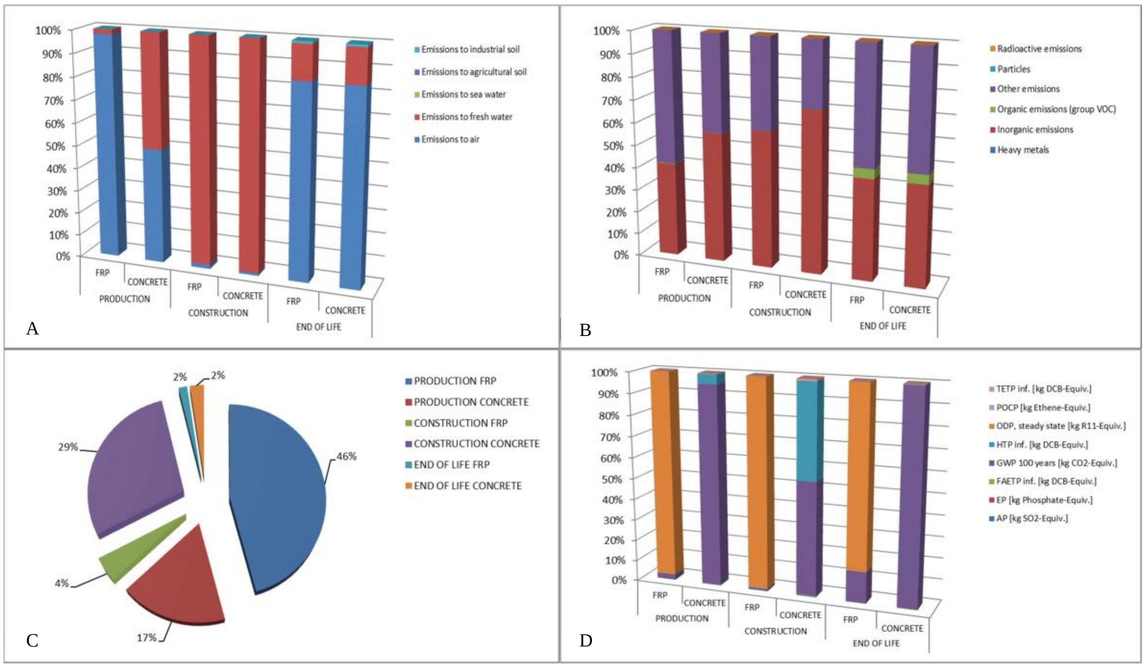


Figure 1. LCA results of a bridge. Comparison between concrete and FRP bridge.

Taking all the results into account it is possible to highlight that regarding general emissions (Figure 1_A), emissions to air and fresh water are the most generated ones during the production and the end of life stages of both types of bridges. During the construction phases, emissions to water are the most released emissions. On average, the construction of concrete bridge is the stage which causes more quantity of emissions to air, water and soil. Moreover, related to emissions to air (Figure 1_B), the highest percentage of emisions to air are caused during the production phase. In particular, the production of raw materials used in FRP bridge is the critical point because of the presence of epoxy resin as well as carbon and glass fibers. Furthermore, inorganic compounds are the most harmful emissions to air in all stages of the life cycle of both bridges, highlighting CO_2 emissions as the most generated. Specifically, the biggest quantity of CO_2 emissions (Figure 1_C) are caused during the production of FPR raw materials (resins and fibers) and during the concrete bridge construction phase. In addition, according to CML 2001 methodology (Figure 1_D), Global Warming Potential, GWP (in all stages of FRP bridge life cycle) and Ozone Depletion Potential, ODP (in all stages of concrete bridge life cycle) are the most harmful impacts to the ecosystem quality and human health. Ecotoxicity is the most generated impact to ecosystem quality during the entire life cycle of both analysed bridges. Human health is affected mainly by respiratory problems caused during the production and construction phases in both cases. Nevertheless, during the end of life phase, GWP is the most damaging impact to human health in both FRP and concrete bridges.

DISCUSSION

LCA methodology applied to a bridge construction is just one of the studies developed by ACCIONA which emphasizes the importance of this method to make strategic decisions. According to the results, considering the "cradle to grave" approach, FRP bridge presents a better environmental behavior than the concrete bridge. The main reasons are the composite lightness, which enables the reduction of fuel and energy consumptions (including transports and installation activities) as well as its excellent mechanical properties which avoid maintenance and reparation activities over the years. In general, the production phase is the most harmful stage. Specifically, the manufacturing of the required raw material for construction of FRP bridge (epoxy resin and fibers). Impacts associated to this stage could be reduced applying new and more efficient manufacturing processes or technologies, even substituting the most harmful raw materials for others. Moreover, emissions and impacts caused during the construction and the end of life stages could be also mitigated by enhancing any construction processes (lamination, infusion, pultrusion, curing, etc) and by developing more efficient and greener end of life strategies, for instance, recycling of composite.

CONCLUSIONS

It is essential to mention the importance of LCA methodology as a key tool for helping to make right decisions related to the development of any new technology, process or product considering environmental performances. ACCIONA is aware of the environmental impact of its construction methods and sites and uses LCA methodology for assessing, measuring and reducing them. This paper shows an example of how ACCIONA uses LCA method to evaluate which stage of the life cycle of a product/process is susceptible to changes or improvements for increasing the sustainability of the overall process, hence achieving the optimum technology from both technical and environmental point of view.

REFERENCES

Ding, Grace K.C. (2008). Sustainable construction- The role of environmental assessment tools. *Journal of environmental management, 86, 3, 451–464.*

Erlandsson, M. & Borg, M. (2003). Generic LCA-methodology applicable for buildings, constructions and operation services—today practice and development needs. *Building and Environment, 38,7, 919–938.*

García, L. (2011). Life Cycle Assessment of railway bridges. Developing a LCA tool for evaluating Railway Bridges. *Master Thesis 323. Structural Design and* Bridges. *ISSN 1103.4297. ISRN KTH/BKN/EX-323-SE.*

LCA-SUPPORTED POLICIES FOR THE ENERGY CONSUMPTION REDUCTION IN THE BUILDING SECTOR: THE ITALIAN ALESSANDRIA PROVINCE CASE STUDY

Giovanni Dotelli, Politecnico di Milano, Dipartimento di Chimica, Materiali e Ingegneria Chimica "G.Natta", and INSTM R.U. Politecnico di Milano, p.zza L. da Vinci 32, 20133 Milano, Italy, giovanni.dotelli@polimi.it*

Marco Borgarello, Francesca Carrara, RSE Ricerca Sistema Energetico, Energy Efficiency Research Group,via Rubattino 54, 20134 Milano, Italy

Keywords: energy efficiency; energy policy; carbon payback time; renewable energy

ABSTRACT

The aim of the study is to assess the feasibility of reducing to zero the use of fossil resources in a typical northern Italian region (Piedmont), and the Alessandria province was taken as case study. First, the present energetic situation was assessed (base scenario), then an ideal scenario where renewable sources and energy saving were maximized was devised, neglecting the economic aspects. In both cases the analysis focused on five main sectors: residential, private and commercial tertiary, industry and agriculture, while transportation was discarded. Although in the ideal scenario any economic or technological restriction was eliminated, the energetic self-sufficiency based on renewable resources was unattainable. The carbon footprint of some refurbishment strategies to be applied to the tertiary sector in the ideal scenario was assessed via LCA and the CO_2-eq payback time calculated.

INTRODUCTION

In 2012 public administrators, representatives of the private industrial sector and of other commercial categories of the Alessandria province, an area situated in the Piemonte (Piedmont) region of north Italy (Figure 1), gave birth to a panel which, in collaboration with universities and a public research center (RSE), had the commitment to devise a plan for reducing the fossil fuel consumption in the whole provincial area.

In particular, the panel should have answered the following question: discharging any economic aspects of the problem, what could be the energetic situation of the province of Alessandria if all decisions finalized to reduce fossil fuel consumptions and improve sustainable resources would be taken?

Considering the technical feasibility of the project and according to the EU directive "20-20-20" goals, the panel tried to justify every energetic decision, with a particular attention to land usage and carbon emissions. Emissions markers and the simplified LCA were adopted to analyze pros and cons of different scenarios.

In particular, refurbishment strategies in the public tertiary building sector have been examined with the aid of LCA methodology (ISO 14040-14044, 2006) and the environmental payback time estimated. To do that, the building stock of the entire province has been classified according to its construction time and role (public school, hospital, etc.); model buildings have been created and energy saving refurbishment strategies devised. Then, an LCA analysis of these retrofitting interventions has been carried out.

Going beyond the “20-20-20” directive, the ultimate goal would have been to reach the “ideal” situation of zero fossil fuel consumption and energy self-sufficiency. Notwithstanding this “ideal” situation (further strengthened by the removal of any economic and temporal limit), the result of the analysis shows that the absence of fossil fuel consumption is not technically reachable without forcing the idea of environmental sustainability. More realistic objectives have been consequently put forward and a holistic approach toward quasi-self-sufficiency in the energy sector of the Italian province of Alessandria suggested.

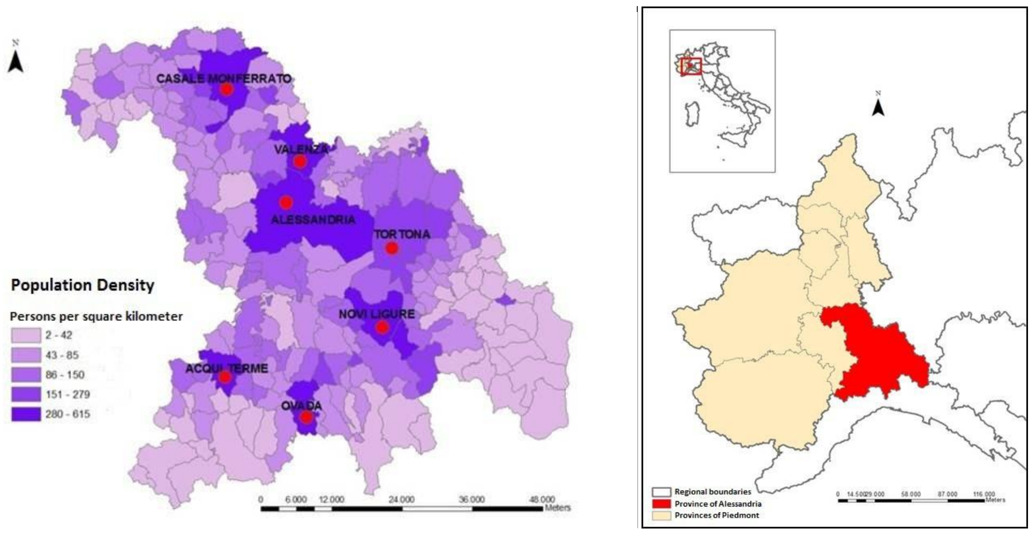


Figure 1. Piedmont region (right) and its location in Italy (inlet); population density distribution in the Piedmont region (left)

METHODS

The base energy consumption scenario of the province was built up starting from local policy directives and regional databases. Data collected were grouped into 5 main sectors: residential, public (or commercial) and private tertiary, industry and agriculture. Transportation was not taken into account considering that is not tightly dependent on local energy policies.

The ideal scenario was devised in accordance with the following assumptions:

- Differentiation between thermal and electrical energy request;
- Application of the maximum energy efficiency potential to each sector;
- Use of renewable energy resources in substitution of fossil fuels whenever applicable.

In the civil sector extensive refurbishment strategies were implemented in the line of quasi zero-energy buildings. To do that, the private and public building stock of the province was classified according to structural characteristics, age, thermal requirement and final use. Proper retrofitting actions were devised for each building class. On the contrary, in the industrial sector only “soft” refurbishments strategies were implemented with the aim of reducing wasted energy and possibly improving process efficiency, but without a drastic redesign of the production process.

LCA analysis of some refurbishment strategies to be applied to representative buildings of the residential and tertiary sector was carried out in order to assess the environmental load due to retrofitting and to calculate the carbon payback time. The system boundaries in the ideal scenario comprise materials used in the retrofitting, use phase of the building (50 years lifetime span) and waste disposal of substituted components, while in the base scenario only the use phase is accounted for.

RESULTS AND DISCUSSION

Energy consumptions of each sector in the two scenarios are reported in Table 1. In the building sector, both residential and tertiary, the potential energy saving ranges between 40 and 60%, while in the industrial sector the target was set to about 10 % reduction, and the outcomes were consistent with this hypothesis. Improvements in the agricultural sector were very low. Energy consumption is converted into CO_2-eq emissions by using proper emission factors (Table 2).

Table 1. Thermal and electrical energy consumption per year of base and ideal scenario subdivided into five main sectors.

	Base Scenario			Ideal Scenario		
Sector	Final Electricity Consuption	Final Heat Consuption	Final Energy Consuption	Final Electricity Consuption	Final Heat Consuption	Final Energy Consuption
	[ktep]	[ktep]	[ktep]	[ktep]	[ktep]	[ktep]
Residential	47,0	224,9	271,9	34,4	130,9	165,3
Public tertiary	13,1	33,4	46,5	12,3	6,1	18,4
Commercial tertiary	38,8	75,1	113,9	34,9	17,8	52,7
Industrial	150,8	310,2	461,0	135,7	279,2	414,9
Agricultural	2,8	57,0	59,8	2,6	51,3	53,9
Total	**252,5**	**700,6**	**953,1**	**219,9**	**485,3**	**705,2**

LCA was performed on representative buildings of tertiary stock, such as schools and municipal offices and the carbon payback time calculated. For nursery, primary, and secondary schools the carbon payback time of refurbishments is about 3 years, while in the case of municipal offices is about 50 months.

Table 2. CO_2-equivalent emissions per year corresponding to energy consumptions in the two scenarios.

Source	Base scenario	Ideal scenario
	Mt CO_2	Mt CO_2
Electrical energy	1,31	-
Natural Gas	1,60	0,79
Oil	0,84	0,41
Total	**3,75**	**1,20**

CONCLUSIONS

Energy consumptions of an entire province located in the northern Italy have been assessed. An ideal scenario was sketched in order to maximize energy efficiency and renewable resources use with the aim of going beyond the 20-20-20 directive and evaluating the possibility of attaining an energy self-sufficiency relative to the province territory. Although high reductions percentages were attainable, it is not feasible to imagine a self-efficiency in the energy sector without a massive use of biomasses which in turn would involve a dramatic change of the local economy. Refurbishment strategies in the building sector have a payback time in the order of few years while entailing substantial reductions in CO_2 emissions.

REFERENCES

Comuni Italiani (2010), Statistical data of the Provincia di Alessandria. http://www.comuni-italiani.it/006/statistiche/.

Ispra -Istituto Superiore per la Ricerca e l'Ambiente, Geoportale MAIS-SINAnet. Accessed October 2012. http://www.mais.sinanet.isprambiente.it.

ISTAT (9 October 2011), 15° Censimento Censimento della Popolazione e delle Abitazioni. http://censimentopopolazione.istat.it.

ISTAT, Statistical data. Accessed October. http://dati.istat.it

ISTAT, Censimento Agricoltura 2010, accessed October 2012: http://dati-censimentoagricoltura.istat.it/. Provincia

di Alessandria (May 2007). Energy policies directives of the Alessandria province (in Italian). http://www.ambiente.al.it/multimedia/381/Piano%20energetico%20Provincia%20Alessandria.pdf

Provincia di Alessandria, SIT, Cartographic documentation. http://www.provincia.alessandria.gov.it.

TERNA S.p.A, Statistical data on electrical energy in Italy. Accessed October 2012: http://www.terna.it.

LIFE CYCLE ASSESSMENT OF FIRE RETARDANT TREATED WOODEN CLADDINGS

Selamawit Mamo Fufa[a] and Rolf André Bohne[a]*

[a]Norwegian University of Science and Technology (NTNU), Department of Civil and Transport Engineering, NO-7491 Trondheim, Norway

Keywords: Coatings, Fire retardants, LCA, Wooden claddings.

ABSTRACT

The aim of this work was to evaluate the environmental performance of fire retardant treated exterior wooden claddings using LCA as a tool. The study takes into account the wood, paint and fire retardant chemicals production, wood treatment processes, use phase and disposal life cycle stages. The assessment was done using a functional unit of 1 m^3 treated exterior wooden cladding with a reference life span of 50 years. The results show that the highest impact from raw material production stage which is mainly contributed from fire retardant chemicals.

INTRODUCTION

Fires occur in buildings have been a concern due to the increased risk of injuries, loss of life and properties. The type of materials selected in buildings play major role towards determining the risk of fire and its propagation through the structure or adjacent units. Wood, one of the well-used sustainable building materials, is combustible and treated with different fire retardant chemicals to reduce the combustibility of wood. Fire retardants (FRs) are used to reduce the temperature at which thermal degradation of wood occurs allowing people more time to evacuate the building and authorities to control the spread of fire. Although FRs including phosphorous, bromine, boron, magnesium hydroxide and their combinations have been used in order to renew wood's popularity by reducing the risk of fires, some of these treatments have been criticized due to their poor performance (Ostman *et al.*, 2001; White, 2009; Hakkarainen *et al.*, 2005). To the best of our knowledge, there are no open references that cover LCA of fire retardant treated wood products using the standard methodologies. This study addresses the life cycle assessment of fire retardant treated wood used for exterior claddings, using ISO 14040 series life cycle assessment methodologies.

GOAL AND SCOPE OF THE STUDY

The goal of this study is to provide a comprehensive understanding of environmental burdens associated with the raw material, impregnation; wood coating; use and end of life (EOL) life cycle stages of fire retardant treated wood based on LCA methodologies. The scope of the study is illustrated in Fig.1.

* *Corresponding author: Tel: +47 40289316, Fax: +47 7397021, E-mail: Selamawit.fufa@ntnu.no*

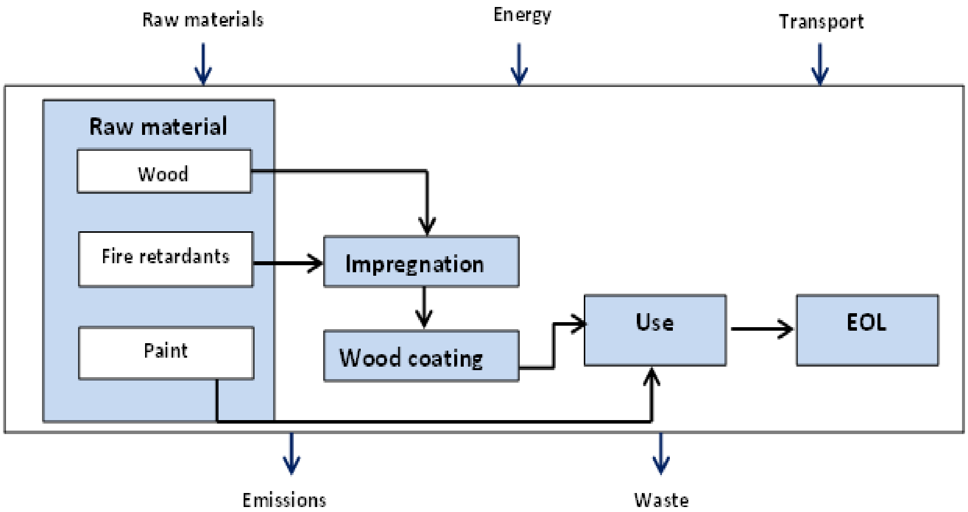


Fig.1. System description of fire retardant treated wood

LIFE CYCLE INVENTORY

The foreground information of the selected process in the wood production is based on the environmental product declaration. Primary input and output data for fire retardant fluid production and impregnation process were collected from Moelven wood. The coatings data was based on environmental data sheet and product technical data of Akzo Nobels products, Cetol BL 21 Plus and Cetol BL Opaque.

LIFE CYCLE IMPACT ASSESSMENT

The effects of resource used and emissions generated are quantified and grouped to limited number of indicators using the Europe ReCiPe midpoint and endpoint H/H LCIA method. The LCIA calculations have been performed by using Simapro 7.3 software.

RESULTS AND DISCUSSION

The percentage contribution values of impact indicator at each life cycle stages presented in Fig.2 shows the highest impact contribution of the raw material stage, predominantly on freshwater eutrophication impact category. From the raw materials, including wood, coating and FRs, the impact is mainly due to the FRs. The type of FR chemicals used and the requirement of higher FR retention in the impregnation process may be the cause of higher impact from FR. The energy consumption in the impregnation process; the fuel consumed during the transportation of the treated wood to construction site and the paint used for the maintenance of the cladding during its life time and finally the energy used as well as the emission generated in the end of life cycle stages may be the source of impacts from impregnation, use and end of life cycle stages, respectively. Relatively, the wood coating stage was with the lowest impact which may be due to the assumption of manual application of the paint on the surface of the cladding.

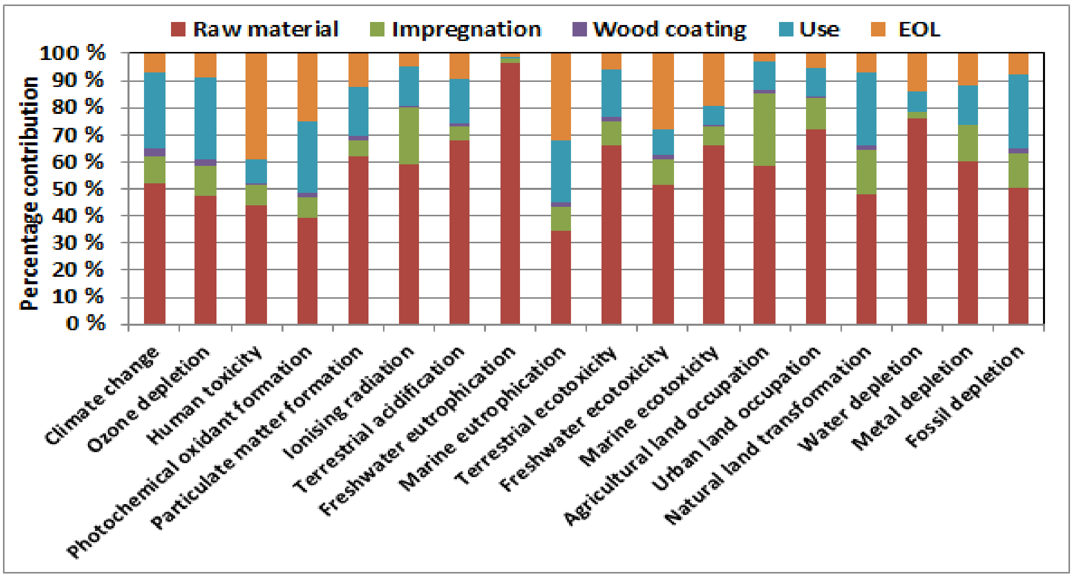


Fig.2. Impact indicator contributions for each life cycle stage

CONCLUSIONS

In this study, the findings illustrate the highest impact from the fire retardants used to improve the durability of fire retardant impregnated wood. Selecting durable and environmentally preferable FRs may reduce the impact of FR treated wood. Furthermore, utilization of durable paint may reduce the impact of the treated wood by reducing the frequency of maintenance required.

REFERENCES

Hakkarainen, T., E. Mikkola, B. Östman, L. Tsantaridis, H. Brumer and P. Piispanen, 2005. *Innovative eco-efficient high fire performance wood products for demanding applications. State of the art. SP report 2006:30*.

Ostman, B., A. Voss, A. Hughes, P. J. Hovde and O. Grexa, 2001. Durability of fire retardant treated wood products at humid and exterior conditions review of literature. Fire and Materials, 25(3), 95-104.

White, R. H., 2009. Accelerated weathering of fire-retardant-treated wood for fire testing. Proceedings of the 20th Annual Conference on Recent Advances in Flame Retardancy of Polymeric Materials, Stamford, CT.

LIFE CYCLE ASSESSMENT OF NORWEGIAN STANDARD ROAD TUNNEL

Lizhen Huang, Rolf André Bohne, Amund Bruland, Pål Drevland Jakobsen, Astrid Salomonsen*

** Department of civil and transport engineering, Norwegian University of Science and Technology, Høgskoleringen 7A, NO-7491, Trondheim, Norway*

Lizhen.huang@ntnu.no

Keywords: road tunnel; life cycle assessment; global warming potential; Norway

ABSTRACT

The environmental impacts of a standard Norwegian road tunnel are evaluated by the life cycle assessment combined with system dynamics. The standard Norwegian road tunnel is defined as a 3 km long 9.5m wide (67 m^2 cross-section) rock tunnel. The result shows that one meter standard tunnel has 13 tons CO_2eq emissions during its whole life. Construction stage dominates nearly all air emissions in the tunnel life. The results also indicate that the improved energy efficiency of construction machines in combination with a decreased use of imported materials will play a key role to lower the emissions from tunnel construction.

INTRODUCTION

The Norwegian Governments' long term target is to become carbon neutral by 2050 and transport is one of the major parts to realize such target. Energy used in construction, maintenance and operation of transport infrastructure is a part of indirect transport energy consumption. The knowledge concerning indirect energy use and emissions in the Norwegian transport system is rare.

The topography and landscape of Norway is challenging for infrastructure construction as they often lead to many and possibly long tunnel sections. According to Norwegian Public Road Administration (NPRA), the last 30 years there has been considerable development in the Norwegian underground activity. There are around 1,000 tunnels in Norway with a total length of over 800 km. And 20-30 km of new tunnels is built recently. Construction of tunnels is a material and energy intensive process. Such unprecedented growth construction work of tunnel in recent years is associated with significant energy use and air emissions. It is therefore important to quantify road tunnel performance in the GHGs mitigation. To explore the environmental impacts of road tunnel in Norway, the standard 9.5m wide (67 m^2 cross-section) road tunnel will be analysis here. The boundary, assumption and data sourse of life cycle assessment are briefly reviewed below. Then, the detailed results and analysis are presented. A discussion of the findings concludes the paper.

MATERIALS AND METHODS

This LCA study follows the ISO 14040/44 methodology.(ISO, 2006a, 2006b) The LCA modelling has been carried out in Simpro V7.3.3 and the ReCiPe Midpoint (E) V1.06 method has been used to estimate the environmental impacts.

Goal and scope of the study

The goal of the study is to estimate the life cycle environmental impacts of a standard rock road tunnel in the Norway. These results are then used to estimate the overall impacts from the existing road tunnel in Norway to identifying the hot spots and improvement opportunities along the supply chain.

System boundaries, assumptions and data

According geological conditions in Norway and the database of Norwegian Public Road Administration (NPRA), the standard road tunnel is defined as 9.5 wide (67 m^2 cross-section) and 3 km rock tunnel with medium blastability and drillability.

The functional unit is defined as the 'construction and operation of one m tunnel over its lifetime'. The lifetime of a tunnel is a difficult parameter to standardize because it depends on many factors. Here, following other authors (Miliutenko, Åkerman, & Björklund, 2011), the lifetime has also been assumed as 100 years in this study. Because there are little available information about road tunnel demolition (or lock up), this study comprises two main stages in the life cycle of the tunnel: construction and operation. Construction and maintenance involves extraction and manufacture of construction materials and fuels, transportation through the supply chain and on-site construction activities of the tunnels. The operation stage includes energy consumed by ventilation and lighting in tunnel.

Construction work of Norwegian standard tunnel was estimated by the cost database of Norwegian Public Road Administration (NPRA). Bills on tunnel completed during the period 2004-2011 were used to estimate the amount of different construction process work. The amount of main material is estimated by the information of tenders, related handbooks and personal communication with experts. Energy consumption for excavation is calculated by the database TunSim at NTNU. Machines used for other process were assumed to be typical machines use in Norway and energy consumption was estimated by earlier related studies in Norway and Sweden (NTNU, 1992; Stripple, 2001). The reuse of tools, temporary buildings, water consumption and production of construction machine are excluded in the study. The preparatory, control, monitoring and traffic of worker are also not taken into account here.

Transport is assumed to be done by trucks or semi-trucks that fulfill EURO IV. The distance of main material from the manufacturing gate to the construction site is assumed to be 50km. The weight of the load on the return trip is estimated 20% of material weight that was delivered to the construction site. Transportation of construction machine to construction site is excluded.

Waste disposal during the construction phase of the tunnel considered handling of blasted rock. It was assumed 100% of blasted block are reused. Based on tenders, 6% of blasting rock was reused in tunnel construction and other part was sold to the market. The waste of packaging waste was excluded here due to the accessibility of data.

Operation and maintenance of the tunnel includes electricity consumption for operation (lighting, ventilation, pumps and monitoring systems) and maintenance of the pavement. It was estimated that approximately 1280kWh / (m.year) of electricity will be used during the operation of the tunnel. The pavement during the whole life time was estimated 10 times replacement by the system dynamic model. The data for system dynamic model is based on statistical data published by Statistics Norway (SSB). Due to the difficulty of future pavement technology projection, the material and machine use for pavement replacement is assumed same to the construction stage.

The background life cycle inventory (LCI) data have been sourced from the Simpro V7.3.3 various databases. Where Norway-specific LCI data have not been available, the data used from the databases have been adapted as far as possible to reflect the Norwegian conditions, particularly with respect to the Norwegian energy mix.

RESULTS AND DISCUSSION

Construction stage of emits 6.5 tons CO_2eq (Figure 1A) per 1m tunnel. Production of materials used for the tunnel construction dominates all kinds of impacts in the construction stage. Energy use on construction site is responsible to 9 % global warming potential (GWP) and transportation of materials to and from the construction site account 15% of total GWP. A more detailed analysis of the GWP of onsite construction indicated that the concrete is biggest contribution (42%) and the diesel use for construction machine is the second one (8%). And explosives respond to 4.8% GWP in the construction stage.

Construction stage also occupies 50% of total CO2eq emissions in the whole life span of tunnel (Figure 1B). The contribution to GWP is from the operation stage and maintenance is 35% and 15% respectively. Construction stage also dominates main air emissions such as CO_2, CFC, NMVOC, PM10 and SO_2 during the whole life span of tunnel. Therefore, reduction of air emissions during life time of tunnel relies on the policies and regulations to the tunnel construction. Operation stage has highest share of HTP, IRP, FEP and three main eco-toxicity potential (TETP, FETP and METP). Impacts of tunnel operation came from the electricity production. Thus the control of toxicity during tunnel life span depends on the efficiency of ventilation and lighting system and production of electricity.

When the whole tunnel sector in Norway is taken into account, it is found that at least 0.9 million tons CO_2 was embodied in the new tunnel construction during the period 2004-2011.

Moreover, 53 kilotons CO_2 will emit annually due to the tunnel operation and maintenance when it is supposed no new tunnel will be built. Norwegian population passed 5 million in 2012 and will have another one million growths at the end of next decade. This will result more road and tunnel construction in these two decades. It can be estimated that around annual 180 kilotons CO_2 emit to atmosphere due the construction, maintenance and operation of road tunnel when it assumed new 20 km tunnel will be built annually. Material, diesel use for construction machine, electricity and transportation of materials contributes 57%, 16%, 16% and 11% to such emissions. Moreover 20% of building materials used in Norway is imported. And 50% of energy use in Norwegian manufacture sector is hydropower which has considerably lower output level of CO_2. Therefore domestic materials are recommend to be used due to their lower CO2 intensities when were compared with imported one.

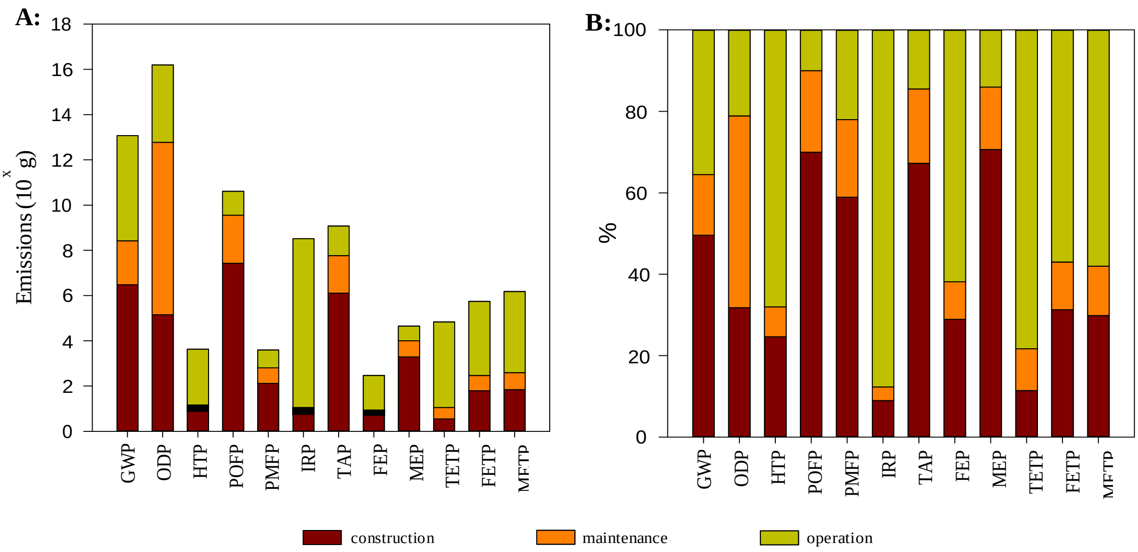


Figure1 A: Impacts of one meter tunnel during its life cycle (left); B: Distribution of impacts of one meter tunnel during its life cycle (right)

(Note: Climate change (GWP): 10^6g CO_2 eq; Ozone depletion (ODP): 10^{-1}g CFC-11 eq; Human toxicity (HTP): 10^6g 1,4-DB eq; Photochemical oxidant formation (POFP): 10^4g NMVOC; Particulate matter formation (PMFP): 10^4g PM10 eq; Ionising radiation (IRP): 10^6g U235 eq; Terrestrial acidification (TAP): 10^4g SO2 eq; Freshwater eutrophication (FEP): 10^3g P eq; Marine eutrophication (MEP): 10^3g N eq; Terrestrial ecotoxicity (TETP): 10^3g 1,4-DB eq; Freshwater ecotoxicity (FETP): 10^4g 1,4-DB eq; Marine ecotoxicity (METP): 10^4g 1,4-DB eq)

CONCLUSIONS

By life cycle assessment of the Norwegian standard road tunnel, this paper reveals that:

The total GWP over the lifetime of 100 years for one meter Norwegian standard road tunnel is 13 tons CO2 eq. The construction stage is the main contributor to all air emissions. The operation stage dominates the main toxicity impacts which are mainly related to energy use. There is a significant pontetial of reducing the environmetal impact from Norwegian tunnels with increasing the share of domestic materials, improving energy efficiency of construction machine, and ventilation lighting system in the tunnel.

REFERENCES

Huang, L., & Bohne, R. A. (2012). Embodied air emissions in Norway's construction sector: input-output analysis. *Building Research & Information, 40*(5), 581-591. doi: 10.1080/09613218.2012.711993

ISO. (2006a). ISO 14040-Environmental management -- Life cycle assessment -- Principles and framework. Geneva.

ISO. (2006b). ISO 14044-Environmental management - life cycle assessment- requirements and guidelines *Geneva*.

Miliutenko, S., Åkerman, J., & Björklund, A. (2011). Energy use and greenhouse gas emissions during the Life Cycle stages of a road tunnel - the Swedish case norra länken. *European Journal of Transport and Infrastructure Research, 12*(1), 39-62.

NTNU. (1992). Project report 15B-92: construction machine cost account (in Norwegian). Trondheim, Norway.

Stripple, H. (2001). Life cycle assessment of road: A pilot study for inventory analysis, IVLSwedish Environmental Research institute, Gothenburg, Sweden

LIFE CYCLE INVENTORY OF CONSTRUCTION OF HYDROELECTRIC DAM IN CHILE

Mabel Vega Claudio Zaror Claudia Peña Carolina Scarinci*

**Department of Chemical Engineering, University of Concepcion, Chile. PO Box 160-C correo 3, Concepcion, Chile. mabvega@udec.cl*

Keywords: Life cycle inventory (LCI); construction; hydroelectric dam.

ABSTRACT

Currently, there are plans to build five hydroelectric dams in Southern Chile, amounting to 2,750 MW, with a total flooding area nearly 6,000 ha. Given the relatively pristine ecosystem in Chilean Patagonia, where these plants are to be located, potential environmental impacts associated with this project have led to considerable public concern. This paper presents results of the life cycle inventory related to the dam construction stage. Hydroelectric dams require significant amounts of energy and building materials during construction. Data was obtained from environmental impact assessment official documents mainly, and the system boundaries include cements, steel, and materials transport from production plants to building sites. Results show that the flooding area does not correlate with the installed power, and LCIs are highly dependent on topographic features, and transport distances.

INTRODUCTION

Currently, 33% of electricity generated in Chile comes from hydroelectric sources. All Chilean reservoir hydroelectric plants are located in the Andean zone, where rivers are mostly sourced by melting ice from high lands (CDEC-SIC, 2011). The LCI reported here is based on inventories from a big hydroelectric complex to be built in Southern Chile, involving 5 reservoir plants and one pass-through, with a total installed capacity around 2.75 GW. These plants will be sited in the Baker and Pascua river basins in the XI Region, between latitude 47° and 49°S (Patagonia), Chile.

GOAL AND SCOPE

As a first approximation, a cradle-to-gate approach has been followed here, including construction operations, building materials, machinery, electricity generators, transportation, and other upstream processes. Plant operation, maintenance, mechanical pieces replacement and end-of-life activities were not included here. Data was obtained from primary sources, and official environmental reports (Centrales Hidroelectricas Aysen, 2008).

RESULTS AND DISCUSSION

As shown in Table 1, the inventory data did not show a direct correlation between land transformation and installed power, due the singularity in the hydrographic basins. Indeed, steep terrain upstream the dam will lead to lower flooded surface area, than in the case of flatter lands.

Additionally, dam size (ie. length and height), is determined by the basin topographical features and, to a lesser extent, by the power capacity. Therefore, cement, steel and other building materials requirements are also dependent on such local topographical features, affecting directly the environmental burdens associated to materials transport.

In the case of GHG emissions, Baker 1 showed the highest level per MW installed, mainly due to emissions from materials transport. The energy sources used for this plant are dramatically higher than others plants, that which would determine the major magnitude in the others emissions of the inventory.

On the other hand the main source of GHG emissions in Pascua 2.1 comes from the use of machinery for construction, based on internal combustion of fossil energy sources, as was identified in other previous study (de Miranda, 2010).

These cases support the idea that every single dam has singular features, which determine the environmental burdens.

Table 1: Life cycle inventory for dam construction en Chile

	Baker 1	Baker 2	Pascua 1	Pascua 2.1	Pascua 2.2
Coal, in ground [kg/MW]	$1{,}87\ 10^{6}$	$2{,}51\ 10^{5}$	$3{,}44\ 10^{5}$	$4{,}40\ 10^{5}$	$2{,}89\ 10^{5}$
Gas, natural, in ground [m^3/MW]	$1{,}04\ 10^{6}$	$7{,}64\ 10^{4}$	$7{,}49\ 10^{4}$	$1{,}10\ 10^{5}$	$4{,}95\ 10^{4}$
Oil, crude, in ground [kg/MW]	$9{,}42\ 10^{6}$	$6{,}55\ 10^{5}$	$6{,}20\ 10^{5}$	$1{,}21\ 10^{6}$	$3{,}79\ 10^{5}$
Transformation to water bodies, artificial [m^2/MW]	$1{,}47\ 10^{4}$	$1{,}01\ 10^{5}$	$1{,}15\ 10^{4}$	$1{,}33\ 10^{4}$	$2{,}57\ 10^{3}$
GHG emissions to air [kg CO_{2eq}/MW]	$3{,}09\ 10^{7}$	$2{,}30\ 10^{6}$	$2{,}45\ 10^{6}$	$4{,}58\ 10^{6}$	$1{,}67\ 10^{6}$
Nitrogen oxides [kg/MW]	$2{,}48\ 10^{5}$	$1{,}64\ 10^{4}$	$1{,}50\ 10^{4}$	$4{,}26\ 10^{4}$	$7{,}74\ 10^{3}$
Sulfur dioxide [kg/MW]	$3{,}38\ 10^{4}$	$3{,}49\ 10^{3}$	$5{,}13\ 10^{3}$	$8{,}56\ 10^{3}$	$4{,}16\ 10^{3}$
BOD_5, water [kg/MW]	$8{,}24\ 10^{4}$	$6{,}19\ 10^{3}$	$6{,}05\ 10^{3}$	$1{,}55\ 10^{4}$	$3{,}80\ 10^{3}$
Sulfate [kg/MW]	$1{,}69\ 10^{4}$	$2{,}70\ 10^{3}$	$1{,}89\ 10^{3}$	$2{,}27\ 10^{3}$	$1{,}42\ 10^{3}$
Oils, to soil [kg/MW]	$2{,}49\ 10^{4}$	$1{,}83\ 10^{3}$	$1{,}84\ 10^{3}$	$4{,}97\ 10^{3}$	$1{,}16\ 10^{3}$

Unfortunately, methane emissions from hydroelectric reservoirs in the Southern hemisphere has not been studied in depth, and reported works are based on data from boreal zones (Huttunene, 2002), and mostly in tropical and Amazonian zone (Barros, 2011)(Bastviken, 2011)(Rosa, 2004) (Kemenes, 2011)(Kemenes, 2011) (Demarty, 2011). Moreover, reported data on methane emissions rates from hydroelectric plants vary over a wide range, and there is no agreement on recommended values (Rosa, 2006)(Fearnside, 2006).

It is important to mention that local considerations play a significant role in LCI inventory for hydroelectric plants. Indeed, additional to the basin topographical features mentioned above, consideration has to be made of the organic matter content in the water system. In this respect, it must be mentioned that cold high mountain Andean rivers feature negligible organic matter content. Thus, methane generation due to anaerobic digestion should be much less significant than reported values for tropical latitudes, where the high organic matter loads constitute a considerable carbon source for biological processes, as shown in the methane emissions reported in the literature. At present, no studies on methane evolution from pristine water ecosystems such as Baker river in Chilean Patagonia has been reported in the literature.

Others relevant factors such as dam age, characterization and impacts on biodiversity, sediment composition and deposition, social displacement or ecosystem modifications, and impacts from decommissioning, are not included in this assessment as presented or recommended elsewhere

CONCLUSIONS

This work presents LCI information associated to the construction of hydroelectric dams in Southern Chile. Results show that the flooding area does not correlate with the installed power. LCI are highly dependent on topographic features, and transport distances.

REFERENCES

Alexandre Kemenes. Bruce Forsberg. John Melack. (2011). CO_2 emissions from a tropical hydroelectric reservoir (Balbina, Brazil). *Journal of Geophysical Research, 116, G03004.*

Alexandre Kemenes. Bruce Forsberg. John Melack. (2011). Methane release below a tropical hydroelectric dam. *Geophysical Research Letters, 34, L12809.*

Center for economic load dispatch of Central Interconnected System, CDEC-SIC. (2011). Annual Report Statistic and Operation, Chile. http://www.cdec-sic.cl/datos/anuario2012/espanol/index.html

Centrales Hidroeléctricas de Aysen S.A. (2008). Environmental Impact Study “Aysen Hydroelectric Project”, Chile.
http://infofirma.sea.gob.cl/DocumentosSEA/MostrarDocumento?docId=e8/03/92eaee0642bbba32b4c1a28aeec61da6e66d

David Bastviken. Lars Tranvik. John Downing. Patrick Crill. Alex Enrich-Prast. (2011). Freshwater methane emissions offset the continental carbon sink. *Science, vol. 331, N° 6013, p.50.*

Flávio de Miranda Ribeiro. Gil Anderi da Silva. (2010). Life-cycle inventory for hydroelectric generation: a Brazilian case study. *Journal of Cleaner Production, vol. 18, p. 44-54.*

Jari Huttunene. Tero Väisänen. Seppo Hellsten. Mirja Heikkinen. Hannu Hykänen. Högne Jungner. Arto Niskanen. Markku Virtanen. Ossi Lindqvist. Olli Nenonen. Pertti Martikainen. (2002). Fluxes of CH_4, CO_2, and N_2O in hydroelectric reservoirs Lokka and Porttipahta in the northern boreal zone in Finland. *Global Biogeochemical Cycles, vol 16, N°1, 1003.*

Luiz Rosa. M. A. dos Santos. B. Matvienko. E. Sikar. E. Oliveira dos Santos. (2006). Scientific errors in the Fearnside comments on the greenhouse gas emissions (GHG) from hydroelectric dams and response to his political claiming. *Climatic Change, vol. 75, Issue 1-2, p. 91-102.*

Luiz Rosa. M. A. dos Santos. B. Matvienko. E. Oliveira dos Santos. E. Sikar. (2004). Greenhouse gas emissions from hydroelectric reservoirs in Tropical Regions. *Climatic Change, 66:9-21*

M. Demarty. J. Bastien. (2011). GHG emissions from hydroelectric reservoirs in tropical and equatorial regions: Review of 20 years of CH_4 emission measurement. *Energy Policy, 39:4197-4206.*

Nathan Barros. Jonathan Cole. Lars Tranvik. Yves Prairie. David Bastviken. Vera Huszar. Paul di Giorgio. Fábio Roland. (2011). Carbon emissions from hydroelectric reservoirs linked to reservoirs age and latitude. *Nature Geoscience Letters, Published online 31 July 2011.*

Philip Fearnside. (2006). Greenhouse gas emissions from hydroelectric dams: reply to Rosa et al. *Climatic Change, vol. 75, p.103-109.*

PASSIVE HOUSING - NEW ROLES AND RESPONSIBILITIES FOR THE BUILDING CHAIN

Birgit Brunklaus [1], Henrikke Baumann [1].*

[1] *Environmental Systems Analysis, Chalmers University of Technology, S-41296 Gothenburg, Sweden.*

**Email: birgitb@chalmers.se.*

Keywords: passive housing; LCA; actor analysis; communication.

ABSTRACT

.

Does passive housing really have better environmental performance than conventional housing? Three passive houses and four conventional houses were compared using a life cycle assessment (LCA) methodology. The comparison also provided an actor analysis for the building supply chain and building inhabitants. Actor analysis shows that inhabitants' and material producers' electricity choice are very important. The introduction of passive house technology shifts responsibilities from building constructors to municipalities and residents, which is not currently communicated. To avoid shifting responsibility within the building chain and to meet future trends, communication needs improvement. The findings highlight the importance of environmentally responsible decisions throughout the whole life cycle and the need for appropriate behaviours and actions, along with implications for improved communication.

INTRODUCTION

Passive housing is seen as the solution for environmental problems in the building industry in Sweden and elsewhere. However, the success of passive housing is based on the assumption, that reducing energy will also reduce environmental impacts. With a life cycle perspective it is clear that it is not the use of energy, rather the production of energy that is causing environmental impacts such as climate impacts. Still, most of the life cycle studies consider rather energy than environmental issues (Satori 2007). The question for the constructor is: do passive housing have better environmental impacts than conventional housing? This question will be answered with the example of three passive housing in Sweden and four conventional housing in Sweden.

This study is based on three levels similar to (Raab and Brunklaus 2012) to give the constructor an overview about those products and to gain important information for producers:

1st level: Environmental impacts of passive and conventional housing

2nd level: Constructors and other actors' possibilities for reducing environmental impacts

3rd level: Constructor's influences on their own and other actors' actions

METHODS

Data for the comparison of passive housing and conventional housing in Sweden are based on energy studies of Adalberth (2001) and Thormark (2007), described in Brunklaus et al (2010). The energy for passive housing is connected to an electrical cartage, while the energy for conventional housing is connected to district heating.

The method used to calculate the environmental impact is based on the Life Cycle Assessment (LCA) methodology. Instead of using ready made LCA programs, calculation have been performed in excel, which is more appropriate within the development of the LCA methodology. Furthermore, this study has further developed the actor analysis (Berlin et al 2008) and the distinction of three levels, adapted from Brunklaus (2011). The actors of the building chain are the material producer, transport company, the building constructor, the residents, and the district heating company. Due to this actor analysis, the direct environmental impacts and possibilities of constructors and other actors can be shown. Furthermore, the constructors' influences on their own and on the others' activities can be analyzed.

RESULTS

The results are based on the calculation in 2008 and the article in 2010 (Brunklaus et al 2010). The following examples chosen are on climate impacts and acidification impacts (1st level).

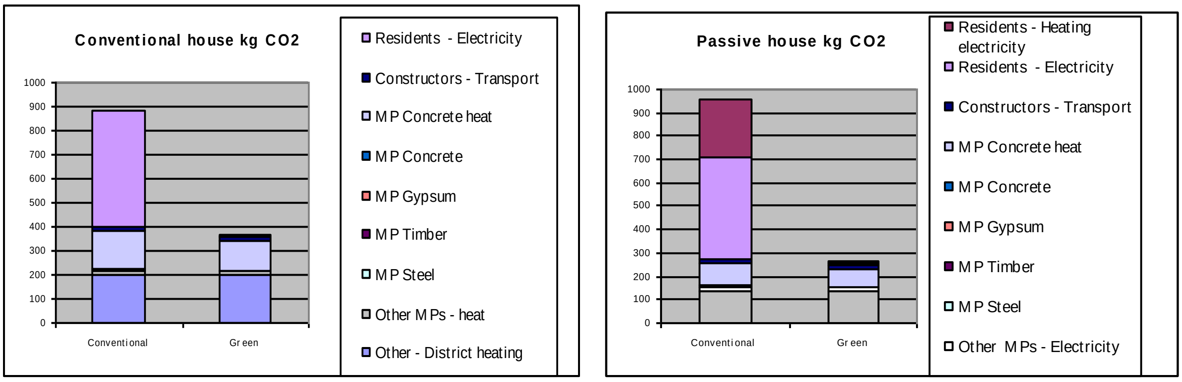


Figure 1: kg CO2-eq for passive housing and conventional housing in Sweden (based on Brunklaus et al 2010)

GWP: Conventional housing with district heating in Stockholm shows in total 900 kg CO_2-eq and half of them are caused by residents, and passive housing in Lindås shows in total also about 900 kg CO_2-eq. Figure 1 is based on average results of the studied buildings.

AP: Conventional housing with district heating in Stockholm shows in total 3200 kg SO_2-eq and half of them are caused by residents, while passive housing in Lindås shows in total over 4000 kg SO_2-eq.

Both conventional and passive housing have residents as their main contributor, both regarding climate impacts and acidification impacts.

The constructors' possibilities of reducing environmental impacts are low while other actors have larger possibilities (2^{nd} level). Those green actions are: choosing renewable based electricity for residents, choosing renewable based production for material producers, while transport does not effect the result too much. Figure 1 "green" shows the results when all actors in the chain do make their green choices.

The constructors' influence (3^{rd} level) on other actors can be direct or indirect. In this case the constructor can influence the residents, as well as the material producer and the transport directly, while the district heating companies can be influenced indirectly. Direct influence means also more power. Indirect influence is evident with all actors, since it keeps the building chain together, such as waste and recycling companies.

The results show passive housing is not always better than conventional housing, when residents do not make green choices. Together, the constructors' low possibilities and high influence on other actors, gives another picture of constructors' role and responsibilities. Constructors can influence residents and material producers directly. The introduction of passive house technology shifts responsibilities from building constructors to residents, which is not currently communicated.

DISCUSSION

The results show that we need to consider several actors in order to decrease the environmental impact of buildings, such as material producers and residents. This need to collaborate within the building chain is recognized by Cooper et al (2008).

The three analysis levels in the actor analysis in combination with LCA give new insights, like in the study of the food chain (Raab and Brunklaus 2012). Important and new knowledge could be gained especially for building constructors and residents. For constructors and residents the energy label is a start to raise awareness of environmental issues in buildings. On the one hand, energy labels are not enough, environmental requirements on energy production need to be set as well. And besides residents, municipalities have larger possibilities to set requirements here. On the other hand, other environmental and social impacts based on Life Cycle Assessment; such as health and socio-cultural issues might be important as well. The Swedish conventional housing is based on district heating, which has quite good environmental performance; while others European housing might use gas or wood-based resource for heating. The introduction of passive housing shifts the environmental impact from district heating to electricity production, which means larger possibilities for municipalities and residents.

CONCLUSIONS

Does passive housing really have better environmental performance than conventional housing? Three passive houses and four conventional houses were compared using a life cycle assessment (LCA) methodology. The comparison also provided an actor analysis for the building supply chain and building inhabitants. Actor analysis shows that inhabitants' and material producers' electricity choice are very important, while other choices (e.g. green transport) are less important. The introduction of passive house technology shifts responsibilities from building constructors to municipalities and residents, which is not currently communicated. To avoid shifting responsibility within the building chain and to meet future trends, such as the recent trend of building passive housing in sheet metals or with district heating, communication needs improvement. For constructors' green strategy, decisions on renewable material production and renewable energy production are important. The findings give suggestions highlight the importance of environmentally responsible decisions throughout the whole life cycle and the need for appropriate behaviours and actions, along with implications for improved set of requirements and collaboration.

REFERENCES

Adalberth K, Almgren A, Petersen EH. (2001). Life Cycle Assessment of four Multi-Family Buildings. *International Journal of Low Energy and Sustainable Buildings* 2001; 2.

Berlin, Johanna; Sonesson Ulf; Tillman AnneMarie (2008). Product Chain Actors Potential for greening the product life cycle: The case of Post-farm Milk Chain. Journal of Industrial Ecology Vol 12, Nr 1 , p 95-110.

Brunklaus, B., Thormark, C. & Baumann, H. (2010). Illustrating limitations of energy studies of buildings with LCA and actor analysis. Building Research & Information, 38: 3, 265-279

Brunklaus, B. (2011). Actor's behavior matter – organizing green product chains. Poster presented at the ISE conferences, 7-10th of June 2011, University of Berkley, San Francisco, USA.

Cooper J, Fava J, and Baer S. (2008). Life Cycle Assessment of Buildings in North America: Demand and Supply. *Journal of Industrial Ecology* 2008; 12 (1): 7 - 9.

Raab, M. & Brunklaus, B. (2012). Carbon Footprint of organic Spanish compared to conventional Austrian/Swedish cucumbers - Consumer and producer perspective on reducing greenhouse gas emissions. Gothenburg: Chalmers University of Technology.

Sartori I, Hestnes AG. (2007). Energy use in the life cycle of conventional and low-energy buildings: A review article. *Energy and Buildings 2007*; 39: 249 - 257.

Thormark, C. (2007). Energy and resources, material choice and recycling potential in low energy buildings. CIB SB *Conference Proceeding of Sustainable Construction, Materials and Practices, Lisbon, Portugal*, 2007.

THE SWISS PLATFORM OF LIFE CYCLE ASSESSMENT DATA IN THE BUILDING SECTOR - CONNECTING INDUSTRY, ADMINISTRATION, BUILDERS AND RESEARCH

Rolf Frischknecht*, treeze Ltd., Reinhard Friedli, Swiss Federal Office for Buildings and Logistics, Heinrich Gugerli, Buildings Administration, City of Zurich
*treeze Ltd. Kanzleistrasse 4, 8610 Uster, Switzerland, frischkhnecht@treeze.ch

Keywords: buildings; building materials; environmental impacts; life cycle assessment; building sector network

ABSTRACT

In late 2011 the platform life cycle inventory data in the building sector was launched. Representatives from professional public and private building owners, from building industry and associations, from public policy makers as well as from research and academic institutions joined together to enhance the application of life cycle assessment data in the building sector. Its main objective is the publication, maintenance, and extension of sector tailored life cycle assessment data.

Data are used in several national guidelines and standards related to buildings and in the 2000W society concept. Copared to other information systems, the LCA data lists prove to be efficient in terms of costs, efforts and accessibility.

INTRODUCTION

With a reduced energy consumption during the use phase of buildings, the energy embodied in the building gets more important. In buildings with low to very low operational energy demand, the energy required to build a house is equal to the energy required during operation. In further optimised buildings, the energy demand of construction is even much above the energy demand during operation as can be seen in SIA 2040 (SIA 2011a), which publishes guideline and target values regarding operation and regarding construction. According to this publication half of the greenhouse gas emissions are caused by construction, one third by induced mobility and only one sixth to the operation of the building.

Thus it is not astonishing that the environmental impacts related to the construction of buil-dings get more and more into the focus of building owners and planners. Even more, a comprehensive assessment including environmental impacts of buildings is considered a must when designing and commissioning buildings in the future.

Reliable and quality assured data are needed to establish an LCA of a building. The life cycle assessment data of the building sector provide these data to a large extent. The data are documented in a recommendation document (KBOB et al. 2012), issued by KBOB (coordination conference of public building owners), IPB (institutional professional building owners) and eco-bau and they are frequently being used by architects and planners.

The data in the recommendation rely to a large extent on ecoinvent data v2.2 (ecoinvent Centre 2010), one of the world leading databases operated by the ecoinvent Centre, a competence centre of ETH Zürich and Lausanne, Paul Scherrer Institute (PSI), Empa and agroscope ART.

MATERIALS

The platform “life cycle assessment data in the building sector” was launched in late 2011. Representatives from professional public and private building owners, from building industry and associations, from public policy makers as well as from research and academic institutions joined together. The platform aims to enhance the consideration of environmental aspects when planning the construction or refurbishment of buildings by the application of life cycle assessment data in the building sector. The platform works on the following tasks:

- Priority setting with regard to LCI data updates and LCI data extensions, focusing on the building sector and its suppliers.
- Co-ordination of the work flow of update tasks, including data quality assurance
- Support in data investigation with associations of the building material industry (1st choice) and individual companies in order to establish representative LCI data.
- Inclusion / consultation of LCI data stakeholders such as the building materials associations
- Information exchange between administration, research, building owners and associations of the building materials industry
- Deal with requests, questions and complaints regarding the LCA data either by answering directly or co-ordinating the answers.
- Organise agreements regarding data updates and data use.
- Clarify methodological issues regarding the LCA data in the building sector, taking inpto account that the methodological settings are valid for all product groups (eco-points, recycling rates, waste management processes, etc.)
- Development of a sustainable strategy from the viewpoint of the building sector regarding methodological settings of life cycle inventory and impact assessment of building products, including the consideration of new technologies in compliance with standards (such as the CEN standard 15804, the Swiss SIA recommendation 493 “declaration of environmental properties of building products”, the Swiss SIA 2032 “Grey energy of buildings” and others more).
- Ensure and facilitate to create and supply LCI datasets from publicly and privately commissioned projects, which are of use for the ecoinvent database.

METHODS

The list of LCA data in the building sector covers mineral materials (such as concrete, tiles, gypsum, mortar and plaster), windows and metal-glass façades, metals (steel, aluminium and copper sheets, metal beams), wood and derived timber products, adhesives, liner sheets, insulation materials, flooring materials, doors, pipes, paintings and coatings, plastics, building technology (boilers, heat distribution systems, ventilation systems, sanitary equipment, electrical systems), energy supply (fuels, district heat, useful heat, electricity), and transports (persons and goods). The list uses the indicators cumulative energy demand (renewable, non renewable, Frischknecht et al. 2007a; Frischknecht et al. 2007b), greenhouse gas emissions (IPCC 2007) and the ecological scarcity method 2006 (Frischknecht et al. 2009).

The platform adopted the quality guidelines of ecoinvent data v2.0 and the ecoinvent data v2.2 as their current solid foundation. The quality guidelines are used whenever LCI data of a building material yet missing in the list are generated.

Up to now, an institutional support including updates and targeted extensions was missing. The new platform "life cycle assessment data in the building sector" takes care of these tasks and is at the same time facilitating the co-ordination between research, industry and the buildings industry.

RESULTS

The LCA data published by the platform is being used in several Swiss standards and concepts. In particular, the LCA data are used in the Swiss codes of practice about "Energy pass for buildings" (SIA 2031, SIA 2009), "Cumulative energy demand of buildings" (SIA 2032, SIA 2010), "Mobility, enery demand dependent on the building location" (SIA 2039, SIA 2011b), and "SIA-efficiency path energy", (SIA 2040 and SIA D0236, SIA 2011a, c). The LCA data are also used in the accounting concept of the 2000-Watt-Society (EnergieSchweiz für Gemeinden et al. 2012).

Several planning tools used by architects and civil engineers exist which contain the LCA data in the building sector. Others are using tools such as Vitruvius that rely directly on the contents of the ecoinvent database.

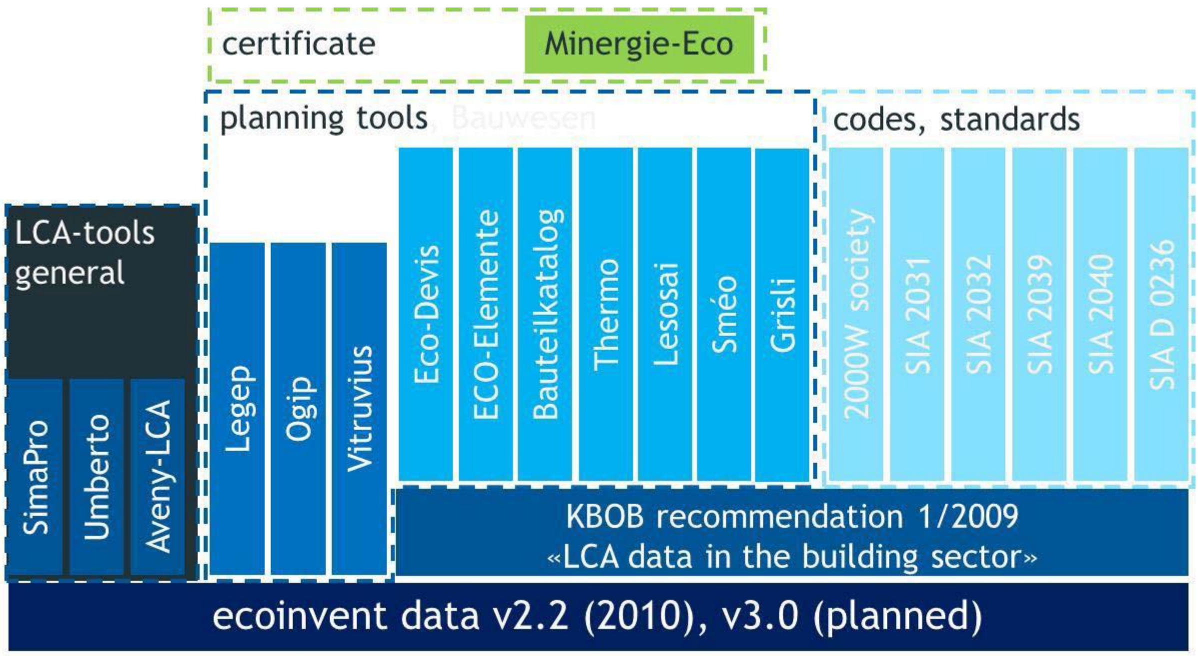


Figure 1. Planning tools, codes and standards in the building sector relying on ecoinvent data v2.2 and the KBOB recommendation 1/2009 (version July 2012, KBOB et al. 2012)

DISCUSSION

The KBOB recommendation 2009/1 with its "LCA data in the building sector" is facilitates the use of environmental information when planning new buildings or retrofitting existing ones. It is a cost efficient, solid and harmonised foundation for planning tools, codes and standards. However, improvements are still needed and on the way. On one hand data of several construction materials are rather old and ask for updates. On the other hand the current list does not yet cover all environmentally relevant elements of buildings and thus projects are being launched or co-ordinated for targeted extensions of the LCA data list. The co-operation between representatives from building owners, scientists and the building industry is a unique opportunity to further increase the usefulness and acceptance of the LCA data.

CONCLUSIONS

The KBOB recommendation 2009/1 prepared, maintained, extended and issued by the platform "LCA data in the building sector" is a cost efficient and powerful tool for architects and engineers. It helps them to include the environmental dimension into the planning process, be it within the preproject or competition phase or during the project realisation. Using the Swiss eco-factors of the ecological scarcity method 2006 (Frischknecht et al. 2009) the environmental assessment of buildings are in line with the Swiss environmental legislation.

REFERENCES

ecoinvent Centre (2010) ecoinvent data v2.2, ecoinvent reports No. 1-25. Swiss Centre for Life Cycle Inventories, Duebendorf, Switzerland, retrieved from: www.ecoinvent.org.

EnergieSchweiz für Gemeinden et al. 2012 EnergieSchweiz für Gemeinden, Stadt Zürich and Schweizerischer Ingenieur- und Architektenverein SIA (2012) Bilanzierungskonzept 2000W Gesellschaft. EnergieSchweiz für Gemeinden, Ettenhausen.

Frischknecht R., Althaus H.-J., Dones R., Hischier R., Jungbluth N., Nemecek T., Primas A. and Wernet G. (2007a) Renewable Energy Assessment within the Cumulative Energy Demand Concept: Challenges and Solutions. In proceedings from: SETAC Europe 14th LCA case study symposium: Energy in LCA - LCA of Energy, 3-4 December 2007, Gothenburg, Sweden.

Frischknecht R., Jungbluth N., Althaus H.-J., Bauer C., Doka G., Dones R., Hellweg S., Hischier R., Humbert S., Margni M. and Nemecek T. (2007b) Implementation of Life Cycle Impact Assessment Methods. ecoinvent report No. 3, v2.0. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.

Frischknecht R., Steiner R. and Jungbluth N. (2009) The Ecological Scarcity Method - Eco-Factors 2006: A method for impact assessment in LCA. Federal Office for the Environment (FOEN), Zürich, Bern, Switzerland, retrieved from: www.bafu.admin.ch/publikationen/publikation/01031/index.html?lang=en.

IPCC (2007) The IPCC fourth Assessment Report. Cambridge University Press., Cambridge.

KBOB et al. 2012KBOB, eco-bau and IPB (2012) Ökobilanzdaten im Baubereich, Stand Juli 2012. Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren c/o BBL Bundesamt für Bauten und Logistik, retrieved from: http://www.bbl.admin.ch/kbob/00493/00495/index.html?lang=de.

SIA (2009) Energieausweis für Gebäude gemäss SN EN 15217 und SN EN 15603, Merkblatt 2031. Schweizerischer Ingenieur- und Architektenverein (SIA), Zurich.

SIA (2010) Graue Energie von Gebäuden, Merkblatt 2032. In: Merkblatt 2032 (ed. SIA). SIA, Zurich.

SIA (2011a) SIA-Effizienzpfad Energie, Merkblatt 2040. Schweizerischer Ingenieur- und Architektenverein (SIA), Zürich.

SIA (2011b) Mobilität – Energiebedarf in Abhängigkeit vom Gebäudestandort, Merkblatt 2039. Schweizerischer Ingenieur- und Architektenverein (SIA), Zürich, Schweiz.

SIA (2011c) SIA-Effizienzpfad Energie, Ergänzungen und Fallbeispiele zum Merkblatt SIA 2040, Dokumentation D 0236. Schweizerischer Ingenieur- und Architektenverein (SIA), Zürich.

USE OF LIFE CYCLE THINKING FOR ENVIRONMENTAL IMPACT ASSESSMENT OF BUILDING MATERIALS: NEW DEVELOPMENTS IN THE LEED CERTIFICATION SYSTEM

Cristiane Bueno*, João Adriano Rossignolo, Aldo Roberto Ometto. * Architecture and Urbanism Institute, University of São Paulo. Avenida Trabalhador São-carlense, 400, CEP 13566-590, São Carlos, Brazil. Tel.: (+55) 16 81286432, Email address : cbueno@sc.usp.br.

Keywords: environmental assessment of buildings; life cycle assessment; building materials; LEED rating system.

ABSTRACT

The present paper reports on the state of the art of Life Cycle Assessment (LCA) as a tool for the assessment of building components and analyzes its application in the environmental certification system of buildings LEED. We considered the LEED version 3 for New Constructions and Major Renovations compared to the new principles approached in the LEED for Building Design and Construction version 4, to be released in 2013. A summary table was built as well as a discussion on the environmental assessment methods used by these certification systems. The analysis revealed that the version 3 uses exclusively the assessment by the recognition of product attributes, such as cost, durability, renewability and recycled content, while the new version already shows some approaches based in life cycle thinking.

INTRODUCTION

To a better assessment of the overall impact of a building during its lifetime, a life cycle assessment of the building and its materials and components has proved to be a valuable tool (Verbeeck and Hens, 2010). The life cycle of a building comprises the production of building materials, building construction, operation, maintenance, disassembly and waste management (Gustavsson and Joelsson, 2010), thus the LCA methodology is an important part of the environmental assessment methods of buildings.

Earlier studies of Erlandsson and Borg (2003) Haapio and Viitaniemi (2008) and Nibel et al. (2005) have discussed the LCA methodology for buildings, but there are still lacks regarding environmental indicators, complexity of LCA studies communication for users, assumptions, simplifications and adaptations for various purposes (Bribián et al., 2009).

Concerning the environmental assessment of building materials - within the main building environmental certification systems - the recognition of product attributes, such as cost, durability, renewability, and recycled content still prevails. Such approach deals with attributes alone, even if they are mostly in conflict and interfere with each other (Silva, 2007). Thus the attributes approach lacks an overview of the overall impact of a product.

This paper reports on the evolution of lifecycle thinking application from the LEED version 3 building environmental assessment certification system (USGBC, 2009) to version 4 (USGBC, 2012), to be launched in 2013.

METHODS

The purpose of this study is to build a summary and a discussion on the methods used by LEED certification systems versions 3 and 4 for the environmental assessment of building components through data collected from the literature review, focused in the evolution of their strategies of application of LCA methodology.

The LEED version 3 for New Constructions and Major Renovations will be compared to the new principles approached in the LEED for Building Design and Construction version 4, to be released in 2013.

RESULTS AND DISCUSSION

In the LEED version 3 certification system, all the credits related to the issue addressed in this study apply the attributes evaluation.

The first, "Materials with recycled content", evaluates the use of materials so that the sum of the pre-consumer and post-consumer recycled content constitutes 10-20% of the material, whose score varies according to the achieved percentage.

The credit "Regional materials" assess if the distance from the extraction site and production plant is shorter than 500 miles from the construction site for at least 10-20% of the materials.

In the evaluation of "Rapidly renewable materials", the objective is to use products with rapidly renewable main raw materials (products of vegetal origin, with renovation cycles of less than 10 years) for at least 2.5% of the total cost of materials and building systems.

The use of certified wood is also evaluated in at least 50% of the wooden systems.

There are also some credits concerning the evaluation of building materials comprised in the Indoor Environmental Quality category. Some of them, which also use the attributes method, regard the VOC (volatile organic compounds) emissions from materials, such as adhesives and sealants, paints and coatings and flooring systems.

In the LEED version 4 all these credits comprised in the Indoor Environmental Quality category which use the attributes method regarding the VOC emissions from materials were fused in one single credit called “Low-emitting interiors”.

Although the aggregation of various credits into a single one related to VOC emissions seem like a simplification, further observation of their requirements leads to the conclusion that such a unified credit remains applying the same evaluative criteria present in the previous version.

Despite such credits within the Indoor Environmental Quality category, described above, all other credits regarding evaluation of construction materials and components in LEED version

4 are placed in the Materials and Resources category, and all of them have an intrinsic life cycle thinking concept.

The most embracing credit under such point of view is “Building Life-Cycle Impact Reduction”, which proposes the implementation of a comprehensive LCA study in the whole building for new constructions that are not reusing any existing building. Such credit is already consolidated in the rating system to be launched in 2013 and it is not open to any public comments anymore.

Still there is one concern regarding such credit which is not a prerequisite and thus, not obligatory. For this reason it will still be possible to the user to drop such credit choosing to attend easier scoring ones. This issue can be pointed as a weakness of the system, once, due to its complexity, there is a clear tendency of users for skipping LCA based assessment. In any way, the optional presence of an LCA credit in the rating system will allow an empirical evaluation of real user behaviour facing the possibility of application of LCA.

Finally all other credits concerning environmental assessment of materials and components are comprised in the broader subject “Building product disclosure and optimization”, and are divided in “Environmental Product Declarations”, “Sourcing of raw materials” and “Material ingredients”. Despite the fact that such credits assess some specific product attributes, they do so through the application of LCA and Life Cycle Thinking, seeking a holistic approach of the impacts associated with these attributes.

At this point an especial attention should be given to the “Environmental Product Declarations” (EPD) application. There is an effort in several countries of the world on the proliferation of EPD of various industrial products, including the construction intended ones. The EPD is based on the LCA of such products pointing to potential environmental impacts which require more attention in a region/country. The encouragement of the use of the EPD within certification systems of buildings do not only imply a legitimate form of quantitative environmental assessment, but also stimulate the realization of EPD by major industries involved in the production of building materials and components.

CONCLUSIONS

Many changes have been applied to the LEED version 3 rating system in its transformation into version 4. Most of them regard the inclusion of full sustainability issues and regional assessment criteria.

Regarding the environmental assessment of construction materials changes also have been identified regarding the application of LCA methodology. The overall analysis has revealed that the version 3 uses exclusively the assessment of building materials by the recognition of product attributes, such as durability, renewability and recycled content, while the version 4 already shows some new approaches based in life cycle thinking and even an optional credit for the implementation of a full LCA of new constructions.

At this point it is important to stress that the weakness of the attributes approach lies in the fact that these attributes are treated in isolation and lack the whole concept of impact. In the other hand the life cycle thinking promotes a more integrated evaluation, assessing such materials holistically throughout their life cycle.

Thus it is already possible to conclude that the LEED version 4 rating system will have a significantly better assessment methodology regarding the implementation of life cycle assessment in material-related evaluative credits. It is also important to highlight that such implementation is still probative and optional, and may be considered as a first step towards a more complete and holistic building environmental assessment rating system.

The evaluation of the methods used to apply the LCA within LEED may contribute to the understanding of how to replicate it in other rating systems, and must be the subject of further research.

REFERENCES

Bribián, I. Z.; Usón, A. A.; Scarpellini, S. (2009). Life cycle assessment in buildings: State-of-the-art and simplified LCA methodology as a complement for building certification. Building and Environment, vol. 44, pp. 2510–2520.

Erlandsson, M.; Borg, M. (2003). Generic LCA-methodology applicable for buildings, constructions and operation services — today practice and development needs. Building and Environment, vol. 38, pp. 919 – 938.

Gustavsson, L.; Joelsson, A. (2010). Life cycle primary energy analysis of residential buildings. Energy and Buildings, Volume 42, Issue 2.

Haapio, A.; Viitaniemi, P. (2008). A critical review of building environmental assessment tools. Environmental Impact Assessment Review, 28:469–82.

Nibel, S.; Luetzkendorf, T.; Knapen, M.; Boonstra, C.; Moffat, S. (2005). Annex 31: energy related environmental impact of buildings, technical synthesis report. International Energy Agency. Available online at: http://www.iisbe.org/annex31/index.html.

Silva, V. G. (2007). Uso de Materiais e Sustentabilidade. Revista Sistemas Prediais (Online).

United States Green Building Council – USGBC (2009). LEED: Green Building Rating System – Version 3.

United States Green Building Council – USGBC (2012). LEED: Green Building Rating System – Version 4. Preliminary version for public consultation.

Verbeeck, G.; Hens, H. (2010). Life cycle inventory of buildings: A contribution analysis. Building and Environment, Volume 45, Issue 4.

CURRENT DEVELOPMENTS IN LIFE CYCLE BASED DECLARATIONS

Tuesday, Aug 27: 10:30 am - 12:00 pm

Session chairs: Jeppe Frydendal, Ecolabelling Denmark, Denmark
Michele Galatola, European Commission, Belgium

A UNIVERSAL FOOTPRINT DEFINITION: A CRITICAL NEXT STEP TO SUPPORT WIDESPREAD COMMUNICATION OF LCA DATA

*Bradley Ridoutt *, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Sustainable Agriculture National Research Flagship, Private Bag 10, Clayton, Victoria 3169, Australia (brad.ridoutt@csiro.au)*

Stephan Pfister, ETH Zurich, Institute of Environmental Engineering, 8093 Zurich, Switzerland

Keywords: footprint family; product environmental footprint; environmental labeling

ABSTRACT

Life cycle assessment has traditionally been used to support professional decision-making where an LCA expert usually assists with interpretation of the complex impact category indicator results, potential trade-offs and uncertainties. This has changed with the emergence of footprint-style indicators which are often communicated widely to an audience which is remote, largely non-technical, and unable to benefit from first hand support in interpretation. To support the emergence of coherent footprint indicators based on LCA, we argue the need for a universal footprint definition. Specifically, footprints should not be viewed as simply new names for existing impact category indicators based on the Area of Protection paradigm, but rather as indicators which address specific environmental concerns of broad community interest.

INTRODUCTION

In recent years there has been a proliferation of environmental and social indicators termed footprints (Table 1) and the communication of footprints has become commonplace. Terms like *carbon footprint*, *water footprint* and *environmental footprint* have become part of ordinary language in many countries, no longer exclusively part of the vernacular of scientists and professional decision-makers.

This development represents both an opportunity and a threat to the LCA community. On the one hand, footprints are a means of bringing life cycle thinking and life cycle data into the mainstream and thereby greatly expanding the LCA community's sphere of influence. In addition, the progression toward a family of footprint indicators (Niccolucci et al., 2010; Galli et al., 2012; Fang et al., 2013) is better aligned with the intention of LCA to assess all of the relevant environmental burdens and avoid the unintended consequences which can occur when focusing on a single aspect, such as GHG emissions alone, i.e. carbon footprint (Finkbeiner, 2009).

On the other hand, we express concern that many of the so-called footprint indicators are not based on the well-established principles of LCA (e.g. ISO 14040, 14044), that there are problems of inconsistency and overlap of methods, as well as challenges for interpretation when groups of footprint indicators are presented together (e.g. ecological footprint, carbon footprint and virtual water footprint). Even within the LCA community, there is no common understanding of what defines a footprint indicator and the relationship of footprints to existing life cycle impact category indicators is unclear.

In this presentation, based on a recent column in Journal of Industrial Ecology (Ridoutt and Pfister, 2013b), we argue the need for a universal footprint definition which will provide guidance to support the evolution of a coherent family of footprint indicators based on LCA. This is regarded as a matter of urgency to meet the demand for publicly communicated environmental product information.

Table 1. A selection of footprint indicators reported in the scientific literature (Čuček et al., 2012).

Agricultural land footprint	Financial footprint	Nitrogen footprint
Biodiversity footprint	Fishing grounds footprint	Nuclear energy footprint
Blue water footprint	Food to energy footprint	Phosphorus footprint
Built-up land footprint	Forest footprint	Poverty footprint
Carbon footprint	Fossil energy footprint	Renewable energy footprint
Chemical footprint	GHG footprint	Social footprint
Climate footprint	Grazing land footprint	Solar energy footprint
CO2 footprint	Green water footprint	Waste footprint
Corruption footprint	Grey water footprint	Water availability footprint
Crop land footprint	GWP footprint	Water footprint
Ecological footprint	Health footprint	Water pollution footprint
Economic footprint	Human footprint	Water scarcity footprint
Emission footprint	Human rights footprint	Water stress footprint
Energy footprint	Land footprint	Water supply footprint
Environmental footprint	Land use footprint	Wind energy footprint
Exergy footprint	Methane footprint	Work environmental footprint

FOOTPRINTS VS EXISTING IMPACT CATEGORY INDICATORS

LCA, with its complex models and indicators, has traditionally been used by professional decision-makers, often with the guidance of an LCA expert. This changed radically with the advent of the carbon footprint whereby LCA results entered the mainstream (Weidema et al., 2008) in response to the broad community concern about climate change. While there exists a variety of carbon footprint calculation protocols (e.g. BSI, WRI/WBCSD, Japan METI, ISO), the underlying impact assessment model is the same as for the global warming midpoint impact category indicator. Conveniently, in the case of climate impact, there is one midpoint indicator relevant to all environmental impact pathways.

However, this is not the case for the water footprint. There is no analogous midpoint for water use that is relevant to all of the many potential impact pathways associated with water consumption and degradation. This means that when LCA is used to perform a comprehensive assessment of potential water use impacts a profile of impact category indicator results is produced. This profile may be useful for reporting in the traditional manner to professional decision-makers. However, we argue that a single result reported in an intuitively meaningful unit (similar to the carbon footprint) is needed when reporting to the wider community who generally lack the interest and technical ability to study a profile, yet are increasingly concerned about water stress. Such a solution has recently been presented by Ridoutt and Pfister (2013a) whereby the water footprint is reported as a parameter obtained after weighting using the ReCiPe endpoint modeling system (Goedkoop et al., 2009), with the result subsequently translated into units deemed to be relevant for public communication (i.e. liters of water consumption equivalents [L H_2Oe]). This approach could even possibly be a guide for other footprint indicators where the issue of environmental concern is complex and requires multiple environmental mechanisms to be modeled (e.g. land use footprint).

We propose that, in the LCA context, footprints are best defined as parameters which specifically address environmental concerns of broad community interest and are purposed for mainstream product and organizational environmental reporting. In some cases, these parameters will align with existing life cycle impact category indicators. However, in other cases they will not since the lens through which the community views environmental protection is not generally aligned with the Area of Protection framework which guides classification and grouping of impacts in traditional life cycle impact assessment. Loosely applying the term *footprint* to any life cycle impact category indicator result (many of which are poorly suited for mainstream dissemination) and profiles of complex indicator results would not appear to be helpful in engaging the broader community in life cycle thinking.

CONCLUSIONS

Footprints are emerging as an important mode of communication of environmental information to the wider community. We argue the need for a universal footprint definition to guide the evolution of a coherent family of footprints based on LCA. These footprints should not be constrained by the current Area of Protection paradigm. Instead they should specifically address environmental concerns of broad community interest. The popular interest in footprints represents an important opportunity to take LCA into the mainstream. The risk of inaction is that the community's interest in footprints will be met in less satisfactory ways by others working outside or on the periphery of LCA. The current proliferation of footprint indicators is evidence that this is already happening and some of these footprints report results which are in conflict with LCA.

REFERENCES

Čuček L, Klemes JJ, Kravanja Z. 2012. A review of footprint analysis tools for monitoring impacts on sustainability. *J. Clean. Prod. 34, 9-20.*

Fang K, Heijungs R, de Snoo G. 2013. The footprint family: comparison and interaction of the ecological, energy, carbon and water footprints. *Rev. Metall. 110, 77-86.*

Finkbeiner M. 2009. Carbon footprint – opportunities and threats. *Int. J. Life Cycle Assess. 14, 91-94.*

Galli A, Wiedmann T, Ercin E, Knoblauch D, Ewing B, Giljum S. 2012. Integrating ecological, carbon and water footprint into a "Footprint Family" of indicators: Definition and role in tracking human pressure on the planet. *Ecol. Indic. 16, 100-112.*

Goedkoop M, Heijungs R, Huijbregts M, De Schryver A, Struijs J, van Zelm R. 2009. ReCiPe 2008: A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level, 1st ed. Ruimte en Milieu, Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, The Netherlands.

ISO 14040. 2006. Environmental management – Life cycle assessment – Principles and framework. International Organisation for Standardisation, Geneva, Switzerland.

ISO 14044. 2006. Environmental management – Life cycle assessment – Requirements and guidelines. International Organisation for Standardisation, Geneva, Switzerland.

Niccolucci V, Rugani B, Botto S, Gaggi C. 2010. An integrated footprint based approach for environmental labeling of products: The case of drinking bottled water. *Int. J. Design Nat. Ecodynamics 1, 68-75.*

Ridoutt BG, Pfister S. 2013a. A new water footprint calculation method integrating consumptive and degradative water use into a single stand-alone weighted indicator. *Int. J. Life Cycle Assess. 18, 204-207.*

Ridoutt BG, Pfister S. 2013b. Towards an integrated family of footprint indicators. *J. Ind. Ecol.* DOI: 10.1111/jiec.12026.

Weidema BP, Thrane M, Christensen P, Schmidt J, Løkke S. 2008. Carbon footprint. A catalyst for life cycle assessment? *J. Ind. Ecol. 12, 3-6.*

BARILLA EPD PROCESS SYSTEM TO INCREASE RELIABILITY, COMPARABILITY AND COMMUNICABILITY OF LCA STUDIES

Luca Ruini[1], Laura Marchelli[1], Massimo Marino[2], Assunta Filareto[2,]*

[1] Barilla G. R. Fratelli S.p.A

[2] Life Cycle Engineering

**Corresponding author. Tel. +39 (0) 11 22 57 311; Fax +39 (0) 11 22 57 319. E–mail address: filareto@studiolce.it. Postal address: Life Cycle Engineering c/o Environment Park – 60,via Livorno, I–10144 Torino (TO).*

Keywords: PCR (Product Category Rules); EPD (Environmental Product Declaration); EPD Process System; LCA for food; verified database.

ABSTRACT

The aim of this work is to show how a large company integrates the life cycle approach into its policies. In February 2011 Barilla certified in compliance with the Process Certification Clarifications guidelines for International EPD® System to perform environmental impact calculation in an easy, quick and reliable way and to provide certified and published results. Barilla's EPD internal process is based on the LCA database, the Product System and the Product Specific data. They are used together as a funnel process: data from the database and from product specific information are processes by the product system tool to have the specific LCA data sheet results. The reliability of the system is guaranteed by both internal and external verification.

INTRODUCTION

Barilla, one of the top Italian food groups, produces more than 100 products in about 50 plants around the world. The company has been using the LCA for more than a decade. Since 2008, life cycle thinking made its way into company strategy, as an instrument to thoroughly study the production chain and localize the most substantial environmental impacts.

Barilla decides to join the International EPD System for several reasons: the System acts following the International Standards (ISO 14025); the reliability of the LCA is assured by the Product Category Rules (PCR); the System allows the comparability among the same product group, each document with a public interest (such as Product Category Rules (PCR) and General Program Instruction (GPI)) is published; public register on PCR and EPD is regularly updated; EPDs and LCAs must cover all the environmental issues not merely focusing on greenhouse gases emissions; the System gives the possibility to develop an EPD Process Certification.

Barilla's aim is to develop the EPDs for the major part of its product and the only way to make it in an easy, simple and reliable manner is to use an EPD Process System; for this reason, during 2010, it was developed and certified by Bureau Veritas in 2011. The scope of

the Process System is to prepare, verify and publish EPDs for Barilla's products related to the following Product Category Rules:
- Product Category Rules 2010:01 (CPC 2371): Uncooked pasta, not stuffed or otherwise prepared;
- Product Category Rules 2012:06 (CPC 234): Bakery Products;
- Product Category Rules 2010:09 (CPC 23995): sauces; mixed condiments; mustard flour and meal; prepared mustard
- Product Category Rules 2011:07 (CPC 2372): pasta, cooked, stuffed or otherwise prepared; couscous

MATERIALS AND/OR METHODS

All EPDs coming from the Barilla's EPD Process System are based on the Life Cycle Assessment methodology; using the following three main elements:

1. The Product Specific data
2. The LCA dBase
3. The Product System

The system works like a "funnel process", as showed in figure 1: product specific information are collected and elaborated by the product system using the LCA dBase, then results are collected in a specific LCA data sheet, that is then used for the preparation of the EPD.

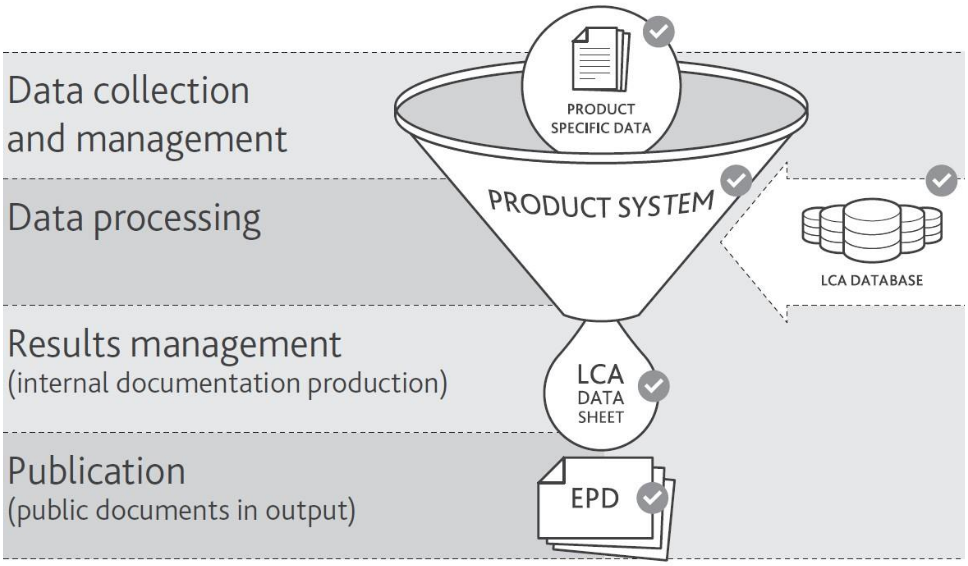


Figure 1. Scheme of the Barilla EPD Process System ("funnel process")

Product specific data represent all the specific information related to the product that has to be analyzed, they have to be collected for each EPD and include the following specific information: product recipe, bill of materials packaging list, production plants where the product is manufacturing, production volume per each plant involved, finished product logistic distribution data and other relevant environmental aspects.

The database is organized among different data modules groups: raw materials, packaging raw materials, energy, plants and transports. Each data module contains all the environmental aspects related to material or process, main hypothesis applied, as requested by the ISO 14040 series (functional unit, system boundaries, data quality, data collection and treatment, allocation and cut-off rules). All data modules are internally verified and are ready to be used for EPD purposes.

The Product System represents the product group model calculation tool. It is developed for each product group in a specific fashion following the Product Category Rule (PCR) and is internally vetted. Barilla's EPD Process System includes Product Systems for pasta, bakery and sauces products. The reliability of the EPDs is ensured by several verification levels done by Data Assessor, Process Assessor and Verification Body:

1. Product System and LCA Database verification is performed by the Data Assessor;
2. Product specific data, LCA data sheet and EPD Document verification is performed by the Data Assessor per each EPD realized;
3. EPD Process verification by means of internal audit, performed by the Process Assessor and external audit, performed by a Verification Body (accredited body certified for audit of management systems).

Barilla EPD Process System is organized in three main processes, under the control of the management activities: EPD project, database update and product system update. The first activity of the system is the EPD planning, it is performed each year to organize all the works related to the EPD Process System. The main process of the system is the EPD Project, which leads to the verification and publication of the EPD document, starting from the Product data collection and passing through data check and elaboration and EPD verification. Database update is performed each time data must be updated (e.g. for energy mix) and at least once a year. In addition, data is updated during the data check of the EPD Project when data is unavailable for the model. The product system update process allows to update the product system model when there is a change to its product category rules and compiles a new product system when a new product must be analyzed and inserted into the system. The Barilla EPD process performances are evaluated by mean of specific indicators. EPD Process management is guaranteed by the mutual works of different actors: EPD process owner (the EPD system process responsible), LCA developer (supported by an LCA team, that manages all the activities necessary for the EPD document preparation), data owners (in charge of providing data and information needed for LCA calculations) and data expert (personnel that could assist both specific data verification during LCA calculation and EPD preparation). The system reliability is guaranteed by several verifiers (data assessor, process assessor and verification body). Data assessor is personnel responsible for the verification of the LCA calculation and of the EPD document. Process assessor: is an internal verifier that regularly assesses the conformity of the EPD process. The Verification Body: represents an accredited body certified for audit of management systems that verifies the entire EPD process system.

RESULTS

Barilla is the first private company that has developed an EPD Process System. More than 50% of the products put on the market by Barilla during year 2012 are covered by an Environmental Product Declaration (EPD). At 30th April 2013, thirty-two EPDs were published on the website and about one thousand data modules were realized; the available data modules are over the 90% and validated data modules among the available ones are over the 75%. The use of the Barilla EPD Process System has shortened EPD publication timing, that now lasts about 8 - 10 weeks.

Table 1. Performance of the EPD Process System

Indicators	Unit	Data
Product volume covered by EPDs (year 2012)	%	58%
Planned projects (year 2013)	n°	38
Open Projects (point at 30/04/2013)	n°	16
Frozen Projects (point at 30/04/2013)	n°	0
Validated EPD (point at 30/04/2013)	n°	36
Published EPD (point at 30/04/2013)	n°	32
Product System (point at 30/04/2013)	n°	6
Product System validated (point at 30/04/2013)	%	80%
Total module (point at 30/04/2013)	n°	1000
Available data module (point at 30/04/2013)	%	91
Validated data module (point at 30/04/2013)	%	76

DISCUSSION

Table 1 shows the Barilla EPD Process System performances through the system indicators, from 2010 to April 2013. Looking at table 1, it's important to point out that there are 38 EPD projects planned for 2013; some of these contain more than one product to be analyzed because there are several recipe variants for some products. Furthermore there are no frozen projects because there were no problems with data availability and there is a higher number of validated EPDs respect to published EPD because it was decided to not publish three of the validated EPDs. From year 2010 to April 2013 more than forty verifications were performed: five external verifications made by Bureau Veritas, and the others made by data and process assessors for internal verifications.

CONCLUSIONS

Barilla's expectations from the EPD System are strong cooperation for the alignment of different systems, that have different rules and provide different results and actions for EPD system divulgation, such as seminars, working group.

REFERENCES

International EPD Cooperation ; PCR 2010:01; CPC 2371: Uncooked pasta, not stuffed or otherwise prepared; version 1.1 of 18/06/2010.

International EPD Cooperation ; PCR 2010:09; CPC 23995: Sauces; mixed condiments; mustard flour and meal; prepared mustard; version 1.1 of 9/11/2010.

International EPD Cooperation; General Programme Instructions for Environmental Product Declaration; version 1 of 29/02/2008.

International EPD Cooperation; PCR 2012:06; CPC 234: Bakery Products; version 1.0 of 17/04/2012.

International EPD Cooperation; Process Certification Clarification (PCC) for the International EPD System; Guidelines; ver. 1.0 of 23/04/2010.

International EPD Cooperation; Process certification clarification for the International EPD® system. Version 1.0 of 23/04/2010.

ISO 14025- Environmental labels and declarations - Type III environmental declarations - Principles and procedures.

ISO 14040 - Environmental management, Life cycle assessment, Principles and framework;

ISO 14044 - Environmental management, Life cycle assessment, Requirements and guidelines;

DEVELOPING SCIENTIFICALLY-SOUND PRODUCT ENVIRONMENTAL FOOTPRINT CATEGORY RULES: DEVELOPMENT OPTIONS, CHALLENGES AND IMPLICATIONS

Erwin M. Schau, Karen Allacker, Camillo De Camillis, Rana Pant*
European Commission, Joint Research Centre, Institute for Environment and Sustainability,
**Via E. Fermi 2749, I-21027 Ispra (VA), Italy, E-mail: erwin.schau@jrc.ec.europa.eu*

Keywords: Product Environmental Footprint (PEF); PEF Category Rules (PEFCR)

ABSTRACT

The Environmental Footprint (EF), launched by the European Commission's Joint Research Centre in cooperation with Directorate-General for the Environment, provides general guidance for comprehensive, scientifically-sound and consistent environmental assessment of products and organisations. The aim of the EF is to ensure science-based decision support for industry and policy making. To make the general-level rules of the EF more relevant and applicable to specific product categories and sectors, the EF guides provide requirements to develop the so called PEF Category Rules (PEFCRs) and OEF Sector Rules (OEFSRs). PEFCRs and OEFSRs are seen as corner stones for consistent and robust assessments instrumental to specific environmental communication forms, namely business-to-business (B2B) and business-to-consumer (B2C) intended to be used for comparisons. The focus of this paper is on the key challenges in developing PEFCRs.

INTRODUCTION AND BACKGROUND

The European Commission's "Roadmap to a Resource Efficient Europe" (European Commission 2011) proposes ways to increase resource productivity and to decouple economic growth from both resource use and environmental impacts, taking a life-cycle perspective. One of its objectives is to: *Establish a common methodological approach to enable Member States and the private sector to assess, display and benchmark the environmental performance of products, services and companies based on a comprehensive assessment of environmental impacts over the life-cycle ('environmental footprint')* (European Commission 2011).

The Environmental Footprint (EF), launched by the European Commission's Joint Research Centre in close cooperation with Directorate-General for the Environment, provides specific guidance for comprehensive, scientifically-sound and consistent environmental assessment of products and organisations. The EF rules are reported in two guidance documents:

- the Product Environmental Footprint (PEF) Guide, applicable to any goods and services,

- the Organisation Environmental Footprint (OEF) Guide, applicable to any organisations.

The PEF and OEF Guides were recently published as annexes of the recommendation linked to the Communication "*Building the Single Market for Green Products - Facilitating better information on the environmental performance of products and organisations*" (European Commission, 2013b)

To make the general-level EF rules even more relevant and applicable to specific product categories and sectors the EF guides provide requirements to develop so called PEF Category Rules (PEFCRs) and OEF Sectoral Rules (OEFSRs). PEFCRs and OEFSRs are seen as crucial especially for consistent and robust business-to-business (B2B) and business-to-consumer (B2C) communication intended to be used for comparisons.

The focus of this paper is on the PEFCRs. This paper highlights the key challenges in the process to develop PEFCRs and takes into account amongst other recent developments led by the US EPA (Ingwersen & Subramanian, 2013) in this area.

MATERIALS AND METHODS

PEFCR shall specify the following model parameters[1] (European Commission, 2013a);

- system boundaries and related processes/activities to be included;
- downstream scenarios;
- use-stage scenarios and associated time span for the use stage;
- transport, distribution and storage scenarios;
- end-of-life scenarios.

Based on the requirement in the PEF Guide, the PEFCR shall 1) specify for which processes specific data shall be collected; 2) specify the requirements for the collection of specific data, and 3) define the data collection requirements for each site for:

- Target stage(s) and the data collection coverage;
- Location of data collection (domestically, internationally, specific factories, and so on);
- Term of data collection (year, season, month, and so on);
- When the location or term of data collection must be limited to a certain range, provide a justification for this and show that the collected data will serve as sufficient samples.

Regarding reporting of environmental impact, the PECRS shall identify the most relevant EF impact categories and justify any exclusion of the default EF impact categories and also identify additional environmental information, if any (European Commission, 2013a).

When preparing new PEFCR, both relevant sector-specific guidance documents and PCR from similar schemes already in place are to be taken into account, such as;

- The ENVIFOOD Protocol by the European Food Sustainable Consumption and Production (SCP) Round Table (Bligny et al., 2012)

[1] This list is not exhaustive.

- European Standard EN 15804: 2012 - Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products (EN 15804, 2012)
- Supplementary requirement (for horticultural products and for seafood) to the PAS2050 (PAS 2050-1, 2012; PAS 2050-2, 2012)
- GEDNets PCRs for Environmental Product Declaration (EPD) (GEDnet, 2012) and the PCR library (2012) (Related to (ISO 14025, 2006))
- Parts of the Repository of good practice in France (c.f. (AFNOR BP X 30-323, 2011))

In addition, the European Commission is part of the Product Category Rule Guidance Development Initiative, a collaborative work for developing guidance for PCR development, an open initiative with public ownership and global validity, although initiated in the USA. (W. Ingwersen & Subramanian, 2013). Where PCR and other sectorial guidance exist, both relevant sector-specific guidance documents and PCR from similar schemes already in place are to be taken into account.

Another important pillar of the coming PEFCR development will be the open process with stakeholders involvement.

RESULTS

A first step to be taken is to define how the product categories and related sectors should be defined. Also Ingwersen and Stevenson (2012) acknowledge the difficulties of defining product group and use the example of two detergent product, liquid and powder, both able to clean textiles, but which are produced in different supply chain.

The product categories can be defined based on e.g.: a) Material characteristics or specific product, such as product category “plastic”, “steel”, “glass”, “bottle of drinking water”, “personal car”, “plane”, b) A specific function, such as “beverage container”, “transport of 1 person over 1 km”, “transport of 1 tonne over 1 km”, “1 liter of drinking water at consumer”, and c) A specific need, such as “housing”, “eating”, “transport”

The main aim of developing PEFCRs is to enable citizens to make informed choices by comparing the environmental performance of products fulfilling the same function. The definition of the product category should therefore take into account that comparability needs are to be ensured between e.g. different material producers like plastic, steel, aluminum which all produce beverage containers. This calls for a functional approach (where the function or functional unit of the product/organization) is essential. A too close (small) category definition would results in a very large number of PEFCR/OEFSRs, in its extreme renders the category / sector rules unimportant. At the same time, the boundaries must ensure that different products capable of fulfilling the same need(s) can be compared against each other and therefore belong to the same category.

According to the PEF Guide, the product shall be encoded and defined using the Classification of Products by Activity (CPA) scheme (Eurostat, 2013). A first approach to define product categories would therefore be to investigate if the CPA scheme has a structure, i.e. detecting where comparable products belong to the same group in the CPA scheme. Unfortunately, this is not always the case. For example, a cup made of plastic and a cup made of ceramic belongs to different CPA codes. Therefore, a combination of different CPA codes in one product category may be necessary.

CONCLUSIONS

PEFCRs aim at simplifying the conducting of PEF studies. When developing PEFCRs, the appropriate scope of product categories needs to be sufficiently broad in order to enable meaningful comparisons of products providing the same function on the one side. On the other side, the scope of product categories should remain focused enough to be manageable from a process point. Different approaches can be used, namely: a need-based approach, a functional approach and a material-based approach. Each of these has pros and cons which need to be taken into account in the open stakeholder process to develop PEFCR. An example of a very wide product group is the food products. The ENVIFOOD protocol of the European Food Sustainable Consumption and Production (SCP) Round Table was developed to be in line with the PEF Guide and can serve as a starting point to develop PEFCRs for food and drink products. Currently, the European Food SCP Round Table working group 1 is discussing how to best define product categories and related PEFCRs below the level of the ENVIFOOD Protocol as well as the PEF guide.

REFERENCES

AFNOR BP X 30-323. (2011). General principles for an environmental communication on mass market products - Part 0: General principles and methodological framework.

Bligny, J.-C., Pennington, D., De Camillis, C., Pályi, B., Bauer, C., Schenker, U., … Vessia, Ø. (2012). ENVIFOOD Protocol. Environmental assessment of food and drink products Protocol. Ispra, Italy: The European Food Sustainable Consumption and Production (SCP) Round Table, European Commission, Joint Research Centre

EN 15804. (2012). *Sustainability of construction works. Environmental product declarations. Core rules for the product category of construction products.*

European Commission. (2011). Roadmap to a Resource Efficient Europe COM(2011) 571 final - Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Brussels.

European Commission. (2013a). Annex II: Product Environmental Footprint (PEF) Guide to the Commission Recommendation on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations (pp. 140). Brussels,: European Commission.

European Commission. (2013b). Communication from the Commission to the European Parliament and the Council - Building the Single Market for Green Products - Facilitating better information on the environmental performance of products and organisations COM(2013) 196 final. Brussels

Eurostat. (2013). RAMON - Eurostat's Metadata Server Retrieved 17 May, 2013, from http://ec.europa.eu/eurostat/ramon

The Global Environmental Declarations Network (GEDnet). (2012). Retrieved 6 Sep, 2012, from http://gednet.org/

Ingwersen, W., & Subramanian, V. (Eds.). (2013). *Guidance for Product Category Rule Development, version 0.9, January 17, 2013*: The Product Category Rule Guidance Development Initiative.

Ingwersen, W. W., & Stevenson, M. J. (2012). Can we compare the environmental performance of this product to that one? *Journal of Cleaner Production, 24*, 102-108. doi: 10.1016/j.jclepro.2011.10.040

ISO 14025. (2006). *Environmental labelling and declarations - Type III environmental declarations - Principles and procedures* (ISO 14025:2006) (1. ed. July 2006). Geneva: ISO

PAS 2050-1. (2012). Assessment of life cycle greenhouse gas emissions from horticultural products - Supplementary requirements for the cradle to gate stages of GHG assessments of horticultural products undertaken in accordance with PAS 2050. London: British Standards Institution (BSI).

PAS 2050-2. (2012). Assessment of life cycle greenhouse gas emissions - Supplementary requirements for the application of PAS 2050:2011 to seafood and other aquatic food products. London: BSI.

PCR Library. (2012). Retrieved 6 Sep, 2012, from http://pcr-library.edf.org.tw/about/index.asp

LIFE CYCLE BASED ASSESSMENT FOR AGRICULTURAL PRODUCTS: AN AUSTRIAN BEST PRACTICE

Wildenberg, Martin; Comploi, Kewin; Frieling, Dominik; Altaparmakova, Tanja; Geiger, Anna*

GLOBAL 2000 / Friends of the Earth Austria

** Neustiftgasse 36, A-1070 Vienna*

Email: martin.wildenberg@global2000.at

Keywords: Product environmental footprinting, sustainable food-chains, labeling, agriculture

ABSTRACT

This paper presents the GLOBAL 2000 adaptive sustainability assessment approach, with which the environmental performance of agricultural products is measured. The aim of the approach is to arrive at a comprehensive understanding of the environmental impacts of an agricultural products and the connected life cycle. Furthermore, it strives to set incentives for farmers to adopt a more sustainable production mode and to help consumers make deliberative consumption choices, by informing them about the environmental impacts of products along the life cycle.

INTRODUCTION

The following describes the GLOBAL 2000 *adaptive sustainability assessment approach* (ASAP) methodology, as it is currently in use in the *REWE, GLOBAL 2000 and Caritas Sustainability Program* for the REWE Pro Planet label in Austria.

Eco-labeling has been suggested as an approach to manage towards a more sustainable world by several authors and organizations (e.g. de Snoo 2006, Bruce & Laroiya 2006, Rigby et al, UNDP(CSD) 1996). Although approaches to "measure" sustainability have often been criticized we follow the opinion of Gomez-Limon & Sanchez-Fernandez (2010) that the "design and use of such indicators can be extremely useful in that they force those involved in the discussion of sustainability to identify the key aspects of sustainable agriculture and to assign weights to them." In such a context the often very general and theoretic discussions about sustainability are confronted with real world practices and problems and are requested to come up with workable solutions and improvements.

Sustainability is a multidimensional concept. It is therefore necessary to use a set of indicators that cover different important aspects of sustainability. We have chosen to use five field-level indicators and five indicators derived from Material Input Per Service-unit *(*MIPS) (Hinterberger et al 1997).

METHODS

Our approach rests on four pillars: (1) the involvement of stakeholders in a process that allows for adaptations, (2) use of well-established indicators calculated from on field and production-chain data (3) a set of rules and guidelines and the (4) benchmarking of the indicator values and the subsequent labeling of products. The indicators are calculated on a yearly basis for each product – farmer combination. The data is provided by the farmers and suppliers via an Internet-interface or directly via their farm-management-software.

Field based indicators

The indicators are (1) Humus-, (2) Nitrogen -, (3) and Phosphorus Balance, (4) Pesticide use intensity, which is calculated out of pesticide application data and (5) Energy intensity on the field-level, which tells us how much energy was invested to produce one kilo of the product, considering the energy contents of all inputs. The calculation of humus-, N- and P-balance includes the effects of crop rotation, type of soil, crop grown, inter-crops and underzone crops as well as fertilization and yield. The five field level indicators are calculated with the agricultural model REPRO (Hülsbergen 2003). The data requirements for calculating the indicators largely overlap with the data farmers need to record for GLOBALG.A.P. GLOBALG.A.P is an international widely accepted business to business certification for 'good agricultural practice' and requested by the supermarkets for all producers entering the market.

Material Input Per Service-unit indicators

We use five MIPS indicators: the Carbon Footprint expressed in CO2 eq. / kg product, abiotic and biotic material input (kg / kg product), water used (l/kg product) and land-footprint in m²/kg product. Data is collected on the farm and supplier level by using a questioner developed in a series of scoping studies. It covers the important steps in the production process, so that all relevant resource inputs and infrastructure are recorded. Climate relevant emissions from fertilization and humus-depletion are calculate within REPRO and added to the CO2-rucksack. The contribution to the resource indicators by the retailers logistic and shelf-live was calculated based on data provided by REWE International.

Benchmarking and labeling

After the indicators are calculated the results are benchmarked using either a best practice approach (for pesticide-index, energy-intensity, biotic and a-biotic resource rucksack and CO_2 emissions) or existing national terms of references (nitrogen phosphor and humus-balance). For the water-rucksack a benchmarking approach based on the Water Exploitation Index (EEA 2012) of the watershed was developed to account for local differences in the water availability and the overall situation in a water-shed.

We apply a process that explicitly involves stakeholders (farmers, subcontractors, suppliers, packer and agricultural extension officers) in the refinement and adaptation of monitoring and benchmarking. This participative process also serves as a discussion and knowledge transfer arena, helping the experts to learn from practical experience and the farmers to access information about alternative approaches.

RESULTS

The program was launched in 2010, with Austrian Strawberries being the first labeled product. By now about 550 farmers and their associated suppliers are participating in the program. 30 Products have been screened from which 25 could be labeled. The products are mainly vegetables and fruits produced in Austria. Italian grapes are currently the only international product labeled. Vegetables and citrus from Spain have been screened, but due to the unsustainable water situation have not been labeled yet. Anyway the process initiated in Spain has led to a dialogue on water management practice and might lead to a range of producers to improve their water management. Beside vegetables and fruits eggs also have been labeled.

In terms of creating concrete impact, we achieved reductions in CO_2 emissions and biotic and abiotic resource use for example through showing that the impact of transport packing is much higher than the transport distance which led to an significant increase of reusable transport-boxes. Also through the assessment and adaptation of packaging the environmental footprint of products was reduced.

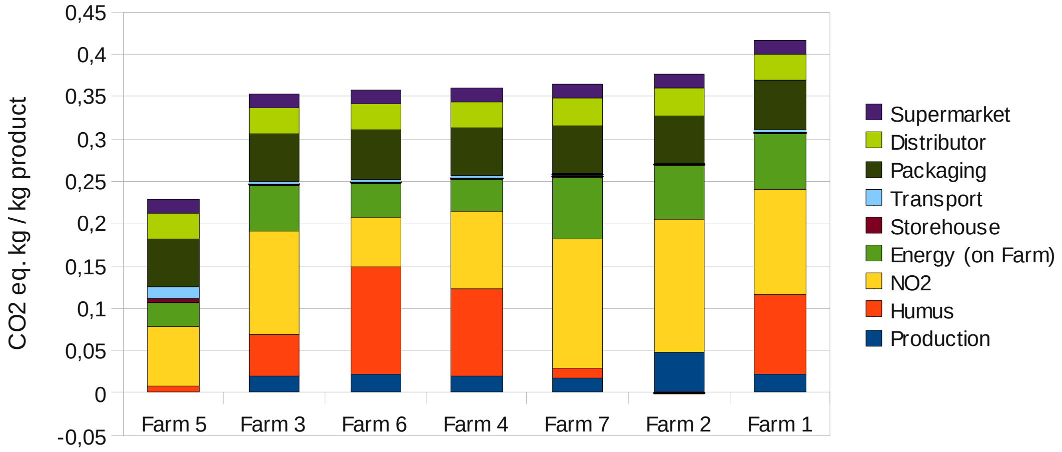


Figure 1: CO2 eq. per kg sweet maize and level od origin. In average soil carbon loss contributes to 16% of total CO2 emissions from field to shelf.

We could also show that in many vegetable production systems reduction of soil carbon content was a considerable contribution to the CO_2 footprint of the product (figure 1). These losses could be traced back to a lack of organic fertilization and insufficient crop-rotation. With the information provided by the program 15 farmers decided to change their crop-rotation or fertilization-management in 2012 to avoid humus loss. The information was also shared with the farm-extension officers that advise the farms.

CONCLUSIONS

Environmental impacts of production and consumption are best linked to production units that are the commonly used by consumers – i.e. kg or pieces. This will make the results useful for the consumers and the retailers at the point of sale and can potentially create a competitive environment around the environmental performance of the products.

A methodology to calculate the environmental impact of products should:

(1) Incorporate indicators that cover both product-specific impacts, in our case: N-, P- and humus-balance, Pesticide-Index, and general impacts like CO_2 emissions, waterfootprint, resource use and land-footprint to allow comparability between diverse product categories.

(2) Rest as much as possible on already available data, which farmers have to record either for certification or subsidies. This also has the additional benefit that external controlling protocols for this data already exist, that ensure the quality and accuracy of the data.

(3) Be as easy to calculate and understand as possible – especially if many small or medium sized businesses are involved. Here the MIPS indicators clearly have an advantage over the product-specific indicators. The models used are often “black-boxes” for all non-experts and can raise distrust and doubt.

(4) Provide information that are also relevant for good management practice like nitrogen-balance, humus-balance and phosphor-balance, which are indicators that farmers are aware of as part of their daily work and which support them in making reasonable economic decisions.

(5) Point to hot spots and enable to easily communicate improvements, if hot spots are solved.

(6) Help decision making by providing information on different aspects of the system and on tradeoffs. For example reducing the heating in a glasshouse production may decrease the direct energy demand but might increase the use of fungicides.

(7) Involve stakeholders in the design and continuing improvement of the process. Discussing results and the methodology with all relevant stakeholders will help to increase the efficiency of the data collection, the acceptance of the process and the development of solutions.

REFERENCES

Bruce C. and A. Laroiya, 2007. The Production of Eco-Labels. Environmental and resource Dynamics (2007) 36: 275- 293

de Snoo, G. R., 2006. Benchmarking the Environmental Performances of Farms. The International Journal of Life Cycle Assessment Volume 11, Number 1, 22-25

EEA 2012 Indicator Fact Sheet (WQ01c) Water exploitaion index. European Environmental Agency (http://www.eea.europa.eu/data-and-maps/figures/precipitation-deficit-in-summer-jja-1)

Gomez-Limon,J.A., G. Sanchez-Fernandez, Empirical evaluation of agricultural sustainability using composite indicators, Ecological Economics, Volume 69, Issue 5, 15 March 2010, Pages 1062-1075, ISSN 0921-8009, DOI: 10.1016/j.ecolecon.2009.11.027.

Hinterberger, F., F. Luks, F. Schmidt-Bleek, Material flows vs. `natural capital': What makes an economy sustainable?, Ecological Economics, Volume 23, Issue 1, October 1997, Pages 1-14, ISSN 0921-8009, DOI: 10.1016/S0921-8009(96)00555-1.

Hülsbergen K. 2003. Entwicklung und Anwendung eines Bilanzmodells zur Bewertung der Nachhaltigkeit landwirtschaftlicher Systeme. Shaker, Halle, 257 S.

Rigby D., P. Woodhouse, T. Young, M. Burton, 2001. Constructing a farm level indicator of sustainable agricultural practice. Ecological Economics 39 (2001) 463 – 478

UNDP(CSD) 1996 Eco-labeling United Nations Commission on Sustainable Development. Available at: http://www.un.org/documents/ecosoc/cn17/1996/background/ecn171996-bp8.htm

RELEVANCE AND UNCERTAINTY OF EPD DATA

Cornelia Stettler and Fredy Dinkel, Carbotech AG, Switzerland.*
Carbotech AG, Postfach, 4000 Basel, Switzerland c.stettler@carbotech.ch

Keywords: EPD, LCA, Relevance; Uncertainty; Transparency.

ABSTRACT

The goal of EPDs is to provide transparent information on relevant ecological impacts over the life cycle of a product or a service. Both criteria, transparency and relevance, are crucial for the use of EPDs and are the backbone for an ecological decision making. Existing EPDs and related PCRs were compared to evaluate if they fulfill the goal to give a sound basis for decision. The following provoking statement arose: “EPDs are often not useful for the decision making.” The following reasons for this statement indicate an optimization demand. The relevance of impacts is often not analyzed and documented. Information of low relevance causes a loss of focus. The uncertainty of results is neglected and frequently higher than the ascertained difference between products.

INTRODUCTION

EPDs are today a relevant factor to obtain confidence of clients and have an advertising effect. The original aim of EPD to deliver transparent and relevant information for the comparison and the continuous improvement of products needs to be quality checked to guarantee an adequate use of the elaborated data. From our experience the following problems have to be considered for the improvement of PCRs and EPDs.

Because there is no indication of relevance within the EPD, it must be assumed that all included indicators are ecologically relevant. Consequently all differences between indicators have to be considered in the comparison of products. Often the results viewed separately lead to different conclusions. As a consequence a subjective choice of indicator is inevitable for the decision process. This leads to different conclusions depending from the point of view of the final user.

Every LCA is linked with uncertainties. This is especially important if results based on different data bases are compared. An interesting study on the robustness of CO_2 balances was presented at the 5th PCF world forum (Schmid H. and Kägi T., 2011). The same data on a defined product was evaluated by five leading LCA experts. The results for the GWP showed differences in magnitude up to a factor two. For the interpretation of results uncertainty information is crucial, but often not included in EPDs.

The following analysis was carried out to show the need for further information on the relevance and the uncertainty of impacts provided in EPDs.

MATERIALS AND METHODS

A random sample of registered EPDs on construction materials was tested on their helpfulness for an ecological decision making. The focus was given to construction materials due to the number of publications in this sector. The example of fiberboards was chosen for a detailed analysis. In a first step the declared impacts of products were compared to determine if this information is sufficient to make an ecological choice of product. The results were compared with the corresponding inventory from ecoinvent v2.2 (ecoinvent, 2010). In a second step the selection of indicators was assessed for the analyzed product. To do so the normalization step from CML for Western Europe (Guinée et al., 2001) and different aggregating methods were applied. Impacts were interpreted as emission of the used equivalents.

RESULTS

In the analyzed examples of EPDs impacts are declared mainly for the production of the fiberboards (cradle to gate). In some cases impacts of the end of life treatment are included. Table 1 gives an overview of the impacts provided in the analyzed declarations (see reference list). The corresponding EPDs are published online by IBU[1], EPD® International System and INIES [2]. Further information on the water consumption, waste amount, wood origin, laboratory results and the CO_2 balance are included in most of the EPDs.

Table 1. Ecological information provided in analyzed EPDs of medium density fiberboards

	Indicators provided in analyzed EPDs	**IBU**	**EPD®**	**INIES**
LCA impacts	Primary energy, non-renewable [MJ-eq.]	yes	yes	yes
	Primary energy, renewable [MJ-eq.]	yes	yes	yes
	Greenhouse warming potential [kg CO_2-eq]	yes	yes	yes
	Ozone depleting potential [kg R11-eq]	yes	yes	yes
	Acidification potential [kg SO_2-eq.]	yes	yes	yes
	Eutrophication potential [kg Phospate eq.]	yes	yes	no
	Photochemical oxidation potential [kg ethylene eq.]	yes	yes	yes
	Resources depletion [kg antimon Sb eq.]	no	no	yes

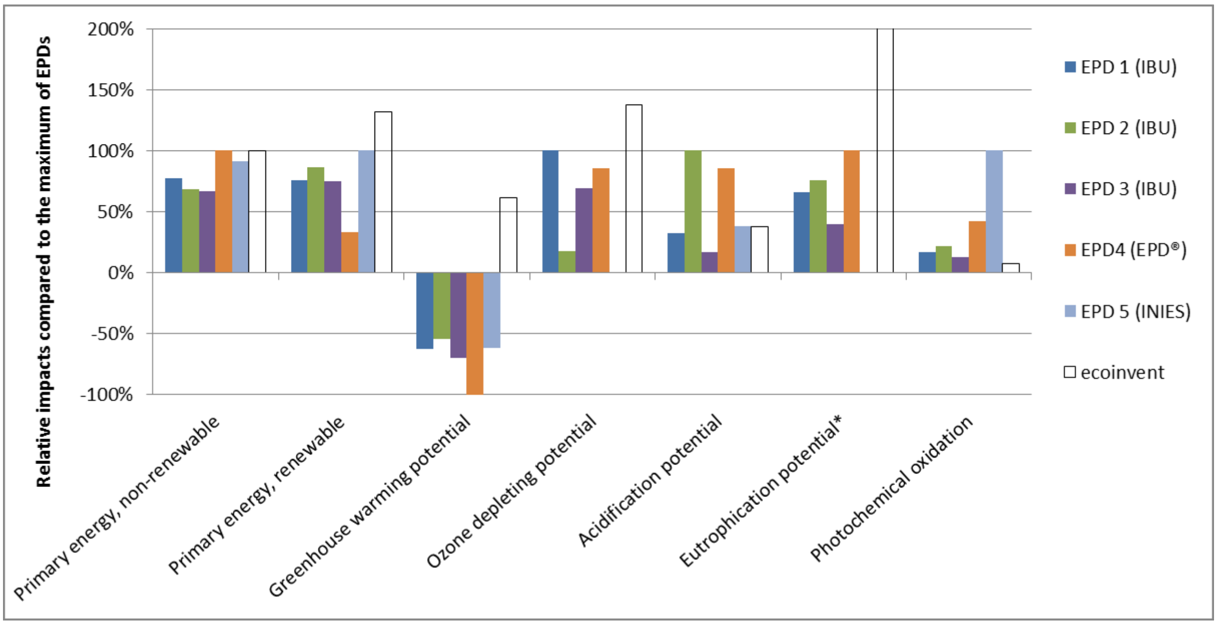
The following evaluations consider the information of the production only (cradle to gate). Data on the end of life treatment included in some of the EPDs is not adequate for the comparison of products for the following reason. An energetic use of biomass with heat and electricity cogeneration is recommended and analyzed, accounting benefits from the replacement of common heat and electricity products. The resulting CO_2 elimination over the life cycle of fiberboards is misleading. The benefits from the use of biomass would also remain if the biomass would be used for other purposes and depend on the location.

[1] IBU: German Institute Construction and Environment, http://bau-umwelt.de
[2] INIES: Base de données française de référence sur les caractéristiques environnementales et sanitaires des produits de construction, http://www.inies.fr

Comparison of EPD data (cradle to gate)

Figure 1 shows the impacts of the production of medium density fiberboards declared in the selected EPDs. The impacts are illustrated relative to the maximal value of analyzed EPDs. Additionally illustrated are the impacts from the corresponding LCI of ecoinvent.

Figure 1. Comparison of EPD results on the production of fiberboards of medium density (additional illustration of corresponding ecoinvent inventory v2.2, CO_2 uptake not accounted)



* The EPD5 from France does not include the eutrophication potential, but further not illustrated indicators

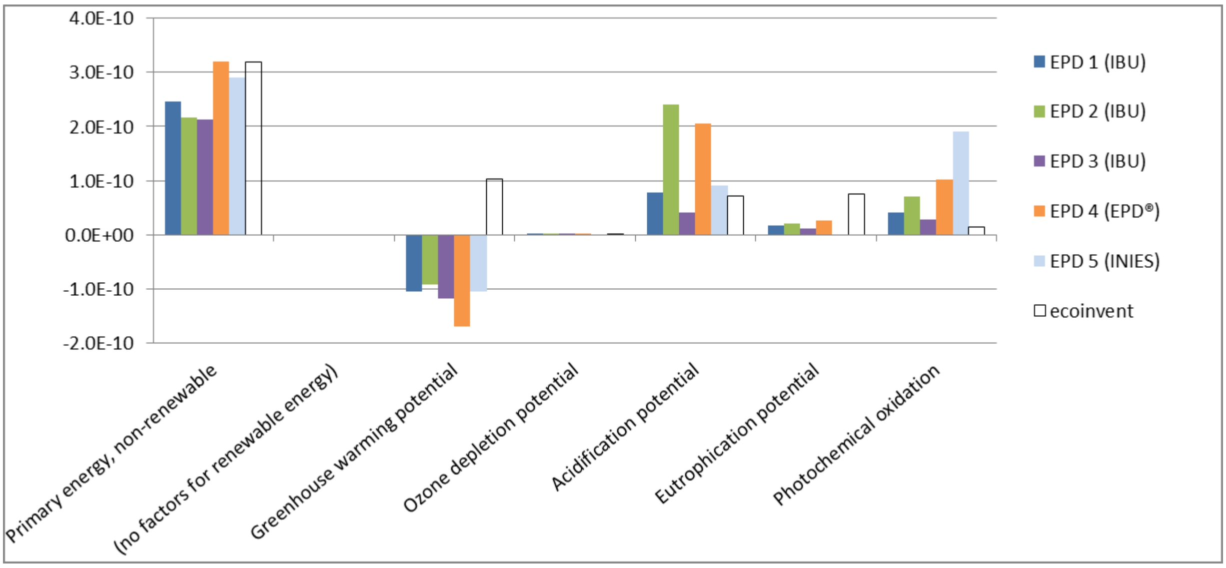
The different impacts do not lead to the same conclusion. An ecological choice of product is not possible without further information on the relevance and uncertainty of different impacts. Regional differences result from the applied land specific electricity supply. Contrary to the ecoinvent data set the short-term storage of CO_2 in biomass is included in all EPDs. For transparency reasons the biogen CO_2 should be declared separately.

Relevance and uncertainty of selected impacts

To assess the relevance of the declared impacts the normalization steps of CML and different aggregating methods were applied. The result illustrated for the normalization step of CML in Figure 2 leads to the conclusion that the primary, non-renewable energy (abiotic depletion) is the most relevant impact, followed by the climate change, acidification, photochemical oxidation and eutrophication. No relevance results for the ozone depletion. Land use, particulate matter formation and toxicity are further relevant aspects if the ecoinvent data set is analyzed with aggregating methods. Those aspects are not covered by the provided impacts in the EPD.

Uncertainty information for the interpretation of the results in figure 1 and 2 is not provided in the EPDs. From our experience lie most of the resulting differences within the uncertainty range.

Figure 2. Relevance of impact categories using the normalization step of CML



DISCUSSION AND CONCLUSIONS

Despite the ample information in EPDs, or perhaps because of the overflow of not relevant data in some EPDs, frequently no objective conclusion can been drawn. Information on the relevance and the uncertainty of provided impacts is desirable for an appropriate use of EPDs. The selection of impacts in the EPDs and PCRs should be quality checked and documented. We recommend for the relevance analysis the additional use of at least the normalization step or better full aggregating methods. The aggregation is excluded under ISO 14250, but more coherent and transparent than the subjective judgment by the final user. The weighting of impacts as an optional step that may support the interpretation of results is also included in the draft for the product environmental footprint guide (European Commission, 2013).

REFERENCES

Ecoinvent (2010). Ecoinvent Data v2.2, Swiss Center for Life Cycle Inventories, Dübendorf

EPD® (2010). Environmental products declaration for plain medium density fibreboards (MDF) and for melamine-coated medium density fibreboards *(EPD 237, FINSA Spain)*

European Commission (2013). Annex II: Product environmental footprint (PEF) Guide (*draft, xxx*)

INIES (2009). Déclaration environnementale et sanitaire conforme à la norme NF P 01-010, Panneau MDF Standard ou Panneau de fibres standard obtenues par voie sèche. (*N° d'enregistrement 05-019)*

IBU (2012/2013). Umwelt-Produktdeklaration nach ISO 14025, DHF/DFF Holzfaserplatte *(EPD-EHW-2008611-D)*, AGEPAN® Holzfaserplatte *(EPD-GLU-2010111-D)*, Kronotec WP50 *(EPD-KRO-2012311-D)*

Guinée et al. (2001). Handbook on life cycle assessment. Operational guide to the ISO standards (*Kluwer Academic Publishers, ISBN 1-4020-0228-9, Dordrecht, 2002, 692 pp.*")

Schmid H. and Kägi T. (2011): Robustness in Carbon Footprint Results: Evidence and Recommendations from a Comparative Study of Beer (*5th PCF World Summit, Zurich, 7-8 April 2011*)

SCIENCE, LCM AND COMMUNICATION TOOLS FOR HARMONISED ENVIRONMENTAL AND SOCIAL SUSTAINABILITY IN THE EUROPEAN FOOD AND DRINK CHAIN – THE SENSE PROJECT

Anna Aronsson[1], Birgit Landquist[1], Ulf Sonesson[1], Aintzane Esturo[2], Jaime Zufía[2], Thorkild Nielsen[3], Erling Larsen[4], Guðrún Ólafsdóttir[5], David Barling[6], Niels Jungbluth[7], Begoña Perez Villarreal[2]*

*[1] Swedish Institute for Food and Biotechnology, Sweden, [2] AZTI-Tecnalia, Spain, [3] Aalborg University Centre, Denmark, [4] DTU-Aqua, Denmark, [5] University of Iceland, Iceland, [6] The City University London, UK, [7] ESU-services Ltd., Switzerland, * Corresponding author, postal address Box 5401 SE 402 29 Gothenburg Sweden, email: birgit.landquist@sik.se*

Keywords: Sustainability, Food & drink chain, LCA, LCIA

ABSTRACT

This paper presents the first outcome of the SENSE project (HarmoniSed ENvironmental Sustainability in the European food and drink chain). In Work Package 1 the main environmental challenges in three European food supply chains (beaf/dairy products, orange juice and farmed fish) have been reviewed. Based on LCA studies, key environmental impact categories (climate change, eutrophication, acidification, human toxicity, ecotoxicity, land use, abiotic resource depletion and water depletion) have been identified as the most relevant for the food supply chains. Life cycle impact assessment (LCIA) methodologies to be used in the project have been chosen for the selected categories. The feasibility to regionalize the characterization factors and the relevance of Key Environmental Performance Indicators (KEPIs) are also being investigated.

INTRODUCTION

The food and drink industry in Europe is highly fragmented, and food chains are very complex. The environmental impacts are normally largest in the first part of the value chain, the agriculture and fishery. They are mainly caused by biological processes, hence difficult to quantify, and show large temporal and spatial variations. To assess and communicate the sustainability impact of a food product there is a need for applying integrated, harmonised and scientifically robust methodologies, together with appropriate communication tools and strategies for making sustainability understandable to consumers. The SENSE project (http://www.senseproject.eu/) will deliver a harmonised system for sustainability impact assessment of food and drink products as a basis for communication. The three year project started in February 2012. The SENSE consortium is formed by a multidisciplinary team involving 23 partners from 13 countries: research organisations, food and drink SMEs, environmental and LCA experts, and European Food Associations. SENSE is coordinated by AZTI Tecnalia, Spain.

The main results of SENSE will be:

- Harmonised methodology for environmental and social impact assessment, regionalised when appropriate
- Key environmental and social performance indicators for beef and dairy products, orange juice and farmed fish
- SENSE tool for simplified data collection throughout the supply chain
- Results presented in an Environmental Identification Document (EID) and a Communication Platform
- Certification Scheme Concept based on EID
- Road map for policy and governance implementation

METHODS

The three food supply chains beef/dairy, orange juice and salmon aquaculture have been selected as case studies. In Work Package 1 (WP 1) the environmental challenges for the food supply chains have been identified and key environmental impacts have been defined based on literature reviews of LCA studies. Furthermore, a set of environmental life cycle assessment methods has been established and regionalisation has been considered.

RESULTS

Key environmental challenges and impacts categories

The production at the farm stage has generally the greatest environmental impact, while the production of packaging, transports and the final disposal (recycling) have less important impacts. The total environmental impact of the life cycle is therefore to a large extent dependent on the variability at the farm stage due to variations in the technical production system e.g. for the beef and dairy chain, extensive grassland versus intensive with high volumes of imported feed. Similarly, for the aquaculture chain the production systems vary and the feed has the main environmental impact caused by the use of forage fish and plant based feed components. For orange juice also fuel consumption is of great importance.

Based on the literature review of LCA studies the key environmental impact categories listed in Table 1 have been identified as the most important for food products. Biodiversity was also defined as a key environmental impact from the study of the three supply chains. However, because of uncertainty and availability of data the project team has decided to handle biodiversity in the SENSE project as part of the environmental impacts due to land use.

Life cycle impact assessment methodologies

Existing LCIA methodologies has been reviewed as well as current developments. The ILCD handbook was a starting point for the review. The LCIA methodologies chosen for each impact category are listed in Table 1 and they are to be used in the LCA’s of the three food supply chains in WP 2 of SENSE.

Table 1. Life cycle impact assessment methodologies to be used in SENSE.

Impact category	**Selected LCIA method**
Climate change	Bern Model – IPCC (Solomon, 2007)
Eutrophication	Terrestrial: Accumulated Exceedance (Seppälä et al., 2006, Posch et al., 2008) Aquatic: EUTREND Model (Goedkoop et al., 2009)
Acidification	Accumulated Exceedance (Seppälä et al., 2006, Posch et al., 2008)
Human toxicity	USEtox Model (Rosenbaum et al., 2008)
Ecotoxicity	USEtox Model (Rosenbaum et al., 2008)
Land use	Soil organic matter model (Milà i Canals 2007)
Abiotic resource depletion	CML 2002 (Guinée et al., 200A2)
Water depletion	Ecological scarcity model (Frischknecht et al., 2009)

Regionalization

It has been found that the LCIA methodologies for water depletion, acidification and terrestrial eutrophication are feasible to be implemented on a country scale. For other impact categories, e.g. land use and ecotoxicity, there are yet no scientifically verified and robust methodologies available

Key Environmental Performance Indicators

In the SENSE tool Key Environmental Performance Indicators (KEPIs) will be used to communicate environmental impact through the supply chain and to the consumers. Those KEPIs must be simple and linked to key environmental challenges, build on accessible production data in the supply chain production steps and should also be easy to understand. Examples of the key environmental challenges that can be communicated as KEPI´s are: use of fossil fuels, use of fertilisers and manure, pesticides, irrigation, land and water use and waste. A key environmental challenge was defined as the activity that can be altered to reduce the specific environmental impact from the production step.

DISCUSSION

The main environmental impact from the food and drink supply chain are normally from the cultivation of biomass and animal rearing, but the feed and food industry as well as transport must also be taken into account to present the total impacts. Furthermore, it is not possible to focus on a few environmental impact categories only, as the emissions and use of natural resources in the food and drink chain contributes to the impact from many environmental categories.

The complexity of both the supply chains and their environmental impact calls for simplification both for measuring and improving but also for communication. The approach suggested in SENSE, that is to use KEPI’s with sufficient accuracy while at the same time being based on easily accessible production data, is a critical factor. Therefore, comprehensive LCA-studies covering the range of different production systems need to be performed to verify the applicability of KEPI’s which fulfil these requirements. Moreover continuous updating will be needed as production systems are developing.

CONCLUSIONS

Based on the research in the study the following environmental impact categories has been identified as the most important for the food supply chain: climate change, eutrophication, acidification, human toxicity, ecotoxicity, land use, abiotic resource depletion and water depletion. For each impact category a LCIA method, regionalized when appropriate, has been selected to be used in the further work in the SENSE project. The development and use of KEPI's are a promising approach to facilitate the application of LCA in complex supply chains with many small actors.

REFERENCES

Frischknecht R., Steiner R., and Jungbluth N. 2009. The Ecological Scarcity Method -Eco-Factors 2006: A method for impact assessment in LCA. *Federal Office for the Environment FOEN, Zürich und Bern*

Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs J., and van Zelm, R. 2009. ReCiPe 2008 - A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. *First edition. Report I: Characterisation. The Netherlands.* http://lcia-recipe.net/

Guinée, J.B.; Gorrée, M.; Heijungs, R.; Huppes, G.; Kleijn, R.; Koning, A. de; Oers, L. van; Wegener Sleeswijk, A.; Suh, S.; Udo de Haes, H.A.; Bruijn, H. de; Duin, R. van; Huijbregts, M.A.J. 2002. *Handbook on life cycle assessment. Operational guide to the ISO standards. I: LCA in perspective. IIa: Guide. IIb: Operational annex. III: Scientific background. Kluwer Academic Publishers, ISBN 1-4020-0228-9, Dordrecht, 2002, 692 pp.*

Milà i Canals, L., Romanyà, J., Cowell, SJ. 2007. Method for assessing impacts on life support functions (LSF) related to the use of "fertile land" in Life Cycle Assessment (LCA). *Journal of Cleaner Production 15, pp. 1426-1440*

Posch, M., Seppälä, J., Hettelingh, J.P., Johansson, M., Margni Mand Jolliet, O., 2008. The role of atmospheric dispersion models and ecosystem sensitivity in the determination of characterisation factors for acidifying and eutrophying emissions in LCIA. *International Journal of Life Cycle Assessment. 13: 477-486*

Rosenbaum, R.K., Bachmann, T.M., Hauschild, M.Z., Huijbregts, M.A.J., Jolliet, O., Juraske, R., Köhler, A., Larsen, H.F., MacLeod, M., Margni, M., McKone, T.E., Payet, J., Schuhmacher, M., and Van de Meent, D. 2008. USEtox - The UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in Life Cycle Impact Assessment. *International Journal of Life Cycle Assessment, 13 (7), 532-546*

Seppälä, J., Posch, M., Johansson, M., Hettelingh, J.P. 2006. Country-dependent Characterisation Factors for Acidification and Terrestrial Eutrophication Based on Accumulated Exceedance as an Impact Category Indicator. *International Journal of Life Cycle Assessment 11:403-416*

Solomon, S., Qin, D., Manning, M., Alley, R.B., Berntsen, T., Bindoff, N.L., Chen, Z., Chidthaisong, A., Gregory, J.M., Hegerl, G.C., Heimann, M., Hewitson, B., Hoskins,B.J., Joos, F., Jouzel, J., Kattsov, V., Lohmann, U., Matsuno, T., Molina, M., Nicholls, N., Overpeck, J., Raga, G., Ramaswamy, V., Ren, J., Rusticucci, M., Somerville, R., Stocker, T.F., Whetton, P., Wood, R.A. and Wratt, D., 2007. Technical Summary. *In: Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. *Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA*

THE INDUSTRY VIEWS ON THE POLICY AND DEVELOPMENT OF CARBON LABELING IN TAIWAN

Lung-Chieh Lin, Dasdy Chia-Pei Lin, Chao-Chi Chen, Wei-Sheng Yen, Chen-Cheng Liu, Wen-Shing Lee*

**Department of Energy and Refrigerating Air-Conditioning Engineering, National Taipei University of Technology; 1, Sec. 3, Zhongxiao E. Rd., Taipei 10608 Taiwan, R.O.C t8459010@ntut.edu.tw*

Keywords: Greenhouse gas; Carbon footprint; Carbon labeling; Taiwan; Product Categories Rules.

ABSTRACT

In Taiwan, in order to mitigate the environmental impacts of the related carbon emission issues, the central government has established the guideline for carbon footprint calculation and the carbon labeling scheme. Chasing green has become an international trend especially for consumer products. Enterprises have gradually participated in the carbon footprint of product (CFP) inventory and applied for the carbon labels to disclose GHG emissions associated with product manufacturing to the stakeholders. The Taiwan carbon labeling scheme was established by the Environmental Protection Agency (EPA) in 2010. Out of the 103 products issued with the carbon labels, 41 products are beverages and amongst the beverages, 22 are tea drinks. Therefore, this study selected a tea product as a case study.

DEVELOPMENT OF TAIWAN CARBON LABEL SCHEME

On June 5, 2008, the Energy Saving and Carbon Reduction Goals of Taiwan's Sustainable Energy Policy Framework to mitigate 1 kg CO_2e of greenhouse gas emission per person per day was passed by the Administrative Yuan. In order to achieve the goal by means of building a sustainable production and consumption, the Taiwan EPA Administration began drafting a Carbon Label System in 2009 and organized a Carbon Label Graphic Design Contest to raise public awareness and participation (Yuan et al., 2012). The final official Taiwan carbon label is shown as Figure 1below.

Figure 1. The Taiwan Carbon Label, Taiwan EPA (2010)

In 2010, the Carbon Label implementation framework as shown in Figure 2 was established with the publication of several Guidelines in assisting the industries on CFP calculation, PCR drafting and carbon label application. EPA organized a Carbon Label Review Committee to aid the promotion and deliberation of carbon label application and management of carbon label usage. Members of the committee include relevant professionals from both the EPA and Central Government, experts from the private sectors, industries, associations and scholars.

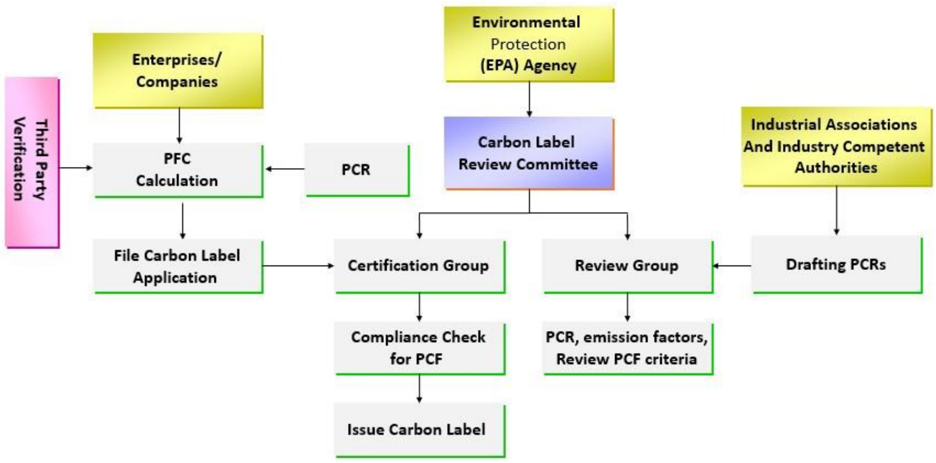


Figure 2. Implementation Framework, Taiwan EPA (2010)

CURRENT STATUS OF TAIWAN CARBON LABEL SCHEME

Since the implementation of Taiwan Carbon Label Scheme, there are 103 products of 44 companies issued with the Carbon Footprint of Product Label Certificate by October 2012 (Taiwan Environment Protection Agency [Taiwan EPA], 2010). The product categories include 3C products, processed foods, beverages, hygiene products, plastics and rubber products, animal and agricultural products and etc. According to Taiwan Environment Protection Agency (2010), there are 41 labeled products in the beverages category, 20 in processed foods, 14 in

3C products, 5 in plastics and rubber products, 13 in animal and agricultural products and 10 in others.

CASE STUDY

CFP Assessment Process

Out of the products issued with Carbon Label, 21% are tea products; therefore, this study focuses on one tea beverage manufacturer as a case study (Taiwan EPA, 2010). According to Taiwan EPA Carbon Label Scheme, in order for the company to file an application, it needs to conduct a CFP assessment followed by a third party verification.

From the formation of the assessing group to the outcome of a CFP assessment report, it takes at least 6 months at the cost of 20 – 30 thousand USD (Taiwan EPA, 2010).

Depending on the type of product involved, most companies carrying out a CFP assessment have to go through many internal CFP education and data collection processes. Most of the CFP assessments require supply chain participation. In this study, for the purpose of a CFP with a LCA perspective, the first stage of the CFP inventory was to draw a process map that contained not only the tea manufacturer’s own internal processes, but also the materials and services from its suppliers.

Obstacles in collecting supply chain data

In this study, the supplier participated in the CFP assessment of the target product were mostly SMEs with employee number of 30 and below. Providing complete activity data that were allocated correctly to the supplying materials was a difficult task for most suppliers. The failure to collect supplier data would have affected the level of assurance during third party verification which would lead to disqualification in Taiwan Carbon Label application. In this study, the time spent in assisting suppliers with competent data collection was around 2.5 months.

Taiwan CFP calculation standard

The international CFP calculation standard ISO 14067 “Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification and communication” is still under communication and negotiation from all stakeholders (Taiwan EPA, 2010). In the meantime, countries around the globe have developed own CFP calculation standards according to different methodologies that are suitable for each distinguished nations. The Taiwan Carbon Label scheme adopted the UK standard of PAS 2050 “Specification for the assessment of the life cycle greenhouse gas emissions of goods and services” and the draft of ISO 14067 with fine tunes to Taiwanese cultures and published “Guide to assess the carbon footprint of products and services”. Companies applying for the Taiwan Carbon Label are to carry out the assessments accordingly.

Assessment scope definition

Countries around the world have different guidelines regarding the Product Category Rules (PCR) development for purposes like environmental declaration, eco labels, CFP calculations and etc. A PCR is a scope setting tool that enables transparency for the LCA based CFP assessments and provides comparability between products in the same category from different manufacturers. Before 2010, Japan was the only country having a specific PCR for CFP calculation, CF-PCR in short. Taiwan followed Japan’s footstep and published a “Guide on carbon footprint product category rules" for enterprises in the preparation of Carbon Label application. In this study, the company initiated the process of CF-PCR development according to the Taiwan EPA guide. Having to involve the beverage association and stakeholders along supply chain and waiting for the verdicts from the Taiwan EPA review group, the process took another 2 months to finalize.

Lack of local LCA database

During the CFP assessment, enterprises often encounter the problem of primary data for GHG emission calculations thus selecting an appropriate emission factor from the LCA database become crucial to the final quantification of CFP. Due to the fact that emission factors from different locations of one material results in different numbers, the final CFP would vary accordingly. Therefore, the lack of public LCA database providing local emission factors in Taiwan becomes another obstacle for enterprises.

DISCUSSION

Due to the fact that most big Taiwanese enterprises relocated factories to mainland China, India, or other South East Asian countries for lower labor costs. Manufacturing companies that remain in Taiwan are small and medium enterprises (SMEs). Throughout the supply chain of tea beverages, large number of raw material suppliers are SMEs. Most of these SMEs exhibit the tendency of lacking green awareness.

Based on the experiences of assisting at least 20% of beverages issued with Taiwan Carbon Label and many Taiwanese enterprises with CFP assessments, this paper discovered and summarized obstacles Taiwanese enterprises face while conducting CFP assessments. These obstacles includes, inability of CFP standard integration, complicated process in CF-PCR development, and the lack of local database. However, Taiwan Carbon Label Scheme provides an example for countries trying to implement a future Carbon Label system.

CONCLUSION

Ever since late 2012, Taiwan EPA has reinforced the communication between several government agencies for the assistance in local GHG emission factor database development. This paper also raise a suggestion to Taiwan EPA in the hope to reach mutual agreements with other national Carbon Label bodies to enhance the integration of assessment standards and label recognitions for the promotion of carbon labelled products internationally.

REFERENCES

Taiwan Environment Protection Agency (2010). Taiwan Product Carbon Footprint. Retrieved from http://cfp.epa.gov.tw/carbon/defaultPage.aspx

Taiwan Environment Protection Agency (2010). A feasibility study of using current eco-labeling system to implement carbon labels on products. Retrieved from http://epq.epa.gov.tw/project/projectcp.aspx?proj_id=ZGVEDJNSCP

Yuan, S., Guo, X., Jane L. W., & Li Q. (2012). Current Development of Taiwan Carbon Label Scheme. *Energy Report*. Retrieved from http://energymonthly.tier.org.tw/outdatecontent.asp?ReportIssue=201203&Page=7

MANAGEMENT OF GREEN PRODUCT PORTFOLIOS: PANEL

Tuesday, Aug 27: 10:30 am - 12:00 pm

Session chairs: Birger Löfgren, SKF, Sweden
Stefan Henningsson, WWF International, Sweden

ACCOUNTING AND COMMUNICATING EMISSION REDUCTIONS ENABLED BY INNOVATIVE PRODUCTS

Annemarie Kerkhof, Vincent Hoen and Giel Linthorst*

Ecofys

**Kanaalweg 15-G, 3526 KL Utrecht, the Netherlands. a.kerkhof@ecofys.com*

Keywords: emission reduction; innovative products.

ABSTRACT

An increasing number of companies position their products in the market as enablers of emission reductions. Examples of such products are low-temperature detergents, fuel saving tires, energy-efficient ball-bearings, and teleconferencing equipment. For a successful market introduction of such products, it is essential to communicate emission reductions in a credible and comparable way. Methodologies, based on Life Cycle Assessment, have been developed by individual companies and at sector level (e.g. ICT and chemical sector). This paper discusses a number of methodological issues, inventoried by WWF, Ecofys, Utrecht University and a number of leading companies, where guidance is needed: 1) definition of the concept, 2) baseline selection 3) multiple environmental impacts, and 4) distribution of emission reductions in the value chain.

INTRODUCTION

Companies want to go beyond emission reductions in their own operation facilities by designing products that reduce emissions downstream of their value chain. Such innovative products often reduce emissions in the use phase. A fuel efficient tire, for example, reduces greenhouse gas (GHG) emissions when driving a car; and teleconferences reduce travel needs and related GHG emissions. Such emission reductions are also called “avoided emissions” (WRI and WBCSD, 2011) or “Climate Positive Products” (WWF Climate Savers Program). Companies in the chemical and ICT sector in particular see opportunities for their products. Several studies demonstrated the large potential of products in these sectors (ICCA, 2009; GeSI, 2010; Denkstatt, 2010).

Many companies already sell innovative products that enable emission reductions and also communicate openly the results. Examples of such products are low-temperature detergents, fuel saving tires, energy-efficient ball-bearings, and teleconferences. Increased sales of such products can shift markets into a more environmentally-friendly direction. WWF included the so-called “Climate Positive Magnifier” in their Climate Savers Program, which deals with the opportunities for business to expand and open new markets for products and services that significantly reduce emissions for their customers.

Despite the opportunities, companies face challenges when introducing their innovative products to the market. One of the main challenges is to communicate potential emission reductions in a credible and comparable way. Currently, companies develop their own methodologies, which hampers comparison of results. Moreover, companies have the freedom to make choices that present their products in the most positive way. Companies recognize this problem, which has driven some sectors to start developing sector guidelines to ensure credible and comparable results. Examples include the ICT sector (GeSI, 2010), and Japan's chemical industry (JCIA, 2012). The chemical sector is now developing worldwide sector guidelines under the umbrella of WBCSD and ICCA (planned publication in fall 2013).

Existing standards and guidelines, such as the ISO standards on LCA (ISO 14040/44) and the GHG Protocol standards, provide guidance to calculate and compare the environmental impact of products. Nevertheless, there are still some issues under discussion in the context of calculating avoided emissions. WWF, together with Ecofys, Utrecht University and a number of leading companies, took the initiative to inventory the main methodological issues related to the calculation and communication of emission reductions enabled by innovative products. This paper discusses the main findings of the inventory and can serve as a basis for dialogue with other stakeholders.

WHAT ARE AVOIDED EMISSIONS?

Certain products can avoid emissions compared to a reference situation or baseline. The use of such an innovative product, produced by the reporting company, enables additional emission reductions in the value chain of a third party and outside the value chain of the reporting company. Therefore, avoided emissions cannot be deducted from the company's own emissions and should be reported separately (WRI and WBCSD, 2011).

Ecofys, Utrecht University and WWF added two elements to this definition:

1. Additionality: It is important that only additional emission reductions are claimed. A product should not have been produced anyway. If an important aspect of the product is emission reduction (decreasing fuel, electricity or energy use) and reduces more emissions compared to the baseline the product can be considered "additional".
2. Innovativity in time: Innovativity is an indicator for how much the product is improved compared to the baseline. Innovation is required to stay ahead of the ascending baseline and stimulates the development of new enabling products. It is a very broad concept which entails a large degree of freedom and is very dependent on the baseline.

HOW TO SELECT THE BASELINE?

To calculate avoided emissions, the emissions of the innovative product are compared to a baseline. The selection of the baseline and the underlying assumptions is crucial, since it largely influences the calculated avoided emissions. Three different baselines have been identified to estimate current emissions reductions:

1. Compared to the old product of the same company
2. Compared to a product from another company
3. Compared to the industry average

The baseline should be regularly updated as it is important to determine the degree of innovation. When a product is compared to the product of another company, it is important to select an established product in the market with a considerable sales volume.

INCLUSION OF MULTPLE ENVIRONMENTAL IMPACTS NEEDED?

A large number of methodologies developed today focus on the reduction of GHG emissions only. Climate change is an important environmental impact, but the production and consumption of products may also result in other environmental impacts, like toxicity and resource depletion (e.g., water). In order to avoid trade-offs to other impacts when introducing innovative products with an enabling effect, other environmental impacts should be taken into account as well.

HOW TO DISTRIBUTE THE EMISSION REDUCTIONS AMONG VALUE CHAIN PARTNERS?

Since the emission reductions take place during the use of a product, it is likely that multiple companies helped to enable these reductions. When calculating the emission reductions at the product level, there is no need to distribute emission reductions among companies in the value chain. When companies want to report the emission reductions at the company level, or even want to sum up the emission reductions realized by their green product portfolio, emission reductions need to be distributed among value chain partners. Yet there is no clear guidance of how to do this. There are a few options, each of which accompanied by pros and cons (see table below).

Distribution method	**Pros**	**Cons**
No distribution: all companies in value chain can claim avoided emissions	No allocation necessary	Often double counting Not a fair comparison if a company with little value added could claim everything
Distribution based on **value added** of (intermediate) products	More fair allocation method where innovation is rewarded	Use of the assumption that innovative companies have more value added
Distribution based on **contribution** of (intermediate) products to avoided emissions	Distribution is as close as possible to actual performance of (intermediate) product	Not easy to quantify contribution of (intermediate) product to total avoided emissions

CONCLUSIONS

This paper described the main findings of an inventory of existing methodologies to calculate avoided emissions carried out by Ecofys, Utrecht University and WWF. The findings show that there are a few, but tough challenges to overcome to arrive at a calculation methodology for avoided emissions that ensures credible and comparable results. All four methodological issues addressed in this paper, namely the 1) definition of avoided emissions, 2) selection of baseline, 3) multiple environmental impacts, and 4) distribution of emission reductions among value chain partners, need clear guidance to avoid misleading results, double counting and trade-offs. The on-going efforts of companies and industry associations to develop methodologies and guidelines makes clear which issues need extra attention and guidance. At this stage it is clear, however, that the accounting and communication of avoided emissions is still in its infancy. The development of an international standard would provide general guidance on how to deal with certain choices and could lead to a wider acceptance of the concept of avoided emissions. It would give the opportunity to companies to increase sales volumes in their green product portfolio, which would also be beneficial for society.

REFERENCES

Denkstatt, 2010. The impact of plastics on life cycle energy consumption and greenhouse gas emissions in Europe - Summary report.

GeSi (Global e-Sustainability Initiative), 2010. Evaluating the carbon-reducing impacts of ICT - An assessment methodology.

ICCA (International Council of Chemical Associations), 2009. Innovations for Greenhouse Gas Reductions – A life cycle quantification of carbon abatement solutions enabled by the chemical industry.

ISO 14040 (2006). Environmental management - Life cycle assessment - Principles and framework.

ISO 14044 (2006). Environmental management - Life cycle assessment - Requirements and guidelines.

JCIA (Japan Chemical Industry Association), 2012. Guideline for Calculating the Avoided CO2 Emission.

WRI and WBCSD (2011). GHG protocol: Scope 3 Corporate Value Chain (Scope 3) Accounting and Reporting Standard.

DATABASES AND CAPACITY BUILDING

Tuesday, Aug 27: 10:30 am - 12:00 pm

Session chairs: Guido W. Sonnemann, University of Bordeaux, France
Sonia Valdivia, United Nations Environmental Programme, France
Bruce Vigon, Society of Environmental Toxicology and Chemistry, United States of America

CHILEAN FOOD & AGRICULTURE LCA DATABASE USING UNEP/SETAC SHONAN PRINCIPLES

*Cristian Emhart[*1], Alejandro Florenzano[1], Cristóbal Loyola[1], Jonas Bengtsson[2]*

[1]Fundación Chile, Avenida Parque Antonio Rabat Sur 6165, Vitacura, Santiago, Chile - [*]cemhart@fch.cl;

[2]Edge Environment, Level 5, 39 East Esplanade, Manly, NSW 2095, Australia

Keywords: Chile; Food; Agriculture; Life Cycle Inventory; Database; Shonan Principles

ABSTRACT

The Chilean Food & Agriculture LCI Database project plans to deliver the following components by 2015/16:

1. LCI/LCIA Methodology: Define the criteria to develop baselines models (BLM), LCI data sets, and impact assessment methods.
2. LCA Tools and Information Platform: Provide BLM´s, LCIA Calculators, and best practice industry data

It is also recognized that there is a need for data collection tools to be practical and efficient to use for different kinds of users, such as small farmers and large food companies, users from government, and consultants.

To create an approach with high usability and harmonization, this project is being aligned with international guidelines including UNEP/SETAC Shonan Principles, Sustainability Consortium's Sustainability Measurement and Reporting Systems (SMRS®), and the World Food Database.

BACKGROUND

The Chilean Food & Agriculture life cycle inventory (LCI) database is a call from the results from the recent ProChile (2012) study "State of the Art in Sustainability Matters at a National and International Level" found that the current level of implementation of sustainability measurement tools (incl. carbon, water, energy, etc.) in Chile is relatively low. To improve performance and increase efficiency, it is necessary to measure impacts and establish indicators in order to identify a baseline for monitoring progress across the supply chain and to anticipate major vulnerabilities associated with production.. In Chile there is a need to:

- Develop methodologies and tools to involve actors and stakeholders from academia, industry, government, and NGOs. There is no leadership to drive methodological alignment and coordination through production chains to measure and report sustainability performance to standards often required by international markets.
- Provide geo-specific data, collected with a scientific and transparent approach to life cycle assessment (LCA) users around the world, in order to obtain precise and consistent information. This would enable improved product stewardship from

enterprises and public entities – and the creation of public policies – helping increase the product sustainability and economic activities. (UNEP, 2011)

OBJECTIVE

The objective of the Chilean Food & Agriculture LCI Database is to implement an LCA based information system to facilitate the measurement and reporting of product level sustainability performance to support decision-making of companies in the food value chain,.

The Chilean Food & Agriculture LCI Database will deliver:

1. LCI/LCIA Methodology to develop baselines models (BLM), LCI data sets, and impact assessment methods.
2. LCA Tools and Information Platform with BLM´s, LCA Calculators, and leading industry data

METHODOLOGY

Led by the Chilean food industry, the Chilean Food & Agriculture LCI Database intends to provide resources for measuring and reporting the environmental impact for 16 product categories in five groups: (i) Fresh and processed fruits (9 products), (ii) Aquaculture (2 products), (iii) Meat (2 products), (iv) Dairy (2 products) and (v) Wine (1 product) from the Chilean food sector.

IERS, (2012) provided a roadmap consisting of an 8 steps (**Figure 1**) process to develop the national LCI database, including the role of stakeholder engagement, the structure of the tool to manage and update the database and the configuration of the governance body.

An efficient and open access information system will be developed with the food sector for these products. The intention of the system is to give access to end users and allow them to make use of assessment information or communication tools which address the sustainability of its products and traceability of raw materials and inputs used in their production processes. This, in turn, intends to result in a scientifically robust methodology with resources for potential users through a practical and cost-effective way.

Figure 1: Overall structure of the roadmap toward the National LCI database of Chile

Through this process, the following project components will be delivered:

- Chilean National Life Cycle Inventory (LCI) Data Collection Methodology for data collection and development of inventories, which will be internationally validated and appropriate for the Chilean context. This will include established rules and procedures for the collection, management and analysis of information, allowing the initial data raised by this project to be expanded in the future. This methodology will be aligned with the World Food Database, The Sustainability Consortium's Sustainability Measurement and Reporting Systems (SMRS®), and Ecoinvent database.

- Chilean National Food and Agriculture LCI Data Sets following the LCI data collection methodology. The LCI data sets from the 16 product categories will provide BLM´s for the database. This data sets will be constructed to fit unit process operations throughout the supply chain (extraction of raw materials, production processes, transportation, etc.), based on literature review and surveys for the most relevant flows in and out of the product system. This will ensure transparent data that could be easily understandable for users, a higher level of flexibility and adaptability to the database and an easier interpretation of LCIA results (UNEP, 2011).

- Chilean National Food & Agriculture Life Cycle Impact Assessment (LCIA) Methodology based on existing best practice methodologies. The adapted Chilean national Food & Agriculture LCIA methodology will be validated and appropriate for the Chilean context.

- Collection of Food & Agriculture Industry Best Practice: In addition to the LCA measurement and modeling tools, indicators of good industry practices associated with the management and selection of inputs will be provided in order to make it possible for the industry users to implement improvements once their hotspots in their supply chain are identified. The information gathered will be a starting point for a process of continuous improvement, in the first instance, by using the best information available, and drawing from international case studies and databases.

- A platform with integrated calculators models for each of the selected products to allow the users can compare their performance against national BLM´s, modify some parameters associated with their production, and identify the greatest opportunity for improvement across the product supply chain. The platform is also designed so that, in the future, the number of product categories incorporated and new processes and products represented can gradually increase

- Transfer, Dissemination, and Education of Online Platform: Once the platform has been completed, the project participants will be educated on how to begin utilizing the data (i.e. accessing information and reporting results) which, in turn, will strengthen the technical skills of the users while enhancing the database itself.

RESULTS TO DATE

The following key components of the project have been achieved as of mid 2013:

- Stakeholder support: 14 key stakeholder groups have provided signed letters of support for the project, which includes Chilean food product industry associations, the Chilean Ministry of the Environment and international experts in LCA.

- Methodology, Budget and Timeline: A clearly defined methodology has been completed to provide an overall map of the project which includes project budget and a timeline that has set out the project completion fro 2015/16.

- 9 product categories for food products based on literature review and nationally adapted data (electricity grid, transport distances, etc) (Bengtsson et al., 2012)

- Chilean Government Funding Application Submission: The Chilean Economic Development Agency **(**CORFO) Public Good funding application was submitted in March of 2013. If approved, this fund will provide the complete budget for the deliverables of the Chilean Food & Agriculture Database.

- Database Overview: A conceptual system has been designed which presents issues such as information flows and stakeholder engagement.

DISCUSSION

Although the project is still awaiting notification for the acceptance of the fund, which will be presented by the end of June 2013, the achievements made in the development of the application have still been significant. Strong buy-in for the project has been achieved by a wide array of key stakeholder groups and, if this project does achieve its funding requirements, there is a strong opportunity for pioneering the development of numerous life cycle management resources for the Chilean Food & Agriculture Sector, which includes:

- The identification of the critical points regarding environmental impacts of the sector's products, in order to focus efforts and resources to improve their performance, both production and sustainability.

- A range of publicly available information on the opportunities for improvement aimed at the main critical points and environmental terms for each product.
- The resources to incorporate the environmental variables of the decision making for the evaluation of suppliers, product or process modification and optimization of resources.
- Facilitate communication with customers and stakeholders, as well as strategic planning and marketing, positioning Chilean products in domestic and international markets, being well prepared for ecolabelling requirements and other sustainability information schemes emerging products.

CONCLUSIONS

The development of an information management system and harmonized database will allow Chilean industry, government and academia to have easy access to good quality information that can be used to establish benchmarks for impacts of products throughout their life cycle, for public policy, and continuous improvement throughout the supply chain.

Sustainability for competitiveness is undoubtedly one of the lines of work the food industry should take to ensure their permanence and economic sustainability, while increasing the confidence of international buyers and further position Chilean products.

REFERENCES

IERS, (2012). A Roadmap for Developing a National LCI Database for Chile.

Prochile, (2012). State of the Art in Sustainability Materials at a National and International Level.

UNEP, (2011). Global Guidance Principles for Life Cycle Assessment Databases: A Basis for Greener Processes and Products. ‘Shonan Guidance Principles’.

Bengtsson, J., Emhart, C., Florenzano, A., Guccione, L., & Jaramillo, C., (2012).LCA-based hotspot analysis of food products to inform a major Chilean retailer’s sustainability strategy. 8th International Conference on LCA in the Agri-Food Sector, St Malo, France, 1-4 October 2012.

DATA QUALITY ASSESSMENT OF LCI DATASETS – A SYSTEMATIC APPROACH TO INTEGRATE DIFFERENT USER REQUIREMENTS

Kirsten Biemann (KIT), Marco Recchioni** (JRC), Fabrice Mathieux** (JRC).*

** Karlsruhe Institute of Technology, Institute for Technology Assessment and Systems Analysis; E-mail contact: Kirsten.Biemann@kit.edu*

*** Joint Research Centre, European Commission, Ispra (Italy)* *Keywords: data quality assessment, LCI, user requirements, systematic approach*

ABSTRACT

The data quality of an LCI assesses whether different requirements are met taking into account the goal and scope. A systematic approach was developed that checks the data quality of a dataset against different user requirements. As an example this was applied to a data set from the European Reference Life Cycle Database [ELCD 3.0]. Here general requirements from the International Life Cycle Data System (ILCD) handbook and the Product Environmental Footprint (PEF) Guide were complemented by specific user needs. User requirements, data quality criteria and target states were defined. The actual state of the data was compared to the target and possible shortcomings were identified. From this a recommendation how to use or improve the dataset was deducted.

INTRODUCTION

Data quality is defined as “characteristics of data that relate to their ability to satisfy stated requirements” [ISO 14044]. Data quality assesses whether the following aspects are in line with the goal and scope: time-related, geographical and technology coverage, precision, completeness, consistency, reproducibility, sources of data and uncertainty. [ISO14044] Some data quality requirements (e.g. ILCD entry-level compliance, PEF guide quality criteria) have been developed recently in order to facilitate a coherent use of datasets and to ease quality improvements.

To be ILCD entry-level compliant, a dataset needs to follow ISO 14040/44 and to state data quality accordingly. Furthermore the nomenclature and documentation need to be in accordance to the ILCD format and a review must be done by a qualified reviewer for PEF and ILCD entry-level compliance. [ILCD] [PEF]

The PEF guide defines 6 data quality criteria to be rated from 1 (best) to 5: technological representativeness (TeR), geographical representativeness (GeR), time-related representativeness (TiR), completeness (C), precision/uncertainty (P) and methodological appropriateness and consistency (M).

The context-specific TeR, GR and TiR may be further defined in Product Environmental Footprint Category Rules (PFCR). C specifies the share of (elementary) flows that are included in the inventory. P measures the variability of the data values. M checks whether the modeling is PEF compliant. So far the only PCR in existence is for Intermediate Paper Products [PFCR] which was considered for this illustrative analysis.

Score	TeR	GR	TiR	C	P	M
1	Same process/ technology	Country specific	<3 years	>90%	≤ 10%	Fully compliant
2	Technology mix	EU 27 mix	3-5 years	80-90%	10-20%	Cradle to grave Multifunctionality according to ISO 14040/44 End of life modeling included
3		EU countries	5-10 years	70-80%	20-30%	2 out of 3
4	Similar products	Other countries	10-15 years	50-70%	30-50%	1 out of 3
5	Unknown	Global/ unknown	>15 years unknown	<50% unknown	> 50% unknown	none

Table 1: Illustrative example of PFCR quality requirements [PFCR]

In the PEF guide, the data quality rating (DQR) is calculated as follows [PEF]:

$$DQR = \frac{TeR + TiR + GR + M + P + C}{6}$$

For PEF compliance a “good” DQR (≤ 3.0) covering at least 70% of the contributions to each environmental footprint impact category is needed. [PEF]

METHOD

Using qualitative criteria from different data quality assessment methods a systematic approach was developed that enables users to rate data quality according to their needs.

Definition of general requirements

First the envisaged application of the data set is defined. Compliance with ILCD entry-level or PEF requirements may be complemented by user specific quality requirements. By increasing the knowledge about the product or technology, critical aspects that are relevant for the environmental assessment are identified.

Data quality criteria and assessment

A set of indicators and their reference states is defined and the data set is analyzed. The actual states of the data quality are compared to the reference and shortcomings are reported.

Data quality discussion and recommendation

Data quality is discussed and a recommendation on whether to use or how to improve the dataset is given.

RESULTS

For illustration of the approach, the data quality of the ELCD 3.0 dataset “Steel hot dip galvanized (ILCD), production mix, at plant, blast furnace route, 1kg, typical thickness between 0.3 - 3 mm. typical width between 600 - 2100 mm” is rated against different user requirements. Quality requirements from PEF are assessed using the PFCR for intermediate paper products. Then two fictive applications are added: User 1 is an Italian company searching for a full ILCD entry-level compliant LCI on steel coils bought from different suppliers worldwide; User 2 is a German company doing a greenhouse gas footprint on steel coils. For the latter, PEF compliant data for German conditions (or gate to gate data from a similar area) is needed.

User	Criteria	Reference	Actual State	Room for improvement
PFCR	**Time-related representativeness**	< 3 years	2008	*5 years (TiR of 2)*
User 1 and 2		2013		5 years
PFCR	**Geographical representativeness**	Country specific	global	*global (GR of 5)*
User 1		global		-
User 2		Germany		Similar conditions
User 1	**Technological representativeness**	Clearly stated	Technology mix	-
PFCR and User 2		Same process/ technology		*Technology mix (TeR of 2)*

Table 2: Technological, geographical and time-related representativeness

User	Criteria	Reference (R)	Actual State	Room for improvement
PEF	**System boundary**	Cradle to grave (no cut-off) (incl. end of life modeling)	Cradle to gate	*Product flows as in- and outputs* *cut-off criteria used*
User 1		Cradle to gate (incl. end of life modeling)		*No end of life* *Product inflows*
User 2		Gate to gate		*Not gate to gate*
PEF **User 1**	**Multifunctionality**	Dealing with multifunctionality according to ISO 14040/44	System expansion	-
User 2		Multioutput process		*No multioutput*

User	Criteria	Reference (R)	Actual State	Room for improvement
PEF **User 1**	**Elementary flows**	Emissions to water, air, ground Resources (material/energy)	Emissions to water, air and ground Resources (material/energy)	*Resources from ground are listed as output*
User 2		Greenhouse gases		-

Table 3: Methodological appropriateness and emission coverage

DISCUSSION

The example above shows that the data quality of an ILCD entry-level compliant dataset varies greatly depending on different user needs.

The dataset is well suited for user 1 except that the remaining product flows need to be accounted for. However the requirements from user 2 are not met. For the PEF DQR methodological appropriateness (M) is rated 3 since the dataset is cradle to gate and no end of life modeling is included. No data on precision (P) and completeness (C) is found resulting in a score of 5. With a DQR of 3.7 (taking into account the considered PFCR) the dataset seems to require a quality improvement. The development of more specific PFCR or the adoption of qualitative criteria for assessing P and C may however lead to a different result.

CONCLUSIONS

Since the data quality changes significantly for different uses in life cycle based assessments it can only be partly defined by the data providers. While uncertainty and completeness (P and C) can be rated at the dataset level, data on time, geography and technology as well as modeling approaches can be left to the user for rating. A good documentation is essential to enable a data quality assessment by the user. By applying product category rules default requirements for generic contexts can be provided but they cannot replace the need for each user to check whether the data is suitable for a specific context or not.

REFERENCES

ILCD — International Reference Life Cycle Data System (ILCD) Data Network: Compliance rules and entry-level requirements. European Union 2012

ISO 14040/44 — Environmental management- Life Cycle Assessment- Principles, frameworks and guidelines, 2006

PEF — Product Environmental Footprint Guide. European Commission 2013

ELCD database — European Life Cycle Database version 3.0 http://elcd.jrc.ec.europa.eu/ELCD3/

PFCR — Product Footprint Category Rules (PFCR) for Intermediate Paper Products. Final document of the paper PFCR pilot project 2011

Note: The views expressed in the article are personal and do not necessarily reflect an official position of the European Commission.

GLOBAL GUIDANCE PRINCIPLES ON LCA DATABASES: OUTREACH AND TRAINING ACTIVITIES WORLD WIDE AND MULTI-REGION COLLABORATION FOR CONSISTENT LCA DATA

Guido Sonnemann (University Bordeaux 1), Bruce Vigon (Society of Environmental Toxicology and Chemistry), Sonia Valdivia (United Nations Environment Programme),*

Univ. Bordeaux, ISM, UMR 5255, F-33400 Talence, France.
CNRS, ISM, UMR5255, F-33400 Talence, France.
The Life Cycle Group CyVi
Email: g.sonnemann@ism.u-bordeaux1.fr

Keywords: Global Guidance, LCA databases, training, multi-region collaboration

ABSTRACT

The UNEP/ SETAC Life Cycle Initiative organized a Pellston-type workshop in 2011 in Shonan Village, Japan, based on which the Global Guidance Principles for LCA Databases where developed. Following its launch at LCM 2011, a number of outreach events have been organized in particular in emerging economies. Further development of the guidance principles is needed so that they can be used in a practical way for training and other applications. Therefore, outreach activities are being continued and strengthened by the development of training material to be used in future events. Collaboration among regional and country based LCA networks is seen as important elements of the implementation strategy.

INTRODUCTION – THE GLOBAL GUIDANCE PROCESS

The process behind the publication ‘Global Guidance Principles for Life Cycle Assessment (LCA) Databases’, as described by Sonnemann et al. (2011), started back in 2007 when the International Life Cycle Board (ILCB) agreed that the UNEP/SETAC Life Cycle Initiative should produce a manual on developing a country’s life cycle inventory data for energy systems as a starting point for a LCA database. However, the manual was never finalized due to the significant amount of diverging comments from LCA experts. Nevertheless, the need for guidance on LCA databases did not disappear as discussions at various forums highlighted the presence of a range of contentious issues concerning the development of LCA databases and datasets. In particular, emerging economies and developing countries need global guidance for their Life Cycle Assessment database efforts to guarantee an efficient allocation of resources, to ensure reliability and quality and to ensure interoperability between regions.

It was decided that the best way to proceed was to organize a workshop, bringing together LCA experts to address the topics of concern, reaching agreements and conclusions to be included as guidance principles in a publication. A Steering Committee equally composed of representatives from governments, business & industry and NGOs and academia was formed to run the process and lead the organization of the workshop and the publication.

METHODS – THE WORKSHOP

A five-day Pellston workshop was held early February 2011 in Shonan, Kanagawa, Japan. The SETAC Pellston-type workshop brought together 48 invited experts from 23 countries, who were drawn in a balanced way from governments, industry, academia and consultancies, for an intensive, week-long workshop, where, through the use of working groups and plenary sessions, specific topics were addressed and the discussions and decisions incorporated in the final workshop publication. Pellston workshops have been used successfully by SETAC for many years and were therefore deemed ideally suited as a method for the process.

The workshop aimed to achieve an agreement on common practice with regards to LCA databases, striving towards consensus on certain issues, and defining a way forward for addressing the remaining challenging matters later on as part of the process. The focus was on the development of guidance for Life Cycle Inventory (LCI) databases, without being sector-specific and not entailing the development of a common database format.

The participants addressed specific aspects of the topic and were responsible for the related chapter in the final workshop publication. An overarching 'Integration and Cross-Fertilisation' group was also established to ensure efficient communication and exchange of knowledge between the various groups.

RESULTS – THE PUBLICATION

The publication 'Global Guidance Principles for LCA Databases: A Basis for Green Processes and Products' (Sonnemann and Vigon 2011) is an account of the discussions, agreements reached and future roadmap decided upon during the workshop. Other than editorial changes, the authors were not allowed, according to Pellston workshop regulations, to add or change any text after the workshop. The publication did undergo a comprehensive Peer Review Process by SETAC and the UNEP/SETAC Life Cycle Initiative.

The publication was launched at LCM 2011 and consists of 8 chapters and 4 annexes, see Figure 1. Some of the key results and recommendations presented in the publication include:

- Data sourcing and data collection are critical elements in producing datasets that are consistent and exchangeable;
- There is a need to maximize transparency whenever possible,;
- A central position in creating and managing datasets is recommended for data documentation and review elements;
- The Guidance Principles include a clear and meaningful differentiation of what does or does not constitute an "LCI database";
- The primary target audience of the publication is database managers, who manage the data flow and the actors in the data supply chain.
- Various adaptive approaches, including input-output, hybrid, time-dynamic and spatially-explicit approaches, were assessed according to their data-related implications, capabilities and constraints to answer questions about their usefulness, limitations and connection to traditional, process-based data;

- Some consideration was also given to social and economic assessments, and associated data/database aspects, as complimentary to environmental LCA.

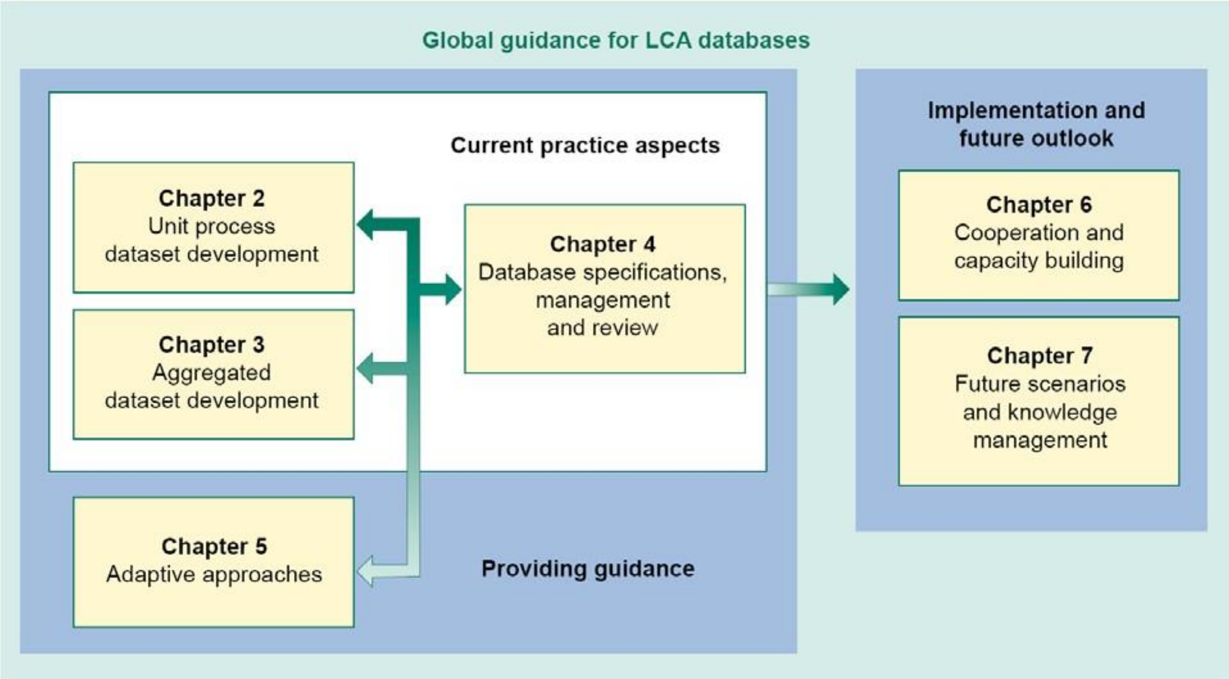


Figure 1. Organizational overview and roadmap of the publication ‘Global Guidance Principles for LCA Databases, nicknamed Shonan Guidance Principles

DISCUSSION – OUTREACH AND TRAINING ACTIVITIES

Outreach on the publication
Following the launch of the publication, presentations were held and forums were provided to present and discuss the process, workshop and document. Outreach activities have been organized in particular in emerging economies. Initial events have been run in Chile at the national level and in Tunisia for the Southern Mediterranean region in December 2011. A launch of the Shonan guidance principles in Japan for the Asia-Pacific region were organised in January 2012. These activities were followed in June 2012 by two events back to back to the ISO TC 207 Plenary meeting in Thailand, one for the participants of the meeting coming from all around the world and one for the interested Thai audience. As a next step outreach events were organised in India (August 2012), Brazil (September 2012), China (November 2012) and Argentina (March 2013). They were seen as a crucial basis for developing datasets and setting up databases in the quickly industrialising parts of the world. These different activities have facilitated to create a global awareness of the Global Guidance Principles for LCA Databases.

Development of training material and multi-region collaboration
Further development of the guidance principles is needed so that they can be used in a practical way for training and other applications. To achieve this is one of the targets and actions identified for a flagship project within Phase 3 of the Life Cycle Initiative. The

training material being prepared includes also the topic of how to set up databases and develop datasets, in particular in the developing world. The topic has been taken up by UNEP in its Rio+20 Voluntary Commitments (UNCSD 2012).

Regional and country based LCA networks are seen as important elements of this implementation strategy. They have already demonstrated their value for the organization of awareness-raising events on the Shonan Guidance Principles. Database managers are identified as central actors in the Shonan Guidance Principles. Therefore, establishing multi-stakeholder and multi-region collaboration worldwide among database mangers that in general are part of a regional and country based LCA networks is seen as an other key element of a global roadmap for capability development on the generation of consistent LCA data and the management of related databases.

CONCLUSIONS – NEXT STEPS

As a result of the publication there are a range of anticipated benefits and future activities. Two priority components of the roadmaps moving forward include the global coordination among LCI dataset developers and LCA database managers, together with data mining, and the use of the publication for capacity building activities worldwide. Greater consistency and interoperability among national, industry association and commercial databases at the global level is another essential advantage anticipated for the future. The adoption of the 'Global Guidance Principles' publication as a de facto global standard is expected to support database teams and collaboration in regional networks, as well as assist in increasing consistency within the generation of LCA data, especially in emerging economies and developed countries. Along with the further dissemination of the publication, training materials are being produced and are to be used in training courses conducted globally.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the financial support of the sponsoring partners of the UNEP/SETAC Life Cycle Initiative and of METI as the Japanese host for the workshop. Moreover, the authors would like to thank the Steering Committee members and the workshop participants for their support in preparing the publication. Finally, UNEP, with the support from the European Commission is implementing a 3-year project 'Integrating resource efficiency in international supply chains - enabling companies and consumers to benefit from information on life cycle environmental performance of products choices' which aims at developing capacities and promoting coordination on LCA databases.

REFERENCES

Sonnemann G, Vigon B, Broadbent C, Curran MA, Finkbeiner M, Frischknecht R, Inaba A, Schanssema A, Stevenson M, Ugaya CML, Wang H, Wolf MA, Valdivia S (2011) Process on "global guidance for LCA databases". Int J Life Cycle Assess 16:95-97

Sonnemann G, Vigon B (Ed., 2011) Global Guidance Principles for Life Cycle Assessment Databases: a Basis for Greener Processes and Products. Publication of the UNEP/ SETAC Life Cycle Initiative, ISBN 978-92-807-3174-3, UNEP, Paris

UNCSD (2012) Development of key environmental indicators and life cycle data for key product chains. UN DESA Sustainable Development Knowledge Platform, http://www.uncsd2012.org/index.php?page=view&type=1006&menu=153&nr=491.

LCADB.SUDOE: LIFE CYCLE INVENTORIES DATABASE OF THE SOUTHWEST OF EUROPE

Gasol Carles,[1], Sanyé Esther[2], Rieradevall Joan[2], Anton Assumpcio[3], [4]Cyril Arnoult, Bellon Veronique[5], Pradel Marylis[5], Lardon Laurent[4], Roux Philippe[5], Dias Ana[6], Arroja Luis[6], Rigola Miquel[7], Morera Serni[7], Comas Joaquim[7], Artola Adriana[8], Villaba Gara[2], Gabarrell Xavier[2].*

[1]Inèdit Innovació, Spain; [2]Sostenipra, Universitat Autònoma de Barcelona (UAB), Spain; [3]Institut de Recerca i Tecnologia Agroalimentaria (IRTA), Spain;[4]Supagro, France; [5]IRSTEA, France; [6]Universidad de Aveiro, Portugal; [7]Universitat de Girona; [8]GICOM. Universitat Autònoma de Barcelona (UAB), Spain

Keywords: Life cycle assessment; France; Spain; Portugal; datasets.

ABSTRACT

LCADB.sudoe (http://lcadb.sudoe.ecotech.cat/) is a database of life cycle inventories of the products and process of the productive sectors of the SUDOE area. The main aim is to share life cycle data with companies, administration, research institutions and in general LCA practitioners for improving the efficiency of the productive sectors. LCADB.sudoe tries to promote the inclusion of environmental information as a decisions factor in the design of products and process.

INTRODUCTION

Data collection is one of the main parts to perform a Life Cycle Inventory (LCI) of the Life Cycle Assessment (LCA) method (ISO, 2006). During the last decades, some databases were created in order to compile consistent and transparent LCI data, such as the ecoinvent (Frischneckt et al., 2007) and the ELCD (JRC, 2012) databases at Europe level.

However, there is a lack of specific databases for the SUDOE (Spain, France & Portugal) area that include local inventory data to avoid the uncertainty of using European data (e.g. specific process and products such as: wine, cork, oil, fish, etc., differences in technology level, efficiency or transport distances). Therefore, a LCI database for the SUDOE area could provide geographic specific LCI with quality data that also focuses on themes with special importance in this regional area (e.g. water).

The main objective of this project is to develop a common database for LCI in the SUDOE region (Spain, Portugal and France) useful for projects and collaboration between the participant institutions. Furthermore LCADB.sudoe (http://lcadb.sudoe.ecotech.cat/) aims to be a replicable and useful data management tool for other LCA databases initiatives especially in Latin America. There are 10 topics covered in the database, as summarized in table 1.

Table1. Topic, scope and some of the specific products and process of LCADB.sudoe

Topic	**Scope of topic**	**Specific products & process in SUDOE area**
Agriculture	Intensive, Extensive, Fruit, Horticulture…	Products as: tomato, fruits, cork. Process as: machinery, agrochemicals doses, operation times, diesel.
Fishing	Fishery	Products as: tune. Process as: machinery, operation times, diesel.
Construction	Construction, mobility, street furniture	Products: construction building materials, infrastructures for recharging electrical car, street furniture products
Energy Production	Renewable & Non-renewable	Products as: biomass production, energy crops.
Waste treatment	Municipal waste treatment	Technologies and infrastructures available of SUDOE area for municipal waste treatment
Water	Municipal Waste Water treatment and Rainwater use	Technologies and infrastructures available of SUDOE area to treat and use several kinds of water
Manufacture process	General	All the production and services process involved in productive sectors of SUDOE regions.
Services		
Transport		
Use and Consumption		

MATERIALS AND/OR METHODS

The database presented in this chapter is being developed in the context of the Ecotech-Sudoe project (ECOTECH-SUDOE project, soe2/P2/E377).

An on-line application (http://lcadb.sudoe.ecotech.cat/) and manual of users & editors were developed to facilitate the introduction of datasets of primary data by different users (LCA practitioners, decision-makers in companies and designers and engineering's of products, processes and services, etc.) and its previous review.

Related to the inventories organization, these has 4 sections: .

- **Information**: includes all the relevant information of the project such as name, type, ID (NACE code), system boundaries (flow chart), etc.
- **LCI & Validation**: includes data about the methodology and approach used.

- **Administrative**: includes the contact details of the author for the purpose of giving feedback, asking for supporting documentation or information.
- **Inventory**: includes all the flows and components of the process.

The steps for the creation of the database are shown in Figure 1.

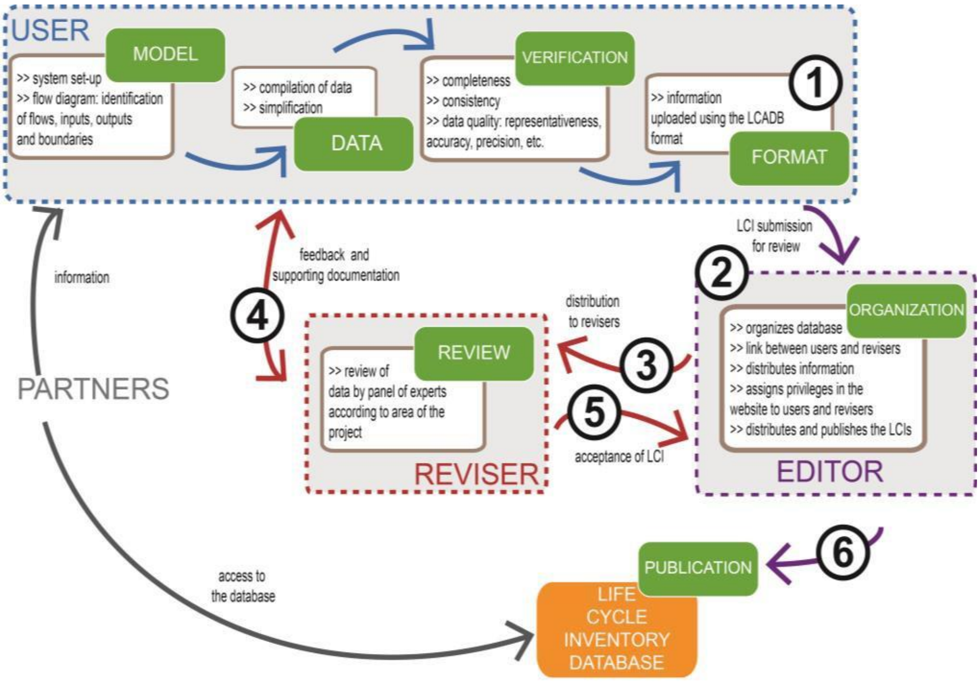


Figure 1. Steps and user of the creation of one dataset in LCADB.sudoe

The dataset is uploaded into the system and sent to the editor of the topic with the aim to be reviewed. The editors of the project organize the different LCIs, as they are the link between the revisers and users. The reviewer receives the information and evaluates the content of the inventory; the points to be assessed are: complete submission of the data in each step (i.e. all required fields completed), nomenclature according the elemental flows from the International Reference Life Cycle Data System, and the correct and sufficient information for the LCI.

The reviewer should contact the database author using the contact data provided in the forma for feedback or in the case that further documentation and/or complementary information is required. The editor, previous communication with reviewer, sets the status of the process: accepted, need to be improved, rejected. In any case the reviser notifies the editor about this decision.

RESULTS

The results of this phase were the development of the LCADB website as a tool for the database creation. The LCADB website has been tested, at user level, for more than 20 research institutions. Another result was the 2 manuals for a proper use of the tool: one for users and another for revisers & editor. The user's manual also defines the quality guidelines of the LCI data collection and the system modelling, that were created according to the ecoinvent (Weidema et al., 2012) and the ELCD databases (JRC, 2012) The expert's manual includes a list of the revisers per category and a checklist in order to review each of the phases of the process in the LCI and assure its completeness.

Currently the database contains more than 100 different datasets and it is provided that the total quantity rises due to the increasing participation of SUDOE & Spanish LCA research institutions in LCADB.sudoe. The inventories categories covered now are: Agriculture (72%), followed by Manufacture processes (9%), Water (5%), Energy production (4%), Cities (3%), Services (3%), Waste (2%), Fishing (2%) and Waste (1%). The inventories accessibility is 61% public, 22% public for partners and 17% private. It is also important to note that half of the inventories uploaded (48%), had been published in journals or in other scientific resources and therefore were evaluated through peer-review process.

CONCLUSIONS

The LCADB.sudoe is a useful tool for compiling consistent and transparent data of local and specific products & processes of the Sudoe area.

Regarding to complete and share life cycle inventory (LCI) data with other existing life cycle databases like ecoinvent and ELCD, we are still working to develop an informatics data management tool capable to export and import datasets. An expert committee with high expertise in LCA has been configured for the review process to secure a high quality, uniform and useful LCI database.

This project fulfils its final objective of improving productive sectors of the Sudoe area (South of France, Spain and Portugal) by giving access to useful information about processes in 10 different categories to LCA practitioners, decision-makers in companies and designers and engineering's of products, processes and services. The database is oriented to public and private participants, national and international. Furthermore LCADB.sudoe aims to be a replicable and useful data management tool for other LCA databases initiatives especially in Latin America.

REFERENCES

European Commission - Joint Research Centre (2010) International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guid.. Publict. Office of the EU, Luxemburg.

Frischknecht R, Jungbluth N, Althaus H-J, Doka G, Dones R, Hischier R, Hellweg S, Nemecek T, Rebitzer G, Spielmann M (2007) Overview and Methodology. Final report ecoinvent data v2.0, No. 1. Swiss Centre for Life Cycle Inventories, Dübendorf.

ISO (2006) ISO 14044:2006 Environmental management -- Life cycle assessment -- Requirements and guidelines. International Organization for Standardization, Geneva.

JRC (2012). ELCD database – online application. European Commission - Joint Research Centre. Available on: http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm. Accessed 20 October 2012.

Weidema BP, Bauer C, Hischier R, Mutel C, Nemecek T, Reinhard J, Vadenbo CO, Wernet G (2012). Overview and methodology. Data quality guideline for the ecoinvent database version 3. Swiss Centre for Life Cycle Inventories, Dübendorf.

METHODOLOGICAL CHOICES FOR AN LCI DATABASE OF FRENCH AGRICULTURAL PRODUCTS

*Thibault Salou[1], Peter Koch[2], Jerome Mousset[3], Armelle Gac[4], Gerard Gaillard[2], Hayo van der Werf[1]**

*1, * INRA, 65, rue de Saint Brieuc, 35042 Rennes, France; hayo.vanderwerf@rennes.inra.fr, 2 Agroscope, Switzerland; 3 ADEME, France ; 4 IDELE, France*

Keywords: Agri-BALYSE, environmental labelling, scope, models, coproducts

ABSTRACT

Two laws were passed in 2009 in France on Life Cycle-based environmental labelling. To allow the implementation of such labelling, the Agri-BALYSE programme provides a public database of 114 LCIs of French agricultural products at the farm gate, as well as a comprehensive methodological report. To ensure consistency, a common methodology was defined, consistent with French and international standards. This paper presents an overview of methodological choices regarding: i) definition of the scope and the systems studied, ii) choice and parameterization of models for estimating direct emissions and resource consumption, iii) choice of methods to assign impacts to coproducts. We hope that the methodology will contribute to the harmonisation of methods for agricultural LCAs, both in France and internationally.

INTRODUCTION

Two laws were passed in 2009 in France on the provision of reliable and complete environmental information on “product plus packaging” to consumers. The Life Cycle Assessment method was chosen to assess environmental impacts. ADEME, the French Environment and Energy Management Agency, was mandated to set up an LCI database to support this policy. The Agri-BALYSE programme (2010-2013) aims to provide a public LCI database of agricultural products at the farm gate and a comprehensive report describing the methodology used. Results will be available in October 2013.

To ensure consistency of the database, the partners have agreed on methodological choices. Major methodological choices concerned: i) definition of the scope and the systems studied, ii) choice and parameterization of models for estimating direct emissions and resource consumption, iii) choice of methods to assign impacts to coproducts.

METHODS

Methodology was designed to be consistent with the French BPX30-323 standard (AFNOR, 2011) and the ILCD standards (JRC and IES, 2010).

RESULTS

Definition of the scope and the systems studied
Agricultural systems are a source of variability for product LCIs due to differences in production systems (e.g. open-field versus greenhouse-based production), farmer practices within a given production system, and natural production conditions (climate, soil type).

Considering differences in production systems and farmer practices for a given product, 46 product groups (ex. “pig”, “pea”) were identified. Within a product group one or more production systems with typical farmer practices were defined, e.g. “Pig, French average, conventional production”, “Pig, organic production”, “Pig, rapeseed-meal-based feed, conventional production”. In total 114 LCIs “at the farm gate”, representative of a large fraction of French agricultural production, have been produced. To capture variability due to natural production conditions and prevent artificial differences in the results, 2005-2009 was the reference period for data collection. This period was extended to 2000-2009 for crops subject to biennial bearing (ex: apple).

Considering system boundaries, it was decided to set the cut-off criterion to zero. The inclusion or exclusion of input/output is not determined by quantity considerations, but by explicit enumeration of the processes.

Choice and parameterization of models
The choice of appropriate models for the estimation of direct emissions and resource use was a major challenge: 14 major substances (nitrate, methane, etc.) and 3 resources have been considered. For most of them several options have been considered, based on a review of available models. The choice of the most appropriate models was based on: i) the international scientific recognition of the model; ii) the degree to which the model is directly operational; iii) the consistency of the implementation of the model with the production system data collected and with the time-frame of the programme.

To ensure the consistency of the database, only methods based on emission factors (IPCC 2006, EMEP/EEA 2009) or mechanistic simulation models (Foster, 2005) were retained, thus the use of estimations based on field measurements was avoided. To ensure the accuracy of estimations of direct emissions, when possible, models were parameterised to consider specific French or regional conditions. For instance, emissions of enteric methane were estimated according to an IPCC 2006 Tier 2 method, considering detailed data on type and quantity of feed intake by animals. Similarly, for erosion the Revised Universal Soil Loss Equation (RUSLE; Foster 2005) model was used and parameterised for French regional conditions. When data were not available a standard parameterization of models (e.g. for N_2O, NH_3) was used.

Choice of methods to assign impacts to coproducts
Agricultural systems are often multifunctional, and thus a production system frequently produces two or more co-products. Consequently, the choice of an appropriate method to assign environmental impacts to the co-products is an important issue. Within Agri-BALYSE, this environmental impact attribution concerns: i) co-products of animal and crop production systems (ex: milk/cull cow/calf; grain/straw); ii) shared inputs across a cropping sequence (e.g. P-fertiliser which is consumed by all crops being applied once every 3 years to the crop

with the highest P requirement). A specific method was developed within Agri-BALYSE for such shared inputs.

Choices for the allocation of impacts were made according to international and national standards (ISO 2006, AFNOR 2011) which are: i) avoid allocation; when allocation is unavoidable, allocate the impacts according to ii) a physical criterion that reflects the underlying relationships between the co-products, or iii) the economic value of each co-product.

Considering this, allocation methods retained were based on: i) economic value of grain/straw for cereals/protein crops and Clementine for exportation/Clementine for local consumption; ii) mass of mown grass/grazed grass for grassland. For animal production, a "bio-physical" method consisting of two steps (Figure 1) was developed. In the first step, in accordance with international recommendations, allocation is avoided by dividing the production system in several unit processes. Each of these corresponds to a characteristic physiological stage of the animal. When a stage yields a single product, all impacts are attributed to this product. Thus for several sages, allocation is avoided. For stages yielding several products, allocation is based on the metabolic energy required to produce each co-product. The metabolic functions considered are: maintenance, activity, growth, lactation and gestation.

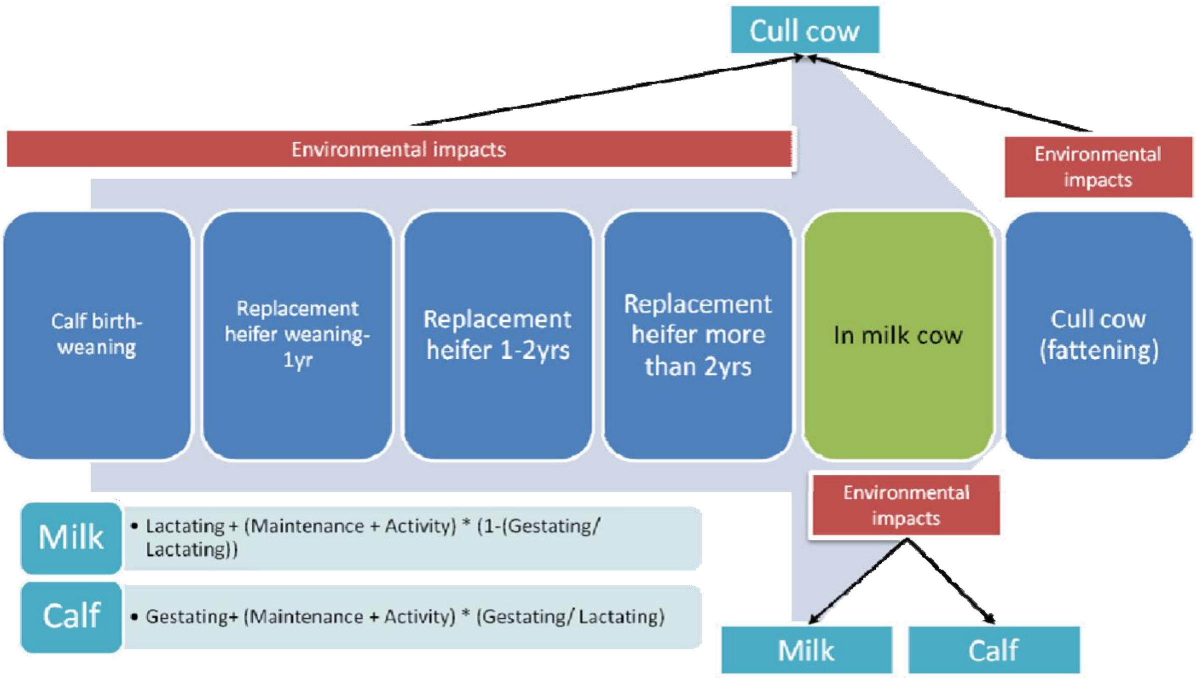


Figure 1: Attribution of environmental impacts for animal production according to the "bio-physical" model; case of dairy cow production. During the "In-milk cow" phase, environmental impacts are allocated according to the energy needed to produce the calf and milk.

DISCUSSION

The aspects presented here show how Agri-BALYSE has ensured the methodological consistency of the LCIs produced thanks to appropriated choices, adaptations of existing models or specific developments. The methods used within the program have been documented in a comprehensive and detailed methodological report (over 300 pages) to be published in October 2013. The aim of this document is to allow the realisation of LCIs of agricultural products, according to the Agri-BALYSE methodology, by different users, to reach various goals. We hope that the methodology developed and described in the programme will contribute to the harmonisation of methods for agriculture LCAs, both in France and internationally.

CONCLUSIONS

Considering the objective of Agri-BALYSE, relatively simple methods were implemented, especially for the estimation of direct emissions. It is expected that there will be a follow-up to the current project, which will allow further methodological developments, based on ongoing developments in the field of LCA, in order the improve the quality of LCIs in the Agri-BALYSE database.

REFERENCES

AFNOR, 2011. BPX 30-323-0 : Affichage environnemental des produits de grande consommation – Principes généraux et cadre méthodologique. Ed AFNOR, La Plaine Saint-Denis, France. http://www.boutique.afnor.org/norme/bp-x30-323-4/principes-generaux-pour-l-affichage-environnemental-des-produits-de-grande-consommation-partie-4-methodologie-d-evaluation-d/article/619574/fa174367#info

EMEP/EEA, 2009. Air polluant emission inventory guidebook. Technical report No 9. Ed European Environment Agency (EEA), Copenhagen, Danemark.

Foster G. R., 2005. Revised Universal Soil Loss Equation – Version 2 (RUSLE2). USDA – Agricultural Research Service, Washington D.C., 286 p.

IPCC, 2006. Guidelines for national greenhouse gas inventories. Vol No 4 : Agriculture, forestry and other land use (AFOLU). Ed Eggleston S., Buendia L., Miwa K., Ngara T. et Tanabe K., Kanagawa, Japan.

ISO, 2006. ISO 14044. Environmental management – life cycle assessment – principles and framework. Geneva, Switzerland, 46 pp.

JRC and IES, 2010a. ILCD Handbook : General guide for Life Cycle Assessment – Detailed Guidance, First edition. Ed Joint Research Center, Ispra, Italy. p414.

THE WORLD FOOD LCA DATABASE PROJECT: TOWARDS MORE ACCURATE FOOD DATASETS

Jens Lansche (1), Gérard Gaillard (1), Thomas Nemecek (1), Patrik Mouron (1), Laura Peano (2), Xavier bengoa (2), Sébastien Humbert (2), Yves Loerincik (2)*

Agroscope Reckenholz-Tänikon Research Station ART, Reckenholzstrasse 191,

8046 Zurich, Switzerland

(2) Quantis, Parc scientifique EPFL, Bât. D, 1015 Lausanne, Switzerland

** Reckenholzstrasse 191, CH-8046 Zurich, jens.lansche@agroscope.admin.ch*

Keywords: agriculture; food processing; food eco-design; environmental product declaration; LCI.

ABSTRACT

There is an increasing demand for LCA applied to the food and beverage sector. However, major limitations in doing LCA studies in this sector are currently the lack of inventory data and processes, and the absence of consistency among existing food datasets. Several libraries of data on food already exist but most of them provide little transparency and are often incomplete, outdated or not regionalized. Therefore, there is a need to develop detailed, transparent, well-documented and reliable data in order to increase the accuracy and comparability of LCA in the food sector. This need is being addressed by the World Food LCA Database (WFLDB) project. The main aim of the WFLDB is to create a basis to assist companies and environmental authorities in processes like Environmental Product Declarations (EPD) or food eco-design, but also for academic research.

INTRODUCTION

Agricultural production and food processing contribute significantly to environmental impacts on global warming, eutrophication and acidification (Pardo and Zufia 2012; Ruviaro et al. 2012; Saarinen et al. 2012). In the last decade, LCA is increasingly used for the quantification of these impacts and to meet the demand for optimization of food production (Notarnicola et al. 2012).

However, major limitations to such assessments are the lack of reliable and consistent inventory data. Existing libraries of LCI data on food are most often:

• Not transparent enough

• Incomplete: only few inventory flows are accounted for, which leads to an incomplete overview of the impacts of food products and misleading interpretations and conclusions

• Inconsistent among each other, due to different approaches and assumptions

• Outdated and consequently unreliable

• Not regionalized: country-specific data are not available or the region under study is not represented

Therefore, it is critical to develop detailed, transparent, well-documented and reliable data to allow for more accurate and comparable LCA in the food sector. This need is being addressed by the World Food LCA Database (WFLDB) project. The main aim of the WFLDB is to create a basis to assist companies and environmental authorities in processes like Environmental Product Declarations (EPD), but also for academic research.

MATERIALS AND METHODS

A new set of food inventory data is being developed from existing LCA studies on food products (project partners' past LCAs, Agroscope and Quantis existing databases), literature reviews, statistical databases of governments and international organizations (such as the Food and Agriculture Organization of the United Nations), environmental reports from private companies, technical reports on food and agriculture, information on production processes provided by the project partners as well as primary data. Background datasets from the ecoinvent database are being used as a basis and compatibility with ecoinvent will be ensured. The developed datasets include, when relevant, different production schemes (such as conventional, integrated or organic production), regional specificities and deforestation impact. To guarantee its transparency, the inventory database is fully documented, unit processes are visible (except for confidential data) and all sources are referenced. The end-user will be able to differentiate among different stages of the process (e.g. agricultural production vs. food product manufacturing) and to identify the main impact contributors for each dataset (e.g. pesticides, fertilizer use, etc.).

Datasets created within the project will initially be solely available to the project partners but are intended to become public later through their integration in ecoinvent. The scientific modeling principles of the WFLDB are at a first instance based on:

1. ISO standards14040 and 14044 (ISO, 2006a; ISO 2006b)
2. ecoinvent quality guidelines (ecoinvent, 2013; Weidema et al, 2013)
3. ILCD guidelines (JRC, 2010)

The project managers apply scientific rules for modeling of the WFLDB datasets. These rules are based on the above-mentioned documents and on other existing guidelines for modeling agricultural processes. By doing this, it is ensured that all datasets within the WFLDB are modeled according to internationally accepted standards and are fully consistent with each other. Furthermore, the project managers follow the developments within other international initiatives and organizations such as The Sustainability Consortium (TSC), the Food and Agriculture Organization of the United Nations (FAO), the Sustainable Agriculture Initiative

Platform (SAI), the EU Food SCP Roundtable and the EU Product Environmental Footprint. Scientific guidelines used in other database initiatives such as Agri-BALYSE (Van der Werf et al., 2010) and ACYVIA (Bosque et al., 2012) are also considered for the definition of the WFLDB modeling principles (developments are considered as they occur).

The aim is to be as compliant as possible with the developments occurring within these different initiatives and organizations. Compliance with other initiatives is assured by the project advisory board, which has a consultative role and is constituted of members of non-governmental organizations, research institutions and/or industrial organizations.

In conclusion, the WFLDB will be a comprehensive LCA food database providing detailed LCI data of high scientific quality, reliability and transparency on food products, while being in line with other database developments such as ecoinvent v3. The database will provide a large number of new food-related inventory datasets with a focus on different production schemes and regional specificities.

RESULTS

The WFLDB datasets will be delivered in the most widely used data exchange formats for LCA software (i.e. ILCD, ecospold v1, ecospold v2, SimaPro-CSV, Quantis SUITE 2.0-excel). This will enable using the datasets in three of the most common LCA software: SimaPro, GaBi and Quantis SUITE 2.0.

The datasets are released in three phases, the first release occurring in the summer 2013. A selection of datasets from the first release will be presented as well as learnings obtained in the last 12 months data collection. Two years after their release to the project partners, datasets will be submitted to ecoinvent for their integration in this public database.

REFERENCES

Bosque, F., Réthoré, O., Bortoli, H., Quantis, Gaillard, G., 2012. Acyvia: Creation of a public LCI/LCIA database of the French food industry, 8th International Conference on Life Cycle Assessment in the Agri-Food Sector. October 2-4, 2012, Saint-Malo, France.

Ecoinvent Centre, 2013. ecoinvent database v 3. www.ecoinvent.ch.

European Commission, Joint Research Centre, Institute for Environment and Sustainability, 2010. International Reference Life Cycle Data System (ILCD) Handbook, General guide for Life Cycle Assessment, Detailed guidance. Publications Office of the European Union.

ISO (2006a) ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework. International Standards Organization.

ISO (2006b) ISO 14044:2006 Environmental management – life cycle assessment – requirements and guidelines. International Standards Organization.

Notarnicola, B., K. Hayashi, M. A. Curran and D. Huisingh (2012). "Progress in working towards a more sustainable agri-food industry." Journal of Cleaner Production 28: 1-8.

Pardo, G. and J. Zufia (2012). "Life cycle assessment of food-preservation technologies." Journal of Cleaner Production 28: 198-207.

Ruviaro, C. F., M. Gianezini, F. S. Brandao, C. A. Winck and H. Dewes (2012). "Life cycle assessment in Brazilian agriculture facing worldwide trends." Journal of Cleaner Production 28: 9-24.

Saarinen, M., S. Kurppa, Y. Virtanen, K. Usva, J. Makela and A. Nissinen (2012). "Life cycle assessment approach to the impact of home-made, ready-to-eat and school lunches on climate and eutrophication." Journal of Cleaner Production 28: 177-186.

Van der Werf, HMG, Gaillard, G., Biard, Y., Koch, P., Basset-Mens, C., Gac, A., Lellahi, A., Deltour, L., 2010. Creation of a public LCA database of French agricultural raw products: Agri-BALYSE. In: Lcafood 2010, 7th International Conference on Life Cycle Assessment in the Agri-Food Sector. September 22–44, 2010, Bari, Italy, Notarnicola et al. (eds.), Università degli studi di Bari Aldo Moro, Bari, Italy, 439-442.

Weidema B P, Bauer C, Hischier R, Mutel C, Nemecek T, Reinhard J, Vadenbo C O, Wernet G., 2013. Overview and methodology. Data quality guideline for the ecoinvent data-base version 3. Ecoinvent Report 1(v3). St. Gallen: The ecoinvent Centre

SUSTAINABLE PRODUCT CHAINS - THE ROLE AND RESPONSIBILITIES OF RETAILERS

Tuesday, Aug 27: 1:30 pm - 3:00 pm
Session chair: Beatrice Kogg, Lund University, Sweden

ENVIRONMENTAL IMPROVEMENT ACTIONS BY RETAILERS

Johanna Berlin [a], Birgit Brunklaus [b]*

[a]SP Technical Research Institute of Sweden, [b]Chalmers University of Technology
**SP Technical Research Institute of Sweden, Section for Systems Analysis, Gibraltargatan 35, SE-400 22 Göteborg, Sweden, Email Johanna.Berlin@sp.se*

Keywords: Life Cycle Assessment, LCA, actor, retailer, food

ABSTRACT

As retailers´ decisions give environmental consequences both upstream and downstream the value chain, there is need of a tool for valuation of decisions and actions. This project has further developed and tested an actor based LCA methodology for retailers in case studies of egg and pork. Retailers improvement actions has been change in storage practice as well as transport practise e.g. home delivery. The result showed no environmental difference in longer storage, while there is a high environmental potential in offering home delivery. The actor based LCA methodology gives retailers better knowledge of their own environmental actions in the life cycle, as well as gives ideas for collaboration along the chain.

INTRODUCTION

Retailers have an important role in the life cycle of products. They are able to make decisions that influence the environmental impact throughout the life cycle. However, retailers come out as low in LCA studies. Conventional LCAs only account only for their contributions to environmental impacts, and not their role of improving the life cycle, which we study here.

METHOD

The study was based on the combination of the methodology life cycle assessment with an actor perspective. This combination was introduced by Berlin et al. (2008), Brunklaus et al (2010) and Baumann et al. (2011) In this study the concept is further developed and the approach is tested in case studies of egg and pork. These were selected to test food products with difference in shelf life as well as storage temperature. Dairy products have already been appointed for in case studies by Berlin et al. (2008).

For each case study several steps were taken; a) an LCA was performed and results presented for each actor b) identification of improvement decisions and actions for the retailer, c) calculation of the environmental consequences of selected actions in a lifecycle perspective was performed and d) a comparison of the result from the actions.

We now describe how step a) and b) were applied, for each of the two case studies.

Case study Egg

The LCA of egg included the whole lifecycle; agriculture, industry, wholesale, retailer, household, waste management, packaging and all transports along the chain. The functional unit was 1 kg of egg in the household. Data from the LCA of Swedish ecological egg by Carlsson et al (2009a) was used for agriculture, industry and packaging with some changes. We used Swedish electricity mix for fodder production. At the retailer the data source of Nilsson and Lindberg (2010) was used for study of the energy consumption and Eriksson and Strid (2011) for the waste figures (0,4%). The storage time at the wholesaler and retailer together was assumed to be 14 days. The energy usage at the household was found in Nilsson and Lindberg (2010) and the waste figure in WRAP (2008). For the transport data the Ecoinvent database together with NTM (2008) were used. The distance between the retailer and the household was assumed to 7.81 km (Orremo et al. 1999) and 59% of the consumers use the car. The shopping bag was assumed to have a weight of 4.2 kg.

The potential improvement actions of the retailers were identified in a brainstorming session with the researchers involved in this project together with Britta Florén and Magdalena Wallman at SIK (Swedish Institute for Food and Biotechnology) which utilized their understanding of life cycle thinking and LCA methodology, combined with their experience of the food chain. The actions identified were; 1. prolong the storage time at the retailer with 50% as the shelf life is assumed for eggs kept in room temperature and most often is the case in Sweden that eggs is kept in fridge temperature which prolongs the shelf life. 2. the retailer offer a home delivery service. The individual car transport was replaced by a small truck delivering food to several households, which we assume reduces the distance with 25%.

Case study Pork

The LCA of pork included the whole lifecycle from agriculture to waste management after the household. The functional unit was 1 kg of pork in the household. Literature and the Ecoinvent database were used as data sources. Data from the LCA of Swedish ecological pork meat by Carlsson et al. (2009b) was used for agriculture with exception of Swedish electricity mix for fodder production. Slaughterhouse data was found in LRF (2002). At the retailer the data source of Nilsson and Lindberg (2010) was used for study of the energy consumption and 1,3% of waste (Eriksson and Strid, 2011). The storage time was assumed to be 14 days. Data sources of transports and household was the same as the egg.

The potential improvement actions of the retailers were identified the same way as the egg study. The action identified was; decrease the waste of product at the retailer with 70% when the assumption of freezing of the meat for one month. Not sold fresh products which will be sold as frozen require a new package as well, which is made for freezing according to the regulatory.

RESULTS

The climate change depending of the lifecycle of today of egg and pork as well as the result of the suggested actions are presented in Figure 1 and 2. It is the action of a changed home delivery routine; the individual car transport was replaced by a small truck delivering food to several households, which gave the best result. A 12 % reduction of the climate change was achieved. By changing storage climate to chilling temperature including a reduction of wastage by 50% for the eggs gave a small improvement. The same came out for the pork with reduction of product waste including freezing and new packaging.

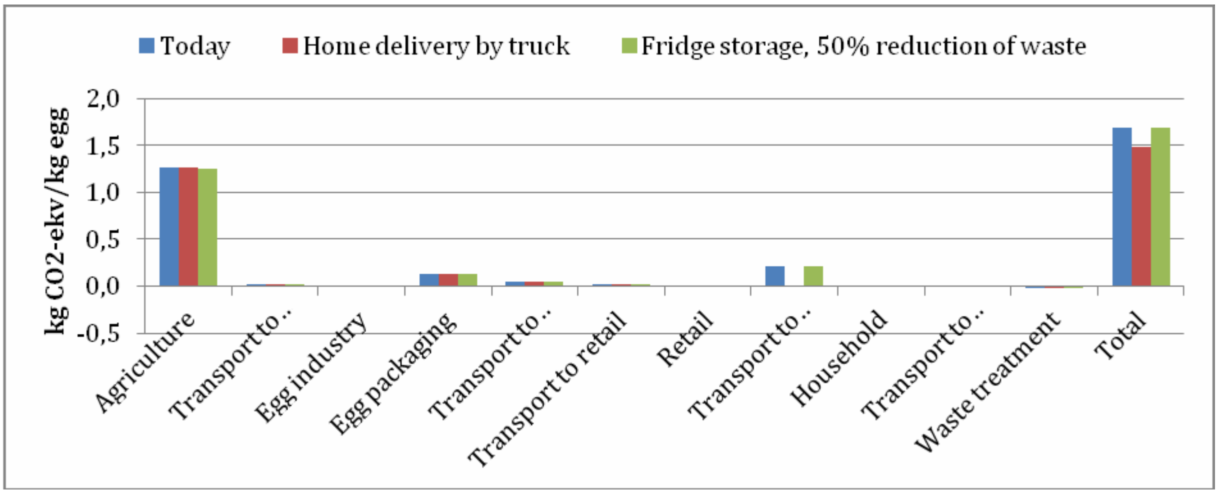


Figure 1. The climate change depending on today´s lifecycle of egg and the improvement actions at the retailer.

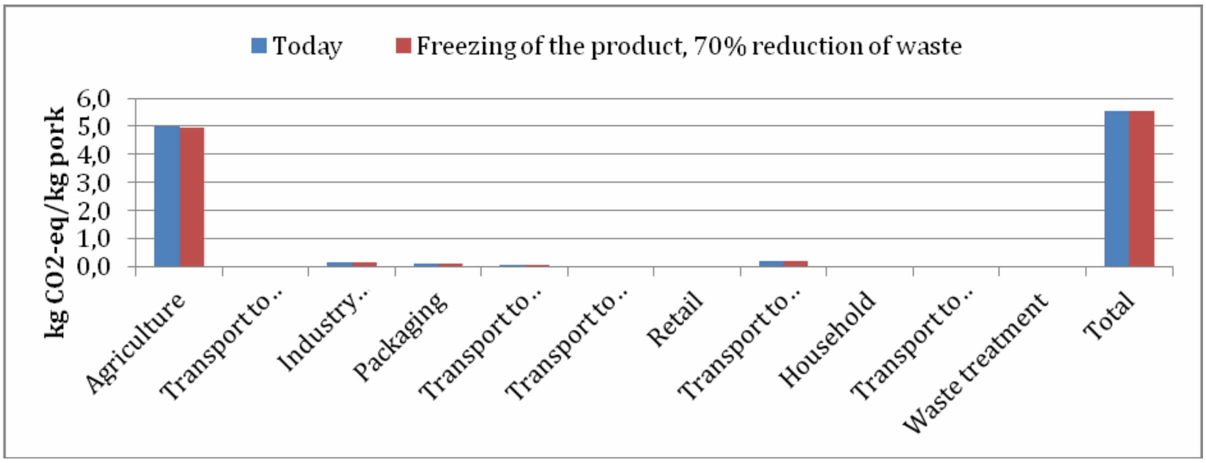


Figure 2. The climate change depending on today´s lifecycle of pork and the improvement actions at the retailer.

DISCUSSION

In an ordinary LCA, retailer often came out as an actor with low contributor to the environmental impact. As can be seen in Figure 1 and 2 this is also the case of this study. But this low contribution is not in correlation with the power of the actions the retailer is able to make decisions on. We found that if the retailer offers a home delivery system with a small truck the impact of this action is in fact higher than the environmental impact of the retailer itself.

To reduce food waste is very important from an environmental aspect as well as others. Nevertheless in this study it did not came out as an improvement of the climate effect. The energy required to change to chilling temperature and freezing respectively as well as the extra package, consumed the same amount of environmental impact which was gained of the reduced food waste. These two examples also shows that it is not easy for an actor to know in advance which actions gives the best result and also shows the importance to have a life cycle perspective of the actions when making decisions.

So far these studies include two of three levels of the actor analysis: LCA level, actor's possibility and influence level (Brunklaus 2011, Raab and Brunklaus 2012). Further studies will be made on others actors possibilities and influence, e.g. farmers and consumers. Based on the actor analysis tool, retailers will be able to derive green strategies for own activities and collaboration activities regarding storing, transport, and purchasing.

CONCLUSIONS

To conclude by combining LCA with an actor perspective the focus shifts from the analysis of technical devices to the analysis of actions and actors in the whole life cycle. More specific, the retailers will be able to get knowledge of which decisions and actions gives best environmental impact in a life cycle perspective, as well as ideas for collaboration along the chain.

REFERENCES

Baumann H. , Berlin J , Brunklaus B., Lindkvist M., Löfgren B. and Tillman A-M. The usefulness of an actor perspective in LCA. Towards life cycle sustainability management 2011, Springer Verlag, Part 2, 73-83, DOI: 10.1007/978-94-007-1899-9_8.

Berlin, J., Sonesson, U. & Tillman, A.-M. (2008). Product chain actors' potential for greening the product life cycle: The case of Swedish post-farm milk chain. Journal of Industrial Ecology, 12(1), 95-110

Brunklaus, B. (2011). Actor's behavior matter – organizing green product chains. Poster presented at the ISE conferences, 7-10th of June 2011, University of Berkley, San Francisco, USA.

Brunklaus, B, Thormark, C. and Baumann, H. (2010) Illustrating limitations of energy studies of buildings with LCA and actor analysis, Building Research & Information, 38: 3, 265 — 279DOI: 10.1080/09613211003654871

Carlsson et al (2009a) Livscykelanalys (LCA) av svenska ekologiska ägg, (Life Cycle Assessment (LCA) of Swedish ecological egg, in Swedish). SIK report nr 797, SIK: The Swedish Institute for Food and Biotechnology, Göteborg, Sweden.

Carlsson et al (2009b) Livscykelanalys (LCA) av svenskt ekologiskt griskött, (Life Cycle Assessment (LCA) of Swedish ecological pork meat, in Swedish). SIK report nr 798, SIK, Göteborg, Sweden.

Davis, J., Wallman, M., Sund, V., Emanuelsson, A., Cederberg, C. & Sonesson, U. (2011). Emissions of Greenhouse Gases from Production of Horticultural Products. Analysis of 17 products cultivated in Sweden. SIK: The Swedish Institute for Food and Biotechnology, Göteborg, Sweden.

Ecoinvent 2.2. http://www.ecoinvent.org/database/ecoinvent-version-2/ 24/05/13

Eriksson M. & Strid I. (2011) Livsmedelssvinn i butiksledet – en studie av butikssvinn i sex livsmedelsbutiker. (Food loss in the retail sector – a study of food waste in six grocery stores, in Swedish). report 035. Department of Energy and Technology, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Lantbrukarnas Riksförbund (LRF) (2002) Maten och miljön, Livscykelanalys av sju livsmedel Food and Environment, Life Cycle Assessment of seven food products, in Swedish, Skövde Sweden.

Nilsson K. & Lindberg U. (2010), Klimatpåverkan i kylkedjan från livsmedelsindustri till konsument, not public report. SIK: The Swedish Institute for Food and Biotechnology, Göteborg, Sweden.

NTM (2008). Additional CO2e-factors in goods transport. NTM Network for Transport and the Environment.

Orremo, F., Wallin, C, Jönson, G, Ringsberg K, (1999) IT, mat och miljö, (IT, food and the environment, in Swedish). Report 5038, Swedish Environmental Protection Agency, Stockholm, Sweden

Raab, M. & Brunklaus, B. (2012). Carbon Footprint of organic Spanish compared to conventional Austrian/Swedish cucumbers - Consumer and producer perspective on reducing greenhouse gas emissions. Gothenburg: Chalmers University of Technology.

WRAP (2008) The food we waste, Food waste report v2, WRAP, The Old Academy, 21 Horse Fair, Banbury OX16 0AH England. www.wrap.org.uk https://www.ns.is/ns/upload/files/pdf-skrar/matarskyrsla1.pdf

LOOKING BACK AT THE FRENCH ENVIRONMENTAL FOOTPRINTING EXPERIMENTATION: HOW INNOVATIVE LCA WEB TOOLS CAN FACILITATE THE INTEGRATION OF LIFE-CYCLE APPROACHES IN RETAILERS' DECISION MAKING

Radtke I.[1], Payet J. [1, 2] 1 Cycleco, 2 ENAC – SIE; Ecole Polytechnique Fédérale de Lausanne. * Cycleco, 1011 ave. Léon Blum, 01500 Amberieu (France)*
isabelle.radtke@cycleco.eu

Keywords: Environmental footprinting, supply chain, textile.

ABSTRACT

Since 2010, the French government has initiated the experimentation for environmental footprinting of mass market products. The majority of retailers encountered real difficulties in the collection of primary data and all were facing the incompleteness of databases. Also, the use of external LCA consultants represented the largest share of the budget.

With the overall purpose of facilitating the use of Life Cycle Assessment (LCA) for companies, Cycleco developed innovative software allowing non-experts to carry out sector specific LCA for purposes of eco-design and/or environmental footprint labeling. This paper illustrates the methods in which such LCA Web tools can facilitate the integration of LCA in retailer's decision making and supply chain management by facilitating networking within and amongst companies.

INTRODUCTION

Life Cycle Assessment (LCA) aims at providing metrics to enable both companies and citizen to find the best way in order to keep quality of life while reducing environmental burdens.

The « Grenelle 2 » law of the French Republic n° 2010-788 (2010) provides that consumers will be informed through an environmental display about the environmental impacts of mass market products. The environmental footprint of products, calculated with methods that are defined by product category rules, will thereby become a new purchase criterion. Within firms with higher standards for performance, environmental requirements are no longer seen as a regulatory nuisance but as a competitive advantage in the long run.

Indeed, more than 168 firms have participated in the French experimentation for LCA-based mandatory environmental communication scheme governed by the BP X30-323-0 (Association Française de Normalisation [AFNOR], 2011). This paper will focus on the example of a clothing retailer, which voluntarily joined the French experimentation, and describes the steps they took towards the integration of life cycle approach in their decision making, providing examples of the difficulties faced by quality managers when trying to implement a life cycle approach and the solutions to overcome them.

METHODS

Looking back at the French environmental footprinting experimentation

During 2 years of the French experimentation, Cycleco has led a pilot project that involved 15 partners in a joint operation to test the feasibility of systematic LCA for textiles products. The project brought together representative of the entire industry: from spinners to distributors and textile institutions, thus ensuring representativeness of the distribution channels, in order to quantify the performance of production processes and identify key points to be dealt with.

The objective was to test the feasibility of a systematic life cycle approach and assessment of products. More than 50 attributional LCA studies were conducted using traditional LCA software Simapro. The following needs where identified:

- Sector specific data and methods should be accessible easily and integrated within a simplified environmental impact calculator adapted to the specifics needs of the users: A mid sized fashion retailer would buy around 45 million garments per year, which represents 20-25K new models per year. Even in considering a steep learning curve, the task is far too big for a mid sized company to undertake. Furthermore the use of an external LCA consultant is of course out of the question.

- The reference database should provide *high range* default values to i) allow any firm, regardless of their knowledge of the supply chain to assess the impact of their product, ii) give a competitive advantage to the firm making the effort to collect specific data. Despite the mobilization of suppliers involved, the majority of retailers encountered real difficulties in the collection of primary data and all were facing the incompleteness of secondary databases. Thanks to a 5 year traceability policy, the quality managers were able to conduct survey of most finishing plants and clothing manufacturers in their supply chain but lacked data for yarn spinning and fabric manufacturing. Yet, they needed to conduct a full assessment of their product through its life cycle.

- Facilitate networking within and amongst companies enabling data exchange and collaborative work through an online platform: The supply chain in the textile industry is relatively complex, and the need for accurate data collection is crucial for the quality of LCA, and subsequently, for the pertinence of decision making based on LCA. Yet, great difficulties in getting and interpreting the results of data collection can occur, from cultural differences and personal ways to interpret and fill out excel sheets for example.

Methodology for the development of Innovative LCA web tools

The structure of specific LCA software developed by Cycleco is made of three parts; the methodology, which can be defined for one product or category of product (PCR) (International Organization for Standardization [ISO], 2006; AFNOR, BP X30-323-X, 2012); an inventory database specific to a given industry sector and finally, the user interface which is the programming part of the application and which ergonomic are defined on the basis of the needs and the constraints of the users.

The textile industry is complex and global, (Gereffi and Memedovic, 2003) many steps are necessary for the production of apparels, and they often occur in different countries. Cycleco has built up a network of industrial partners in order to better identify the needs of each sector and to check step by step the relevance of each solution proposed.

High range default values for common textile processes were developed with the participating companies and literature, and defined in order to provide enough information do make LCA possible, regardless of the degree of knowledge of the supply chain while ensuring that the high value would encourage the retailers to pursue data collection.

The software's main characteristics are the following:

-The methodological guidelines and data including high range default values are integrated as calculation models in the on-line software.

-It is ergonomic and intuitive: even if user guidance is available, the users do not need it to understand how to use the tool; A basic knowledge of the manufacturing steps is enough to conduct the LCA of a clothing article in 5 minutes.

-It guides, encourage and make it easy to collect more information, and analyse results to encourage ecodesign.

-It allows easy project sharing between retailers and their suppliers trough a collaborative online interface that is customizable to ensure privacy.

-Results can be reported in PDF or Excel format.

RESULTS

Through the experimentation, it was clear that in order to allow distributors to conduct the LCA of their entire collection, they needed to be able to conduct such LCA not only independently from consultants but also with specific tools that will allow an easy repetition of the LCA.

Working together with textile quality managers, LCA specialists, and IT programmers, Cycleco developed Spin'IT®, a web application accessible online (SaaS) which allows non-LCA expert to carry out the LCA of their product independently. It allows fast calculation of environmental footprint of thousands of products, ensuring a reliable ranking of products. It takes into account specifics of the fashion industry such as restocking.

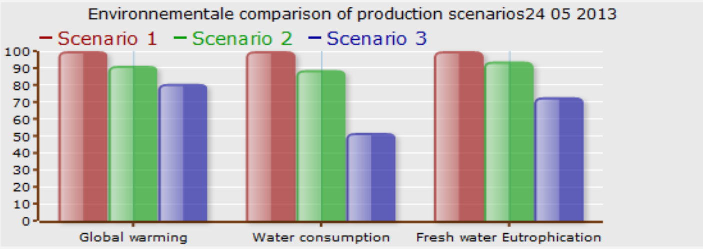
The following goals are achieved:

Independence of the actors is possible through a shift of knowledge:

- The use of an external LCA consultant becomes optional; the ability to conduct in house compliant LCA is now available.
- Sector specific tailored interface give retailers the means to calculate and compare Life Cycle impacts for different supply chain scenarios. Eg: they can evaluate the environmental gain of alternative restocking scenario.
- Suppliers can position their green products or processes through a widely used web tool.

Providing high range default values instead of mid range does establish steps towards LCM improvement in the company:

- Knowledge of the supply chain, including data collection, is a first step in a Life Cycle Approach, so knowing where something is made is already better than not, then knowing how it is made is the next step and finally the decision to buy from one supplier or the other can be based on quantitative measures. See figure 1 below:



	Global warming [Kg eq. CO_2]	Water consumption [m^3]	Fresh water Eutrophication [g P eq]
Scenario 1	18,02	1,02	12,00
Scenario 2	16,46	0,90	11,26
Scenario 3	14,55	0,53	8,73

Figure 1. Illustrate a comparison between 3 scenarii made with Spin'it® (in about 5 minutes). Scenario 1 reflects the environmental impact of a Polyester shirt conducted with 1-no knowledge 2-some knowledge and 3-good knowledge of the supply chain. Another tab of the application gives a single result for Environmental Footprint labeling taking into account a percentage of each stocking and restocking scenario.

Collaboration is made possible through the whole supply chain, and within an organization:

- Online LCA tools are an-easy to access worldwide centralized point to collect data and access sector specific database.

-The modular system allows users (at every level of the supply chain) to create LCI that will be used to build a product oriented LCA for each of the retailer's products.

- Online sharing option allows the entire company to get involved in the evaluation of the products and assess the impact of each process.

CONCLUSIONS

In regards to technology system's dynamics, the spread of one enabling innovation pushes the use of related technologies. Therefore, we believe that the future of LCA should involve the entire supply chain. This shift can be enabled by adequate IT solution, associated with a pragmatic approach of the realities of LCA within specific sectors. With tools that fit them, SME's are empowered and can lead environmental change within their industry.

REFERENCES

Association Française de Normalisation (AFNOR). (2011) BP X30-323-0 General principles for an environmental communication on mass market products : part 0 : general principles and methodological framework. http://www.boutique.afnor.org

Association Française de Normalisation (AFNOR). (2012) BP X30-323-X General principles for an environmental communication on mass market products: part X : Methodology for an environmental impacts assessment of article of clothing , *draft 2012*

French Republic. (2010/July) Law No. 2010-788 of 12 July 2010 the national commitment to the environment: *Titre VI - Chapitre 1 - Article 228, Journal Officiel de la République Française (JORF) du 13 juillet 2010, version consolidée au 10 septembre*

International Organization for Standardization (ISO) (2006); Environmental labels and declarations –Type III environmental declarations- Principles and procedures. ISO 14025: 2006

Gereffi G., Memedovic O., (2003) The global apparel value chain: What Prospects for Upgrading by Developing Countries, *United Nation Industrial development Organization (UNIDO), Vienna*

RESPONSIBILITY IN THE SUPPLY CHAIN – LOOKING AT STANDARDS, CERTIFICATIONS AND THE ROLE OF THIRD PARTY SERVICE PROVIDERS FROM A SUPPLY CHAIN MANAGEMENT PERSPECTIVE

Beatrice Kogg & Olga Chkanikova. International Institute for Industrial Environmental Economics, Lund University. *IIIEE, Lund University, P.O. Box 196, SE-221 Lund, Sweden beatrice.kogg@iiiee.lu.s.*

Keywords: product chain; supply chain management; certification; retailers.

ABSTRACT

This study focuses on the food and fashion retail sector and aims to analyze the role that sustainability standards and associated certification schemes play in the context of retailer's Sustainable Supply Chain Management practices. The objective is to understand weather standards replace the buyers need for an, often costly, collaborative approach to supplier relationship management. In our study we find evidence that affirms standards role in reducing corporate necessity to coordinate sustainabilit y issues upstream the supply chain. However, this is not the case when availability of certified goods is constrained.

INTRODUCTION

Many companies are today faced with requirements from salient stakeholders to address environmental and social issues that arise upstream in the supply chain. The underlying logic here is an increased association between the perceived scope of corporate responsibility and the life cycle impacts of products. However, while the principle of life cycle responsibility is simple and elegant, the exercise of such responsibility can present a significant challenge given the complexity and sheer size of the networks of organizations that may be involved in the supply chain of a retailer.

In this paper we look at sustainability standards and certification schemes from the perspective of the buying company and discuss this in relation to extant research on sustainable supply chain management (SSCM). Many early contributors in this field have argued that companies need to adopt and develop collaborative relationships with relevant suppliers, in order to exercise influence and control over sustainability performance upstream in the supply chain (Bowen, Cousins et al. 2001; Vachon and Klassen 2008). However while inter-organisational collaboration have many potential advantages, some contributors have pointed out that developing and maintaining such partnerships can be both costly and risky. The work on power relations in the supply chain (see e.g. Cox, Sanderson et al. 2001), also suggests that the situations where inter-organisational collaboration between companies is likely to be successful are limited, and dependent the specific dyadic power relation between the buyer and the supplier.

The theory of transaction costs economics (TCE) suggests that a buying organization would approach procurement 'in a transaction cost economizing way' (Williamson 1990, p. 13), a logic that fits nicely with influential purchasing models such as Kraljic's purchasing portfolio (Kraljic 1983). Kraljic suggests that a collaborative relationship is only efficient when *supply risk* and *profit impact* of a purchase is high. Recently portfolio based supply chain management has been discussed also in relation to SSCM. Pagell, Wu et al.(2010) noted that SSCM does not necessarily require a collaborative approach, when sustainability standards and assurance schemes are available, but that in practice collaboration still often take place even for products where the recommended sourcing strategy would normally rather be competitive bidding than collaboration. In this paper we seek to analyze the interplay between corporate practice to exercise responsibility in the supply chain and the existence of certifications, standards and third party service providers. The analysis is based on empirical studies of SSCM practices of large retailers in the textile and food industry. The question we seek to answer is: *what role sustainability standards and associated certification schemes play in the context of retailer's SSCM practices.* In particular, the study seeks to explore if standards replace the need for a collaborative approach to supplier relationship management.

MATERIALS AND/OR METHODS (WHICHEVER APPLICABLE)

This paper is based on a combined analysis of findings from three related but separate studies. The most recent is an empirical investigation of SSCM in the food retail industry (Chkanikova 2012), a study is based on two case-studies of two major Swedish food retailers supplemented by in-depth interviews with three other large retailers recognized for active engagement into sustainable sourcing activities. The findings from this study is then analyzed in comparison with two previous studies on SSCM practices in the retail sector; one focusing on fashion (Kogg 2009) and another focusing on sourcing of sustainable fish products (Rogers 2011).

RESULTS

The empirical findings indicate that there are indeed occasions where presence of third-party certification schemes removes, or reduce, the need for companies to adjust their sourcing and supply management practices. For several products the process of sourcing "sustainable" products resembles purchasing procedures for conventional products. Indeed, in the food sector it is not uncommon that retailers source the conventional and the sustainability certified products from the same supplier.

However we also identified several examples where even when certifications schemes exist, the companies still engage directly with relevant suppliers (sometimes several tiers upstream) and where practices in purchasing of sustainable products differ from how the company purchases conventional products. Typically this has been observed when the buyer perceives supply of sustainable products to be in someway constrained along with a desire to change this situation. Constrained supply is not necessarily only related to availability in terms of volume, but also to prices of available certified goods, as well as the quality and variety (range) of certified goods. When faced with constrained supply the buyer typically assumes the task of actively seeking to motivate, and sometimes assist, the supplier to get a certification. Sometimes buying companies also engage in control processes that complements third party verification processes set up by the certification scheme.

Another observed phenomenon is that buyers ask for a combination of different certification schemes (e.g. double-certification of products with organic and fair-trade standards) and/or add their own criteria on top of criteria defined by an existing scheme. In the latter case an increased level of interaction between the buyer and relevant suppliers has been observed in some cases but not always. The data indicate that this is linked to buyer assessment of risk of non compliance with the additional criteria.

There are some indications that the absence of standards and certification schemes, have delayed corporate SSCM initiatives (companies deciding to wait for the development of a common standard) but when the buyer perceives a need to move forward in spite of lacking or underdeveloped certification schemes an increased level of interaction between the buyer (or service providers to the buyer) and the relevant parties in the supply chain has been observed. Interaction is then required both in order to convey the message (the sustainability objectives that the buying party want to achieve) and in order to control performance upstream. As many aspects of product sustainability can be described as a *credence good*, meaning it can’t be controlled through inspection of the delivered goods, control of processes on site is very often necessary and the task of verifying compliance clearly presents a range of challenges both in the food sector and in the textile sector. Not only because of the often large and complex structure of the supply chains, but also because of the complex nature of the issues that the buyers seek to control.

DISCUSSION

If current supply does not meet sustainability expectations or if the supply of certified goods is perceived as constrained, the buyer may need to exercise influence and control, sometimes several tiers upstream. The control process increases the need for interaction between the buyer and actors in the chain and consequently the associated transaction costs. From a business perspective the increased transaction cost must therefore be motivated either by a potential for higher earnings or a risk of financial losses associated with not taking action. In relation to the ability to exercise influence upstream the power perspective (Cox, Sanderson et al. 2001) becomes relevant both as an explanation for observed changes in the supply base as a result of SSCM programs but also as part of the explanation for corporate failure to exercise influence over sustainability practices upstream in the supply chain. Power contexts vary between different dyadic relationships and even for large retailers, relative dependencies in the supply chain are far from always rendering them a position from where they can exercise coercive power over suppliers. (Cox, Sanderson et al. 2001)

When unilateral approaches are too costly or when power contexts in the supply chain are not favorable for unilateral action, certification schemes can be seen as an important service provider that enable buyers to exercise responsibility in the supply chain. The empirical data collected in the food and the fashion retail industry suggests that that if availability of certified products satisfies the buyers demand for sustainable products, they can in effect outsource the “sustainability element” of their sourcing strategy to the certification providers. However, if the price, volumes, variety and quality of sustainable products is perceived as not satisfactory, or if the level of control performed through the certification scheme is perceived as non satisfactory, retailers still need to adopt their purchasing practices and typically engage into closer forms of interaction with suppliers.(Kogg 2009; Chkanikova 2012)

CONCLUSIONS

If early contributors in the field of SSCM, who suggested that collaboration is necessary to enable companies to influence and control sustainability performance had been correct, SSCM would entail a dramatic restructuring of supply chains for many retailers. While we have seen examples of such shifts to reduce the number of suppliers and vertical integration, we have also seen a new type of change in the supply chain where rather than reducing the number of suppliers, the supply chain has been largely maintained but with the addition of SSCM service providers such as certification bodies, sustainability consultants and accredited certifiers who enable suppliers to perform in accordance with standards and the buyers to verify credence goods not through process control but through documentation.

Increased transaction cost and complex power relationships along supply chains can both be seen as barriers to SSCM, and widely accepted and adopted certification schemes can mitigate these barriers by reducing costs borne by the buyer and replacing the need for unilateral power with market power. While we have not been able to measure this empirically, in theory good standards may therefore increase the propensity of buyers to put sustainable products on their shelves.

The reality of corporate supply chains is messy and dynamic, and exercising influence and control in this type of context has been found a challenge also by very large corporate buyers. It is clear that standards play an important role in facilitating this work.

REFERENCES

Bowen, F. E., P. D. Cousins, et al. (2001). "The role of supply management capabilities in green supply." Production and Operations Management **10**(2): 174-189.

Chkanikova, O. (2012). Sustainable purchasing in food retail: inter-organisational management to green food supply chains The 3rd Nordic Retail and Wholesale Conference,, School of Economics and Management, Lund University, Sweden, November 7-8, 2012.

Cox, A., J. Sanderson, et al. (2001). "Supply chains and power regimes: Toward an analytic framework for managing extended networks of buyer and supplier relationships." The Journal of Supply Chain Management **37**(2): 28-35.

Kogg, B. (2009). Responsibility in the Supply Chain: Interorganisational management of environmental and social aspects in the supply chain - Case studies from the textile sector. Lund, Lund University.

Kraljic, P. (1983). "Purchasing Must Become Supply Management." Harvard Business Review **61**(5): 109-117.

Pagell, M., Z. Wu, et al. (2010). "THINKING DIFFERENTLY ABOUT PURCHASING PORTFOLIOS: AN ASSESSMENT OF SUSTAINABLE SOURCING." Journal of Supply Chain Management **46**(1): 57-73.

Rogers, E. (2011). Exercising Responsibility in the Seafood Supply Chain: A Case Study on How a Retailer Implements its Commitment to

Sustainable Seafood & Experiences of Other Seafood Buyers. IIIEE. Lund Lund University**:** 106.

Vachon, S. and R. Klassen (2008). "Environmental management and manufacturing performance: The role of collaboration in the supply chain." International Journal of Production Economics **111**(2): 299-299.

Williamson, O. E. (1990). The firm as a nexus of treaties: an introduction. The firm as a nexus of treaties. M. Aoki, B. Gustafsson and O. E. Williamson Londong, Sage.

SMALL SUPPLIER DEVELOPMENT PROGRAM: IMPLEMENTING AND ADAPTING WALMART'S SUSTAINABILITY INDEX FOR 12 SMALL SUPPLIERS FROM WALMART CHILE

Cristian Emhart [1], Alejandro Florenzano[1], Catalina Giraldo[1], Cristóbal Loyola[1], Jonas Bengtsson[2], Laura Guccione[2]*

[1.] Fundación Chile, Avenida Parque Antonio Rabat Sur 6165, Vitacura, Santiago, Chile- [*]cemhart@fch.cl;

[2.] Edge Environment, Level 5, 39 East Esplanade, Manly, NSW, Australia

Keywords: Retail; Sustainability; Supply Chain; SMRS; Indicators.

ABSTRACT

Retailers, as "gatekeepers" between production and consumption, can influence their supply chains to improve their environmental and social performance in key areas (hotspots).

Walmart has been a leader in the sustainability agenda for retailers through the creation of a product Sustainability Index, based on the Sustainability Consortium's Sustainability Measurement and Reporting System (SMRS®).

This paper presents a pilot Supplier Development Program co-financed by the Chilean Economic Development Agency (CORFO) and Walmart Chile.

A Life Cycle Assessment (LCA) based diagnostic approach, aligned with the SMRS®, was implemented with 12 medium and small suppliers for 9 different product categories. The program conveyed an initial qualitative approach and established 2.5 year action plans, which include implementation of management practices using quantitative indicators for the identified environmental and social hotspots.

INTRODUCTION

Through LCA, retailers, as "gatekeepers" between production and consumption, can identify where in the supply chain key environmental and social impacts (hotspots) occur, and influence suppliers to improve performance in these areas.

Walmart, seeking "*to sell products that sustain people and the environment",* has been leading the sustainability agenda for retailers through the creation of a product Sustainability Index (Walmart, 2009), based on The Sustainability Consortium's (TSC) Sustainability Measurement and Reporting System (SMRS®) (TSC, 2012). In pursuing a practical application of the Sustainability Index and SMRS®, a pilot program has been developed to create industry engagement for Walmart Chile's suppliers to promote the implementation of improvements across the products' supply chain.

A LCA based hotspot approach, aligned with TSC's SMRS® (Dooley et al., 2011), was implemented with 12 medium and small suppliers for 9 different product categories (see Bengtsson et al., 2012). The industry engagement started with a qualitative rating of each supplier's performance in each hotspot, which in turn provided the basis for a 2.5 year development plan. The plans include implementation of management practices based on quantitative indicators for the key hotspots with the main objective to provide suppliers the tools and focus to measure life cycle sustainability performance, identifying improvement opportunities and prioritizing and implementing solutions.

The following table summarizes the suppliers respective product category and a general description of their operations:

Product	Operations Summary
Olive Oil	Crop production (40-48 tons of olives during harvest time), oil extraction, packing and distribution.
Lettuce	Hidroponic and conventional cropping, harvesting, packing and transport.
Tomato	Cropping, harvesting, packing and transport to point of sale.
Bread	Producing, packing and transportto distribution point.
Orange Juice	Pulp import from Spain, juice production, packing and transportto distribution point.
Cookies	Producing, packing and transport to distribution point.
Mushrooms	Sowing, harvesting, packing and transport to distribution point.
Detergent	Producing, packing and transport to distribution point.
Rice	Rice import from Argentina, Paraguay and Vietnam, packing and transport to distribution point.

Table 1: Product categories included with description of each supplier's operations

METHODOLOGY

The main objective of this project is to provide suppliers with capacity to measure life cycle sustainability performance, identify improvement opportunities, prioritize and implement solutions. This is primarily realized through:

- workshops,
- establishment of guidelines
- support to meet performance and management goals.

Progress and improvement will be continuously monitored and an integrated life cycle based management tool is being tailored for each supplier.

The project is being implemented in the following steps:

Step 1: Complete a scoping LCA based sustainability management diagnostic for each supplier in order to identify and understand their most relevant process, hotspots and improvement opportunities.

Step 2: Improve each scoping LCA model with real data and develop data for each supplier with information that they manage and have access to. Specific questionnaires, based on hotspot analysis, were developed for each product category. The questionnaire considered social, economic and environmental dimensions.

Every answer was scored from 0 to 4 according to: **0:** it is not a hotspot, **1:** supplier knows and understands the hotspots and its related impacts, **2**: supplier measures and monitors metrics related to hotspots, **3**: supplier has goals for improvement and manages hotspots, and **4:** supplier has implemented solutions on hotspots.

Step 3: Develop key performance indicators (KPIs) that will help establish performance baselines to measure and monitor improvement, and to report progress to relevant stakeholders.

Step 4: Select their preferred list of actions to implement improvements not only for their production process but also across their value chain. The list of possible actions will be technically, economically and environmentally reviewed to integrate each into a strategy for implementation.

Step 5: With the data developed and KPIs identified, those will be integrated into a tailor made LCA based management tool, to support their decision making. This tool will allow immediate evaluation of different actions in the decision making process.

RESULTS

Figure 1 presents the survey results for every supplier, showing their environmental, social and economic management performance. Horizontal lines represent the average score for each dimension.

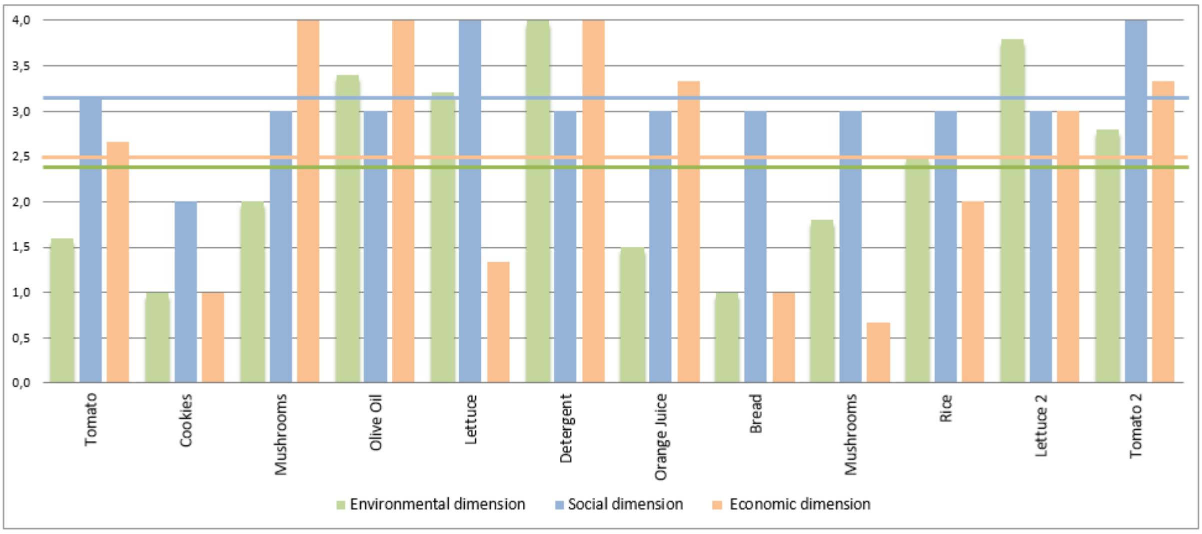


Figure 1: Survey results for supplier´s performance per dimension.

Currently, specific baseline data is being implemented to help suppliers meet the completion of the following three types of baseline data: **(i)** Management level according to diagnostic. **(ii)** Identification of KPIs related to the specific suppliers and the phases they can have influence on, **(iii)** LCIs developed specifically for each supplier, which will be integrated to KPIs identified in previous point.

Meanwhile, several workshops and guidelines have already been completed, introducing suppliers to the LCA framework and methodology, as well as providing the information to understand the impacts of agrochemicals, packaging and energy efficiency in order to further engage and encourage them with the project.

DISCUSSION

The product Sustainability Index, based on the SMRS® provides a flexible framework to focus efforts in social and environmental hotspot management while saving time and resources, providing useful and practical guidelines for improvement, while maintaining business sustainability in sight.

Workshops and site visits have proven crucial to understand how suppliers make decisions and learn about the issues they are most concerned with. This has led the project team to develop customized approaches for improvement, presented as case studies to the suppliers.

Within the first 9 months, several initial improvement opportunities have been already identified and actioned. For example an olive oil supplier replaced heavy glass bottle for lighter ones saving resources for production and transporttaion. A lettuce supplier is implementing a solar powered water pump reducing energy demand and greenhouse gasses. A small tomato supplier identified plant varieties that require low pesticide input.

CONCLUSIONS

The project is successfully engaging with medium sized retail suppliers to realize sustainability improvements using a pragmatic and scientific approach for awareness, education and business management.

The customized approach has been instrumental to encourage the suppliers to further engage with the development of the project.

The project will continue to develop specific LCAs for each supplier, which, along with the customized tool and social guidance, to continue to improveme each suppliers' sustainability performance.

REFERENCES

Bengtsson, J., Emhart, C., Florenzano, A., Guccione, L., & Jaramillo, C., (2012).LCA-based hotspot analysis of food products to inform a major Chilean retailer's sustainability strategy. 8th International Conference on LCA in the Agri-Food Sector, St Malo, France, 1-4 October 2012.

Dooley, K., Carlson, J., Schöner, G., Subramanian, V., & Childs, C. (2011). The Sustainability Consortium: A Stakeholder Approach to Improve Consumer Product Sustainability. In Towards Life Cycle Sustainability Management *(pp. 43-52). Springer* Netherlands.

The Sustainability Consortium, (2012).Sustainability Measurement & Reporting System (SMRS). Retrieved May 20, 2013, fromhttp://www.sustainabilityconsortium.org/smrs

Walmart, (2009). Sustainability Index. Retrieved May 20, 2013, from http://corporate.walmart.com/global-responsibility/environment-sustainability/sustainability-index

THE RETAILER – JANUS CAUGHT IN A MULTISTAKEHOLDER TRAP?

Dr. Kewin Comploi, Dr. Martin Wildenberg, Anna Geiger*

GLOBAL 2000 – Friends of the Earth Austria

** Neustiftgasse 36, A-1070 Vienna*

Email: kewin.comploi@global2000.at

Keywords: sustainable food-chain, retailer, NGO, multi-stakeholder forum,

ABSTRACT

The following (position) paper reflects the experiences and views of GLOBAL 2000 / Friends of the Earth Austria, an environmental NGO that has an extensive record of projects in the field of food production and distribution.

The contribution outlines the retailer's role in the various processes of the food life cycle from the point of view of an environmental NGO, referring especially to the experiences made in various multistakeholder forums over the last 3 years. These forums are composed by the cooperation partners of a collaboration program for more sustainable food production, farmers and their related distributors and external experts (e.g. from universities and chamber of agriculture). Moreover, general insights in the Austrian retail sector and reflections about its business model are given.

INTRODUCTION – JANUS AND THE RETAILER

Janus, the ancient roman god for all beginning and end, of doors and gates, is usually depicted as a two-faced god. The analogy to the retailer is evident: retailers are important gatekeepers, they influence the production systems (the beginning), they have direct contact with the consumer (the end). Like in most western industrialised countries the Austrian retail sector is highly concentrated, augmenting the negotiating power of the few players who can provide access to the mass market (gatekeeper function). However, as most big corporations increasingly face harsh criticism by critical consumers, media, and, not least, social and environmental NGOs, most companies have engaged in sustainability strategies and practices. These agendas are usually taken care of by CSR managers or sustainability divisions (the one face) within the traditional organisational structure (the other face). This internal division often persists eventhough there is a general commitment to integrate sustainability agendas throughout all corporate processes.

DISCUSSION – THE MULTISTAKEHOLDER TRAP

In the multistakeholder context, which characterises especially the upstream life cycle of every food distribution chain, retailers find themselves trapped in a complex net of conflicting interests and trade-offs and therefore face a tightrope walk between conflicting external and internal strategies. For instance, this is the case for the following three areas: i) trade-offs in respect to diverging interests between the stakeholders (e.g. environmental NGOs vs. producers concerning the use of pesticides), ii) trade-offs concerning conflicting goals within the organisation of the retailer himself (e.g. CSR vs. purchasing department concerning price premiums for higher environmental standards), and iii) alleged demands by the consumers and the need for retailers to advocate them (e.g. aesthetical demands for vegetables vs. need to reduce food waste).

The use of pesticides can serve as a good example, where all three strings converge and where the two-faced retailer finds himself in an intricated net of diverging internal and external interests and changing coalitions. The most obvious actors here are the producers of fruit and vegetables, who are generally reluctant to restrict the use of chemical substances exceeding what is already regulated by state or community law; on the other side of the spectrum, environmental NGOs want a wideranging ban or massive reduction of ecotoxic, carcinogenic, and/or humantoxic substances. The retailer, on the one hand, has an interst in keeping prices low (thereby favouring the most cost-effective method of pest control over more expensive methods from organic agriculture) but, on the other hand, is prone to being saveguarded from attacks e.g. by civil society organisations because no measures have been taken in respect to potentially hazardous substances for the human health or the environment. Depending on the perceived risk, the retailer will choose the one over the other position, supporting the farmer on a low risk issue and rather being willing to pay a markup for more environmentally benign practices where the risk is perceived as high.

Coalitions revert completely by slightly changing the issue, for example considering uniquely pesticides used to get a certain aesthetic standard: in this case environmental NGOs argue alongside producers asking for less strict quality standards and thereby reducing the use of pesticides and costs for pesticide application, e.g. against late thrips infestation in the production of leek. The same coalition applies to food waste at farm level, where, depending on the product, a high proportion of the vegetables and fruit produced does not reach the shelf due to aesthetical requirements (only for some products alternative utilisation forms exist, e.g. juice production for apples) – see also contribution to this conference by Frieling et al (2013). In both cases, retailers tend to advocate a theoretical position of consumers (iii), claiming a reluctance to buy visually imperfect products.

In these cases, retailers use their strong position as gatekeepers and hinder significant environmental improvements – as it would be very difficult to quickly reverse a process they initiated themselves a few decades ago, without a general agreement in the retail sector to change these standards. However, this kind of industry-wide consensus is extremely difficult to achieve, as parochial thinking applies to almost all agendas and it is therefore very hard to bring all relevant players on a table and find a common strategy. Instead, the individual retailer prefers to shine alone on the stage with his own initiatives, even though the actual effect is much lower compared to what would be possible with a concerted action.

The lack of will for industry-wide action is one of the most relevant impediments for significant environmental improvements along the life cycle – especially when those improvements are connected to considerable financial investments in new infrastructure and/or perceived potential loss of customers, and the first-mover has to pave the way for his competitors, e.g. the introduction of deposit systems for wine bottles. In this case, state regulation is often the only option to remove the deadlock (e.g. the deposit system for plastic bottles in Germany).

Furthermore, as in most other consumer markets, media pressure and actions by competitors are strong drivers and / or amplificators of sustainability issues. However, even though all big Austrian retailers have already initiated sustainability programs, these initiatives are often counteracted by the well-radicated business-as-usual-dynamics over the whole life cycle. Most evidently, this applies to pricing policy. On the one hand, the retailer follows the current economic paradigm of profit maximisation and therefore tries to keep prices low and build up a strong competitive position; on the other hand, demands for higher environmental standards are followed by requests for higher prices by producers due to increased production costs, which in turn have to be met through markups. So, every single retailer has to trade off a good competitive position in the daily price war against the strategic mid- and longterm need to build up an image of a sustainable actor on the market. Moreover, price premiums for more sustainable products not necessarily reflect the magnitude of financial resources spent in sustainable production practices, but are rather a way to exploit a higher willingness to pay for 'green' products in some consumer segments and therefore get higher margins.

A last critical and related issue, where retailers could play an important role is in respect to consumer awarness. Numerous environmental problems related to consumption could be eradicated or at least considerably alleviated if consumers had a better understanding of those issues, for example about food waste or the seasonality of fruit and vegetables, and realise why a price premium is necessary to avoid some of them. This is of course an essential issue, which at the same time is hard to tackle, especially if one considers, that the proportion of household income spent on food has decreased continuously over the last decades (Statistik Austria, 2010). Of course, retailers are not the only actors to be blamed for this development as it can be regarded as a general tendency in contemporary consumerist society. As long as marketing efforts are principally focussed on price bargains rather than product quality including environmental, social and health impacts and the willingness to pay for those products with higher quality remains fairly low or restrained to certain consumer segments, no huge steps to eradicate systematic detrimental effects can be expected. However, an issue where retailers could give an important contribution is related to knowledge about consumer behaviour. Numerous studies (Auger and Devinney, 2007) have discussed the issue of the intention-behaviour-gap in respect to ethical / sustainable consumption. However, reliable and detailed data about the actual behaviour and the response to green marketing measures is still scarce and often only anecdotal. Sharing some knowledge with the scientific community and civil society organisations dedicated to a transition to more sustainable modes of production and consumption would therefore give a significant contribution to a better understanding of how to achieve more sustainable consumption patterns in the mid- and longterm.

CONCLUSION

Janus, the retailer, is far from taking over the role of the benevolent roman gatekeeper divinity. In fact, excerting enormous pressure on prices for the sake of profit maximisation and playing the role of the front player in the name of a culture where the perceived and actual value of food has reached a historical low-point, retailers are rightly held responsible for many detrimental environmental, social and health-related global developments. Future social, media-, market- and consumer-related, environmental and political developments will determine whether the role of retailers will (be able to) evolve from being prevalently stuck in business-as-usual behaviour to a market actor that fully takes over its responsibilities in respect to pressuring global environmental issues.

REFERENCES

Auger, P., & Devinney, T. M.. (2007). Do What Consumers Say Matter? The Misalignment of Preferences with Unconstrained Ethical Intentions. Journal of Business Ethics, 76, 361-383

Statistik Austria. (2010). Konsumentenerhebung 2009/10: http://www.statistik.at/web_de/wcmsprod/groups/b/documents/webobj/055865.gif

Frieling Dominik, Verena Stricks, Martin Wildenberg, Felicitas Schneider: The Beauty and the Beast – how Quality Management Criteria at Supermarkets create Food waste. Conference Proceeding LCM 2013.

INNOVATION AND PRODUCT DEVELOPMENT

Tuesday, Aug 27: 1:30 pm - 3:00 pm
Session chairs: Alejandro Chacón, Ecodiseno.cl, Chile
Rubén Carnerero, Ingurumenaren Kideak Ingeniería S.L., Spain

ACTIONABLE KNOWLEDGE TO DEVELOP MORE SUSTAINABLE PRODUCTS

Gunilla Clancy[1], Morgan Fröling[2], Magdalena Svanström[1] and Sverker Alänge[3]*
[1] *Chemical Environmental Science, Chalmers University of Technology, Göteborg, Sweden*
[2] *Ecotechnology and Environmental Science, Mid Sweden University, Östersund, Sweden*
[3] *Technology Management and Economics, Chalmers University of Technology, Göteborg, Sweden*
** 412 96 Göteborg, Sweden. Email address: clancy@chalmers.se*

Keywords: sustainability assessment; product development; scenario; team learning; management systems.

ABSTRACT

Companies need to develop more sustainable products to fit into more sustainable future markets, and there is need for ways to guide towards and compare sustainability already early in material or product development. How this can be handled has been studied through action research in a material development project aiming to develop wood-based materials to replace petroleum-based materials while ensuring a more sustainable product. A specific focus was put on creating actionable knowledge to facilitate innovation towards more sustainable products by translating and integrating significant product sustainability characteristics into each team member's specific area of expertise and everyday work. The insights are now used in different other on-going projects in a textile industry setting and in relation to companies' management systems.

INTRODUCTION

In order to stay in business in the long term, companies need to develop and offer more sustainable products. Achieving this involves many different considerations, such as impacts on the resource base, on climate and many other challenging aspects of human society as well as global market issues, like stakeholder interests, patents and policy instruments.

Literature on development of more sustainable products focus on different areas such as on raw materials, technologies, environmental impacts, customers' needs, scenarios as well as the company strategies and code of conduct. The complexity of developing more sustainable products requires many skills. Actionable knowledge (Argyris, 1996) is the knowledge that informs us of how to create and integrate these different skills into, in this case, a more sustainable product. It is, however, common to get stuck within a specific knowledge area or a way of working and only such new knowledge that can be seen as developing the expertise or the way of working is taken in and used. In addition, quality and sustainability staff functions have a tendency to do their job more 'in theory' than having a real 'in action' influence on value adding processes in their organizations (Book, Alänge, & Solly, 2006).

This short paper reports on insights and experiences gained from a research collaboration between industry and university, aimed to develop new wood-based materials that can replace non-renewable materials in products, while ensuring that the new product is also more sustainable than the reference product. The paper also describes further work around actionable knowledge, i.e. on providing useful and relevant knowledge for actors developing products, to facilitate the innovation of more sustainable products.

RESULTS & DISCUSSION

Review of sustainability assessment methods

A literature survey was carried out on sustainability assessment tools used today with emphasis on assessment parameters for comparing petroleum and wood as material resources. The survey was contrasted with the needs in a specific project. Existing gaps in knowledge were evaluated and further steps that needed to be taken were identified. The survey, analysis and results are reported by Clancy, Fröling, & Svanström (2013a) and a selection of the findings is presented below.

A diverse number of tools that can assess different attributes of product sustainability for parts of or whole product life cycles exist, like LCA (Life Cycle Assessment), Ecological footprint and SocioEcoEfficiency Analysis (SEEbalance). Clancy et al. (2013a) list elements of different methods that can be of use in a product sustainability assessment throughout a material development project. The methods identified are normally only suitable for comparing similar types of products or similar sets of impacts, while there is a lack of frameworks for dealing with sustainability impacts that are fundamentally different in character. One example is the comparison of using either renewable or non-renewable material resources, a situation which none of the methods can handle satisfactorily. Available methods mainly rely on quantitative data, thus, preferably assessing existing products with defined product systems and measured process data available. The analysis also identified a lack of product sustainability parameters on social progress and on impacts on ecosystem services, such as biodiversity.

Guiding in early product development – insights from action research

To gain a deeper understanding of the requirements and barriers in guiding product development towards a more sustainable product, experiences from work performed in a material development project were analysed and complemented with information from a literature survey (Clancy, 2012). Three often unstated fundamental conditions in assessing product sustainability in early product development were revealed:

- Product sustainability considerations are case specific and, hence, need to be established for every situation.
- Sustainability assessment implies a future-oriented assessment and no-one knows what the future will look like.
- Product development implies that the product system is under development and not yet clearly defined.

Various activities were performed within the project to provide input to the development of the process (guiding product development) as well as to provide input to the assessment itself. Experiences from such activities emphasise the challenges involved in interacting with the development team, e.g., in terms of motivating the team and in providing meaningful information to the team. The challenge of motivating and the difficulty in comparing different types of considerations verify the importance of having a shared vision and establishing relevant sustainability considerations for the specific case. Based on the analysis of the action research and available literature, a team-learning process for establishing sets of relevant product sustainability parameters was developed (Clancy, Fröling, & Svanström, 2013b). The suggested process emphasises the need of a shared vision and establishing relevant sustainability considerations for the specific case that are translated and integrated into practical meaning for every co-worker’s daily work thus making the knowledge actionable.

Early estimates of product environmental performance

In one of the efforts to guide development within the project, an LCA approach was applied to visualise environmental challenges to team members already in early phases of the material development work (Clancy, Fröling, Peters, & Svanström, 2010a). The LCA visualisation showed that, unless there are positive impacts in other areas that can compensate, environmental impacts from the production of the new material must be rather low if the product using the new material is to be more environmentally benign than the reference regarding most of the common environmental parameters. In particular, performance in terms of energy demand proved to be a challenge for the new material. The findings clearly illustrate the importance of the material development team’s awareness of important sustainability considerations for the product in development.

Considering resource limitations for wood-based products

The understanding gained in earlier reported work (Clancy, 2012; Clancy, Fröling, & Svanström, 2010b) is now taken further in a study of the choice between different bio based raw materials for textiles. The vast environmental, social and health issues connected to conventional cotton and the increased consumption of textiles has resulted in that the forest industry is putting efforts into developing wood-based textiles. Forest area and yield is, however, a limited resource. Much of the annual global yield is already utilised, e.g. for timber and pulp and paper production, and there is an increasing demand for bio-based fuels and materials for replacement of petroleum-based ones. The increasing competition for the biological production from the forests and the land area results in rising concerns regarding biodiversity and other ecosystem services. It is thus important to estimate future global demands on forestry and to visualise the results for the strategy and development departments, using scenarios, how biomass/wood can be used in a responsible way in products for the future. Such visualisations are being created in an on-going project. The aim is to create actionable knowledge so that companies’ can navigate in a sustainable way.

Ecolabels as apparel information carriers to designers and customers

The problem of providing meaningful information to different actors is the starting point for another on-going investigation looking into the connection between ecolabels and the design process of clothes. The analysis, so far, shows that there is currently very weak connection between ecolabels and designer´s work. The lack of connection is mainly due to that ecolabel criteria focus on ecological and social considerations in the supply chain and rarely has criteria on product level such as life span or aspects of use. This work confirms the earlier insight, that developers need actionable knowledge to see the link between their work and the sustainability impact of the final product, which is not provided to designers by current ecolabelling systems.

Understanding organisation for successful change
A shared vision in the development team is vital when developing more sustainable products, as discussed above. To successfully integrate a shared vision or to affect a changed behaviour, such as increased sustainability thinking in a company, requires understanding of how change can be created in the company and how the specific company's management system influences behaviour. In order to increase this understanding, a comparative study has been initiated of how sustainability is integrated into product development in two large international firms and how this integration is influenced by their management system. Preliminary findings show that the ways of creating sustainable products can be very different because of companies' history and specific management systems, which indicate that what is actionable knowledge may differ between different organizations.

CONCLUDING DISCUSSION

Sustainability entails a long-term commitment to and focus on the needs of coming generations, which conflicts with the normal time perspective of 1-10 years in the long-term planning procedures of companies. Approaches are thus needed that facilitate the integration of sustainability considerations, including long-term considerations, into material and product development processes before decisions that will have a profound impact on the sustainability performance of the final product are made.

Actionable knowledge is the type of knowledge that enables the creation of more sustainable products. The studies presented above all aim at contributing to actionable knowledge by identifying strengths and improvement areas and by suggesting ways to visualize and raise team's and individual's practical understanding and ability to develop sustainable products.

REFERENCES

Argyris, C. (1996). Actionable knowledge: Design causality in the Service of Consequential Theory. *Journal of Applied Behavioral Science, 32*(4), 390-406.
Book, S., Alänge, S., & Solly, B. (2006). Quality Management from a Company Development Perspective. *Paper 2 in Stefan Book's PhD thesis "Naturalizing Quality Managment - A problem of organizing in processes of change", Chalmers University of Technology, Göteborg.*
Clancy, G. (2012). *Guiding development of wood-based materials for more sustainable products* Licentiate, Chalmers University of Technology, Göteborg. http://publications.lib.chalmers.se/records/fulltext/166316.pdf
Clancy, G., Fröling, M., Peters, G. M., & Svanström, M. (2010a). *Environmental challenges when developing renewable materials to replace non-renewable materials - guidance from LCA studies.* Paper presented at the EcoBalance 'Towards & Beyond 2020' Tokyo.
Clancy, G., Fröling, M., & Svanström, M. (2010b). *The ageing society: An example of consequences for biomass use.* Paper presented at the MFA-ConAccount Meeting 'MFA for Sustainable Future', Tokyo, Japan.
Clancy, G., Fröling, M., & Svanström, M. (2013a). Changing from petroleum to wood based materials: critical review of how product sustainability characteristics can be assessed and compared. *Journal of Cleaner Production, 39*, 372-385. doi: 10.1016/j.jclepro.2012.07.027
Clancy, G., Fröling, M., & Svanström, M. (2013b). Insights from guiding material development for more sustainable products. *International Journal of sustainable Design, In press.*

BIO-BASED ENGINEERING PLASTICS A TOOL TO REDUCE CARBON FOOTPRINT

Linnea Petersson[1,], Harald Martini[1], Matteo Chiaravalli[2], Valter Patruno[2], Ulrika Överstam[1] and Lennart Swanström[1]*

1) ABB AB, Corporate Research, SE-721 78 Västerås, SWEDEN
2) ABB S.p.A., Low Voltage Product Division, Vittuone, Italy
* linnea.petersson@se.abb.com

Keywords: Bio-based thermoplastics; Polyamide; Low Voltage; Breaker; RCBO;

ABSTRACT

It is believed that the use of materials based on renewable resources can be used to improve the environmental performance of products. In this experiment the plastic used in a housing of a Residual Current Operated Circuit-Breaker (RCBO) was exchanged to two different partially bio-based plastics. The assembled prototypes were tested according to IEC-Standards and both bio-based plastics showed outstanding results. The reduction in carbon dioxide (CO_2) equivalents was around 40% for the housing itself, which unfortunately had a small impact on the final carbon footprint of the product. However, due to the large number of products produced per year the emission of CO_2 equivalents will be reduced by about 250 metric tons per year.

INTRODUCTION

Sustainable development has become an important topic for many companies, since reducing the carbon foot print of new products can result in a competetive advantage. It is believed that the use of materials based on renewable resources can reduce the amount of carbon dioxide accumulated in our atmosphere, since the carbon dioxide release at end-of-life is the same amount as the renewable resource harnessed during its cultivation (Krochta, 1997). The drawback with pure bio-based thermoplastics, like poly(lactic acid) or starch, is that they are biodegradable and many of them have inferior mechanical and thermal properties compared to the engineering thermoplastics used in power products today. Many power products have a long life-span, around 30 years, and it is important that the material properties stay the same during this time for safety issues.

Durable engineering thermoplastics based on renewable resources are currently available. Many of the large thermoplastic suppliers have a few bio-based materials in their portfolio. The durable bio-based thermoplastics use naturally occurring building blocks to form conventional thermoplastic materials, which perform equally to their fossil fuel base counterparts. Durable bio-based engineering thermoplastics are believed to have high growth potential, due to their vast area of use. It is currently possible to find bio-based polyamides, polyesters, polyolefins and polycarbonate blends. Polyamide is current the group of materials with the largest amount of variation of bio-based materials in the market: 4.10., 6.10, 10.10, 11 and polyphtalamide (PPA).

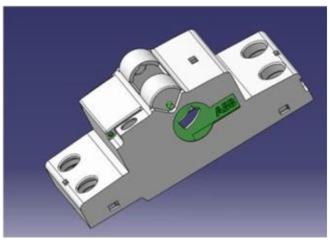
The goal of this work was to prove that the resources used to produce engineering thermoplastics will not affect the performance of the final material. To achieve this, two bio-based materials were incorporated into the housing of a low voltage product. A RCBO with over current protection was selected for the project, since this product has high demands on the housing due to the thermal environment inside the product during the breaking operation. The first material had a bio-based content of 49%, while the second material had 31%. The produced prototypes were type tested according to IEC-Standards. The bio-based materials showed outstanding results, which indicated that there is no problem using engineering thermoplastics that are partially based on renewable resources in low voltage applications. Life cycle analysis (LCA) of a circuit-breaker shows that the user phase stands for the highest emissions (ABB, 2005), which is a common phenomenon among ABB's products due to resistive losses and long life-spans. Low voltage products are often small and the material content is highly optimized. It is therefore important for ABB to look at all alternatives to improving the environmental performance of these products.

EXPERIMENTAL

Materials: The reference resin was a standard PA6 with 30 wt% glass fiber content and V2 performance. The bio-based materials tested were: DSM EcoPaXXTM Q-KGS6 (PA410, 30 wt% glass fiber, V0 with halogen free flame retardant) and RTP 2099 X 115387 B (PA610, 30 wt% glass fiber, V0 with halogen free flame retardant).

Manufacturing: A molding trial was performed on a conventional injection molding machine, using the existing production tools for the RCBO housing. The two parts produced are shown in Figure 1.

Characterization: The characterization of the bio-based resins was made on plates supplied by material producers, housings produced at the molding trial and on assembled products. The following tests were performed in this study: Glow wire test on molded RCBO prototypes (IEC 60695-2-10:2000 clauses 4-8), Moisture absorption using an internal standard (7 days at 30°C and RH 98%), Comparative Tracking Index (CTI) up to 600V and finally the assembled products were type tested according to IEC standard 61009-1:2010.

a) 

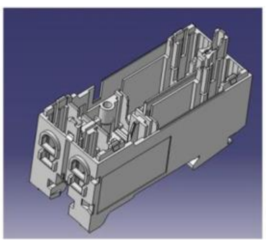
b) 

Figure 1 Drawings of the produced parts. a) Cover, b) Housing

RESULTS

The assembled prototypes passed the type testing according to the IEC standard 61009-1:2010, and the results clearly indicated that these materials can be used in low voltage applications.

The results from experiment also showed that the two tested bio-based materials had;

- Good dielectric properties, since no flashover or breakdown occurred during testing.
- High resistance against impulse voltages and short circuits.
- High reliability, since only a low temperature increase was detected during current testing.
- Low moisture absorption, which resulted in no deformation or warpage occurring during climate cycling with high humidity levels.

DISCUSSION

Bio-based engineering plastics – A tool to reduce carbon footprint

LCA of a RCBO shows that the user phase stands for the largest source of CO_2 (ABB, 2005), which is common among ABB's products due to resistive losses and long life-spans. Activities to reduce the carbon footprint of the product should therefore target the main cause behind the resistive losses. In this specific product the losses come from both resistive losses and contact losses. Contact losses are difficult to reduce; it often demands the use of alternative technologies. One can of course also try to reduce the weight and volume of the product, which will reduce the amount of material in the product and emissions due to transport. The RCBO used in this experiment has a low total weight (~200 gr) and contains about 80 parts. It is therefore easy to understand that weight optimization of individual parts is difficult to use as a route to reduce the carbon footprint of the product. Novel strategies are needed in order to reduce the carbon foot print of this type product. Using materials based on renewable resources can be such a strategy.

Bio-based materials are more CO_2 neutral than their fossil fuel based counterparts (Devaux). This can be explained by that CO_2 from biomass is part of a shorter carbon cycle compared to CO_2 from fossil fuel. CO_2 from biomass is fixed at an equal rate to which it is released and consumed. Figure 2 shows the sources of CO_2 emissions from the production of a bio-based polyamide (PA11). The emissions originate from both fossil fuel (agriculture and material production) and biomass (raw material). Using biomass as raw materials will reduce the CO_2 emissions of the final material, as shown in Figure 2. However, it is important that emissions from material production don't increase due to the incorporation of biomass.

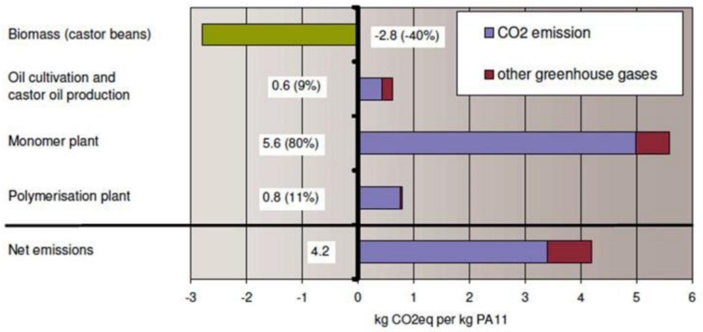


Figure 2 Breakdown of air emission by process step for the production of 1 kg PA 11 (Devaux).

In order to achieve sustainable development one also has to use renewable resources that do not cause any advert social effects. It is important that crops used for material production do not compete with crops used for food production. The renewable resource for bio-based polyamides is castor oil, which is derived from the seeds of the Ricinus Communis plant. This plant can grow on relatively poor soil, and therefore do not have to compete with crops for food production.

Arkema, a thermoplastic producer, has carried out an extensive LCA on their PA11 that is 100% based on biomass (Devaux). They showed that the global warming potential of their grade was less than half of an equivalent material based on fossil fuel (4.2 vs 9.1 kg of CO_2 eq / kg of plastic) (Boustead, 2005). In this experiment an extensive market search was carried out in order to identify bio-based materials that fulfilled the requirement specification. Unfortunately, no material fully based on biomass qualified, and therefore it was necessary to incorporate glass fiber reinforcement. By changing the material in the housing of the RCBO to a partially bio-based resin the change in CO_2 eq (100 years) / kg of resin will be reduced by around 40% (3.4 kg CO_2 eq (100 years) / kg of resin[1]). Even though the weight of the housing is low, about 70 grams, it will have a high impact due to the large number of products produced per year (~1.5 million products). The emission of CO_2 equivalents will be reduced by about 250 metric tons per year. This number corresponds to the emission from the use of 500000 kWh of electricity (European mix).

CONCLUSIONS

This work showed that small changes in carbon footprint on a single product can result in substantial reduction in emissions of CO_2 equivalents when looking at all the products being placed into the market. The product line's entire impact on the environment therefore always has to be considered besides the LCA results. Changing the resource for 7 grams of plastics in only one of ABB's large number of products can make a difference for the environment.

ACKNOWLEDGE MENTS

The authors would like to thank both DSM and RTP for their contributions to this project.

REFERENCES

ABB SACE SpA, 2005. Environmental Product Declaration, F200 2P. Registration number: S-P-00080, Rev 1 – 2005-07-20

Boustead, I. 2005. Eco-profiles of the European Plastics Industry: POLYAMIDE 6 (Nylon 6). PlasticsEurope, unpublished. (www.plasticseurope.org)

Devaux, J.-F., Lê, G., Pees, B. Application of eco-profile methodology to polyamide 11. Arkema, unpublished. (www.arkema.com/pdf/EN/products/technical_polymers/rilsan/rilsan_website_2011/rilsan_ecoprofile_article.pdf)

Krochta, J.M., and De Mulder-Jonston, C. 1997. Edible and biodegradable polymer films: Challenges and opportunities. Food Technology, vol 51, pp. 61-74.

[1] The figures are based on Arkema's calculations and a resin that is 70% bio-based (DSM EcoPaXX™ Q-KGS6.). Weight of glass fibers in the product has been removed.

LCM 2013

The 6th International Conference on Life Cycle Management in Gothenburg 2013

INNOVATIVE PRODUCT DESIGN AND RECYCLING: COMPARATIVE SUSTAINABILITY ASSESSMENT OF THE BUILDING MATERIAL POLLI-BRICK

Jannis Hegenwald, Robert Ackermann, Sabrina Neugebauer, Matthias Finkbeiner*

**TU Berlin, Department of Environmental Technology, Sustainable Engineering, Straße des 17. Juni 135, 10623 Berlin, Germany, Email: jannis.hegenwald@gmail.com*

Keywords: POLLI-Brick; sustainability; innovative; design; assessment.

ABSTRACT

In recent years, the number of reportedly sustainable or eco-friendly products has skyrocketed. One of the promising products in that number includes POLLI-Brick, a recycled building material designed to provide an environmentally friendly and sustainable alternative to common building materials. To measure this claim, the product must be evaluated over the entire product life with thorough assessment.

This case study assesses the functional and environmental performance of POLLI-Brick in comparison with its competitor TEXLON System. Through three assessments exploring areas of the building materials' life cycles, results indicate POLLI-Brick as the more environmentally sustainable product than TEXLON System. The case study shows that innovative product design, such as with POLLI-Brick, can reduce a product's environmental impact while increasing its efficacy.

INTRODUCTION

Accounting for over 30 percent of the global carbon footprint (UNEP DTIE Sustainable Consumption & Production Branch, 2009) and using up approximately 60 percent of all resources consumed in the world (Edwards, 2005), the construction sector is a critical contender to address in fighting climate change. From the choice of building material to the different construction processes to the energy consumed during the use phase of the building, the industry and its impacts on the environment are extremely diversified. Therefore, there are evident opportunities for improvement including the implementation of environmentally friendly technology.

In 2010, the Taiwan based design and architecture firm MINIWIZ developed POLLI-Brick, a new building material that is made from 100 percent recycled post-consumer Polyethylene Terephthalate Polymer. POLLI-Brick is most commonly used as a translucent sustainable curtain wall system or insulated interior partition with options for embedded lighting. Due to its honeycomb-like, self-interlocking structure it is "extremely strong, while weighing only one-fifth of standard curtain wall systems" (MINIWIZ, 2011). By using recycled post-consumer PET bottles as a building material, MINIWIZ is tackling three environmental problems at the same time: waste accumulation, resource scarcity and greenhouse gas emissions. As MINIWIZ is looking to launch POLLI-Brick into the German market, it is necessary to assess if the production process in Germany can facilitate the sustainable attributes of POLLI-Brick, similar to the production in Taiwan.

This paper examines POLLI-Brick's functional properties and environmental impact, in order to find out how POLLI-Brick's environmental performance ranks against its competitor TEXLON System.

MATERIALS AND METHODS

First, a comparative performance analysis is conducted to show potential operative advantages and disadvantages. This includes comparing different properties (thermal insulation, sound insulation, fire protection, weight, UV-resistance, translucency). qualitatively and quantitatively. Then, an energy analysis is conducted, using a model to simulate a practical application and compare the two building materials by energy used during the operation phase of the building. Following the functionality assessment, POLLI-Brick's environmental performance is analyzed through a cradle-to-gate life cycle assessment (LCA). Using the software GaBi 4, the LCA explores POLLI-Brick's environmental impact in several impact categories following the CML 2001 baseline. Like the functionality assessment, the LCA is designed to compare POLLI-Brick to TEXLON System. Since the information on TEXLON System is provided through an Environmental Product Declaration (EPD), the LCA of POLLI-Brick is conducted according to the same Product Category Rules (PCR), the EPD was created upon, as well as similar product specifics.

To provide a full life cycle assessment for POLLI-Brick in terms of a realistic application, POLLI-Brick's environmental performance over the whole life cycle is assessed using the model, which was designed for the energy analysis mentioned above. The simulation model was chosen to resemble a realistic project so that the results could be transferred to actual ventures. Based on the results of the assessments, areas for improvement as well as potential applications of POLLI-Brick are identified. This paper does not provide a generic life cycle assessment of POLLI-Brick. The LCAs conducted in this paper only report on the environmental impacts of a potential production process of POLLI-Brick in Germany, regarding the simulated model and the PCR. This paper also does not go into any detail considering the structure of the building used in the case study scenario or cover financial aspects. Other complex calculations such as Life Cycle Costing are not within the scope.

RESULTS

The functionality assessment showed significant advantages to POLLI-Brick in terms of thermal (+95 percent) and sound insulation (+70 percent), whereas TEXLON System proved to be the lighter building material, weighing about 75 percent less. The performance of the other properties is either close to equal (fire protection, transparency/translucency) or not comparable (UV resistance, wind pressure).

The results of the energy simulation showed a significant difference between the two building materials. Due to its better thermal insulation properties, POLLI-Brick used between 13-20 percent less energy than TEXLON System (depending on the scenario). Additionally, TEXLON System constantly uses up energy, as it requires constant provision of air to keep up the internal pressure in the cushions. Therefore, POLLI-Brick clearly shows the better performance in terms of energy consumption during the operational phase. The environmental assessment showed no distinct advantage for either material across all seven impact categories. POLLI-Brick displayed clear advantages in four categories (on average 30 percent less contribution), whereas TEXLON System outperformed POLLI-Brick in the other three (on average 25 percent less contribution), although one of them only by four percent. However, TEXLON System was significantly more economical in water and power consumption.

DISCUSSION

In summary, in the production and manufacturing phase of the products, both building materials show advantages and disadvantages, but there is no distinct trend in terms of which building material would be preferable, apart from the water and power consumption, which is clearly in favor of TEXLON System. However, considering the whole life cycle of a building material, in this case 25 years, the impact (e.g. greenhouse gases) of the production and manufacturing is small compared to the relevance of the operational phase, which accounts for 70-90 percent of the total energy use (cf. Rønning & Lyng, 2011). Looking at the functional properties and the operational phase, POLLI-Brick outperforms TEXLON System, especially when considering the full lifespan of 25 years. The advantage in the energy consumption during the operational phase (18873000 MJ) clearly outweighs the total energy necessary for the production, manufacturing, disassembly and disposal of the simulation model. The difference in the energy consumption during the operational phase is even more significant, when considering a building life cycle of 75 years, which includes three full life cycles of POLLI-Brick and TEXLON, which in return could multiply the different consumption values and would make the difference even bigger.

For POLLI-Brick, most of the impacts can be associated with the production of polycarbonate granulate and power generation. Therefore, it would benefit the product's environmental performance to redesign the product or the production process regarding the use of polycarbonate and look for more environmentally friendly solutions than polycarbonate, e.g. secondary material. Though there are only a few products from secondary materials that meet the requirements, it could be beneficial to consider these options.

The aspect of TEXLON System using less water and power in the production process seems to point towards TEXLON System being the favorable option for short term projects, such as pavilions, exhibitions or other non-permanent constructions. When looking at short term projects though, it is important to consider the aspect of a building material going through multiple short term uses over its lifespan. For short term applications, building materials need to be sturdy enough to bear the stress of multiple mounting and transports and they need to be easy to install. Due to its flexible modular structure, its high strength and its sturdy material, POLLI-Brick can be easily mounted and dismounted and endure mounting and transport strains over its lifetime. TEXLON System's ETFE foils are not as strong and sturdy as POLLI-Brick and its mounting and dismounting process appears to be less universal than POLLI-Brick's.

CONCLUSIONS

Although the results of this study should not be considered universally valid, they indicate that for the applications presented in this paper, POLLI-Brick is a more sustainable building material than TEXLON System. Moreover, the paper shows that the exclusion of life cycle stages can lead to flawed or biased results. The operational phase is especially important for building materials, as their performance indirectly causes a secondary impact and their life cycle is significantly longer than that of other products. POLLI-Brick shows that innovative solutions tackling these issues can have a significant impact on the environmental performance of a product.

In the case of POLLI-Brick, its production process in Germany and the comparison to TEXLON System, it would be advisable to conduct a comparative cradle-to-grave life cycle assessment of POLLI-Brick and TEXLON System, using more primary data from actual producers. This way, both life cycle assessments could be executed as similar as possible to guarantee a high level of comparability and thus produce more valid results. Specific attention should be paid to the optimal allocation of environmental burdens from secondary material. Furthermore, the use-phase of both building materials should be assessed in more detail, investigating both general environmental impacts during the operational phase, as well as different benchmarks for universally transferable types of buildings and construction.

The results of this paper also show that statements on the environmental superiority of one building material over another need to be developed carefully, as current frameworks leave room for individual adjustments, which can reduce the validity of comparative assessments. However, LCA, PCR and EPD are good ways to investigate building materials and identify advantages or disadvantages when comparing them.

REFERENCES

Edwards, B. (2005). *Rough Guide to Sustainability* (2nd ed.). London, England: Riba Enterprises Ltd.

MINIWIZ (2011). *POLLI-BRICK YOUR TRASH IS OUR BUILDING MATERIAL.* Taipei, Republic of China: MINIWIZ.

Rønning, A., Lyng, K. (2011). State of the Art Study - How is Environmental Performance Measured for Buildings/Constructions? In: Finkbeiner, M. (Ed.), *Towards Life Cycle Sustainability Management (pp. 141-152).* Berlin, Germany: Springer.

UNEP DTIE Sustainable Consumption & Production Branch. (2009). *Buildings and Climate Change: a Summary for Decision-Makers.* Retrieved by CAKE http://www.cakex.org/virtual-library/885

INTEGRATING LCA WITH DESIGN TOOLS (PLM, CAD)

Jean-Pierre THERET, Dassault Systèmes; 10 rue Marcel Dassault, 78140 Velizy, France ; Tel: +33(0)6 2080 5969; e-mail: jeanpierre.theret@3ds.com*

Damien EVRARD, Peggy ZWOLINSKI, University of Grenoble, G-SCOP laboratory, France; Tel : +33 (0)4 76 82 70 28; e-mail: evrard.d@gmail.com;

François WITTE, Yannick Le GUERN, BIO Intelligence Service, France; Tél : +33 (0)1 53 90 11 80; e-mail: francois.witte @biois.com;

Mario FLIEGNER, Pernexas, Germany. Tel: +49-173-3130871; email: mario.fliegner@pernexas.com

Michael SROCKA, Andreas CIROTH, GreenDelta, Germany. Tel. +49 30 48 496 031; email: srocka@greendelta.com

Keywords: Environmental Design, LCA, PLM, PDM, CAD

ABSTRACT

One of the barriers to green product design remains the cost to collect or to share data between Design and Environmental Design tools. The proposal is to favor sharing data between Environmental Design and Design activities, integrating the Life Cycle Assessment [LCA] tools with the Product Life Cycle Management [PLM] tools.

Three software prototypes will be presented based on the ENOVIA v6 PLM platform (by Dassault Systèmes) and Simapro, openLCA and the ReSICLED recycling tool. The options for the interface implementation, the data pattern mapping and the materials and processes reconciliation between PLM and LCA databases will be detailed with the benefits to support "Design for Environment" use cases and business scenarios. Perspectives of that work will be discussed.

INTRODUCTION

Current acute environmental challenges require that preventative approaches to environmental pollution be urgently deployed into day-to-day practices within manufacturing industries. Interconnecting Environmental Assessment tools with design tools, such as Computer Aided Design (CAD) and Product Lifecycle Management (PLM) tools, used for designing products based on "Life Cycle Thinking" is one of the emerging challenges that design software companies like Dassault Systèmes have to face.

The crux of this problem is not as simple as extracting the product CAD digital structure from a CAD Tool, i.e. the product "Bill of Materials" with all the Materials of the Parts, the corresponding weights, and other properties like Surface (for coating treatment) or the associated packaging, in order to send them as inputs into environmental assessment tools.

Efficient product stewardship requires that product and environmental information is shared among the design stakeholders and along the product design process. To address this issue, new concepts for design tools have been defined. A new product data model based on the triplet Product-Process-Resource (PPR) linked to the Product Lifecycle Phases has been proposed and is used to facilitate data mapping and exchange.

Different levels of Information and Communication Technology (ICT) interconnections between design tools and environmental assessment tools are proposed to support various business scenarios and the tool capabilities.

This paper describes three software prototypes implemented in the context of the GIPIE2.0 project, started in September 2010 and ended in November 2012, by Dassault Systèmes, BIO Intelligence Service, G-SCOP laboratory, Pernexas and Green Delta, and funded by the Department for the Competitiveness of Industries and Services of the French Ministry of Economy (DGCIS), following the GIPIE project (2008-2010) whose first results have been described in (Jean-Pierre Theret, 2010).

METHODS

Environmental Design starts with the collection of the product features along its lifecycle: Material Weights, Chemical Substances and Recycling properties of Materials, Energy and Raw Materials flows, Waste scenarios, corporate or suppliers' Assembly/Dismantling scenarios. Many of these data are available in PLM or CAD systems and may be shared with Environmental Design tools. This data sharing may be implemented along two ways:

- Either Environmental Design modules are **integrated** into CAD or PLM tools;
- Or Environmental Design tools are **interfaced** with CAD and PLM tools to exchange the data and to return the results.

SolidWorks Sustainability was the first proposal by Dassault Systèmes on 2010 of an integrated solution with an environmental dashboard of four indicators (CML 2001 method) to be available real-time and on demand in the SolidWorks CAD tool.

Because many other Manufacturers have started their Environmental Design studies with professional tools, like SimaPro, GaBi or EIME, the “interface” way between the ENOVIA PLM system and those tools was investigated. Here, the mapping of Materials & Processes from different tools is the main issue. Two methods have been tested:

- An **inclusive mapping** (or one-to-many) has been implemented for the Materials between the ENOVIA PDM tool and the ReSICLED recyclability tool for Electrical and Electronic Equipment (EEE). This is feasible because the ReSiCLED Materials database contains a small count of Material Families grouped in Categories: Polymers (PE, PP, ABS…), Metal (Steel, Aluminum, Copper…), Components (cables, screens, batteries, PWBs…).
- An **extensive mapping** (or one-to-one) has been implemented for the Materials and Processes between the ENOVIA PDM tool and the PPR extension, and the EcoInvent2 database using the mapping file of the EcoSpold1 XML format.

Another issue comes when designing complex products with a large number of Parts: addressing all the Parts individually is not possible, because it would be very time-consuming. Two approaches have been implemented:

- **Part Family** and automatic inheritance of LCA model from the Family to the Part. This solution is based on the existing concept, Part Family, in PDM system; that means the Part classification is not an additional work.
- **Material Family**, in accordance with the inclusive mapping described above; here the Material classification is an additional work, but it is done only once and can be reused for several usages of the Materials.

RESULTS

Three prototypes have been implemented based on these methods:

1 - Easing data collection from PLM to LCA with ENOVIA to Ecospold1 export

Based on the ENOVIA Product-Process-Resource data pattern, a mapping between the ENOVIA and EcoSpold1 concepts have been established:

- All ENOVIA Products, Processes and Resources map with a Process in the dataset;
- Resources are used as Input and may be associated to an Input Group;
- Parts and Processes are used as Output and may be associated to an Output Group;
- Quantities are managed using the Part Quantity and Unit of Measure from the Product BOM, taking into account the Functional Unit ratio of the Processes and Resources.

Categories for Simapro 7.3 have also to be defined, to locate the imported data in the targeted folders. Possible choices depend on: the Product network for LCI: either BOM oriented, or lifecycle oriented; and the type of Categorization: close to the network, or a single Category per SimaPro process type.

A prototype with a lifecycle oriented network and a single category for imported datasets was implemented. The EcoSpold1 mapping file was not generated and had to be built manually. It should be enriched when new Materials or Processes are established in ENOVIA to find out the matching in the EcoInvent2 database. This eventually becomes a problem because the declaration sections have to be written manually. Future work should include a way to generate this file.

2 - Run LCA from PLM with the eLCA interface between ENOVIA and openLCA

Even LCA models available within LCA tools (SimaPro, GaBi, EIME…), may be difficult to use for complex products because the data exchange activity is time-consuming. A direct connection between the PDM system and the LCA tool may ease that.

The eLCA interface between ENOVIA v6 and openLCA 1.2.8 (Michael Srocka, 2012) was implemented based on Part Family and Material Family existing information in the PDM side:

- The LCA Product Systems are built in the LCA tools; here openLCA is considered. They are defined for a given dimension: weight, surface, energy, volume, length.
- Then in ENOVIA, using the eLCA connector, LCA Containers are created and refers one or several Product Systems for a given Part Family; one is the default. A Life Cycle Impact Assessment (LCIA) method is assigned to the Product System.
- Parts are assigned a Part Family according to business rules (supposed existing).

- LCA Containers are assigned to Part Families; then, their default product System is assigned to the Part; it can be changed for another one from the Container.
- Then an LCA calculation is run for all Parts with a Product System: according to their dimension, the relevant attribute are applied to the Functional Unit. The result is an environmental footprint with indicators according to the LCIA method.

The ENOVIA-openLCA interface was implemented by Pernexas using native Java API and new ones implemented by Green Delta in the context of the open source openLCA project.

3 - Compute recycling & recovery rates with ENOVIA-ReSICLED interface

The ReSICLED Material Classification was created using the ENOVIA format and applied to the Bill of Materials (BOM) of our test case: the “IDevice” cell phone.

The Out-of-the-box XML export capability of the ENOVIA PDM platform was customized to flatten the BOM tree structure (ReSICLED uses only flat BOM – two levels), to include the Material Classification for each Material using the ReSICLED Family Name and to comply with the custom XSD pattern defined by Dassault Systèmes and G-SCOP Laboratory.

This new XML export capability for the Part BOM has been successfully tested with the online version of ReSICLED (Damien Evrard, 2011) based on XML file. The web services were not yet ready for use with a direct connection between ENOVIA and ReSICLED.

DISCUSSIONS AND PERSPECTIVES

The prototypes were implemented at the end of the GIPIE2.0 project and were not yet tested by manufacturers. Deploying a new data model like ENOVIA PPR requires a data migration activity that is not always possible for former version of Information System. In this case, PDM tool may be connected to professional search engine dedicated to Environmental Data that can also solve the issue of the data collection activity required by the Environmental Design activity.

In addition to the Environmental Design tools, new collaborative practices and associated tools are needed to enable stakeholders from various organizations (Designers, Engineering Experts, Project Managers, etc.) to share their knowledge and to collaborate during the design and review of new Products / Processes / Resources with both a holistic view and different levels of details for each expertise.

REFERENCES

Jean-Pierre Théret, Damien Evrard, Fabrice Mathieux, Yannick Le Guern, Patrick Chemla (2010). Integrating CAD, PLM and LCA: new concepts, data model, architecture & integration proposals. EnviroInfo conference, 2010-10-05, Ispra.

Damien Evrard (2011). Presentation of the ReSICLED software. http://genie-industriel.grenoble-inp.fr/recherche/resicled-un-outil-informatique-d-aide-a-l-eco-conception-performant-319821.kjsp?RH=1283439792057 , accessed on 20/07/2011, [in French].

Michael Srocka (2012). Presentation of the openLCA project; http://www.greendelta.com/openLCA.115.0.html?&L=1

LCA, ECODESIGN AND ETHICS FOR A COMPLETE REVISED COFFEE LIFE CYCLE: A TASTE OF INNOVATION

*Philippe Schiesser, écoeff *.*

ZI Mozinor – 2 à 20 avenue Salvador Allende – 93 106 Montreuil cedex

philippe.schiesser@ecoeff.com

Sylvain Grelet, écoeff Jean-

Pierre Blanc, Malongo

Delphine Brudoux, Malongo

Keywords: coffee; life cycle assessment; coffee maker; ecodesign; ecoinnovation

ABSTRACT

Malongo is a French roastery - founded in 1934. It evolved into a prominent company and became the French leader in fair trade and organic coffee markets, bringing its on supermarket shelves. Malongo prides itself on favoring quality over productivity, added a strong social commitment to its values in the early 1990s, joining Max Havelaar fair trade network.

With the entry into the market of ground coffee pods, and associated coffee makers, Malongo decided to differentiate itself with the association of its traditional values with a complete LCM (Life Cycle Management) of its products (coffee makers, pods, packaging, …).

All these improvements redesigned the production lines and uses and offered Malongo a clear advance and coherence in the coffee sector.

INTRODUCTION

Malongo is a coffee roaster located in Carros in south of France. It is a serious actor of sustainable development. Its commitment starts in the ‘90s by joining the Max Havelaar fair trade network. The firm formalized its environmental commitment in the mid-2000s by obtaining ISO 14 001 certification and being a leader in organic coffee, developing water based decaffeinated and integer LCA (Life Cycle Assessment) and ecodesign in its strategy. Since 2009, écoeff realized LCA studies on boilers coffee makers, coffee markers complete system and coffee pods systems.

Thank to these studies, Malongo developed a new pod made of paper and a new coffee machine named *Ek’oh!*. This coffee maker is produced in France whereas the old one that was produced in China. Consequently, the three pillars of sustainable development are taken in account in the Malongo strategy.

MATERIALS AND METHODS

Malongo uses four main tools in order to apply its LCM strategy. These tools are environmental certification, life cycle assessment, production relocation and ecodesign and ecoinnovation.

Environmental certification

In the mid 2000s, Malongo's managers felt like extending the company commitment toward a greater environmental responsibility. It obtained ISO 14001 certification with its environmental management, and started to ecodesign its packaging.

New pod material choice is also based on certification with the selection of FSC and PEFC certified paper and cardboard.

Life cycle assessment

Since 2009, several life cycle assessment studies were realized by écoeff according to international standards ISO 14040 – 44.

A critical review was realized on boilers study and another one is being completed on pods full system study. The latter deals with coffee life cycle from the green coffee cultivation to the pod end of life (taking into account transports, pod production, use phase with a capsule coffee maker and cup use).

For the pods full system life cycle study, écoeff determined the following functional unit : "Serve a cup of 40 ml espresso coffee extract in a coffee machine from a pre-measured pod" and choose to realize this study with Simapro 7.3.3, which is the world most used LCA software, and EcoInvent V2.2 database.

Seven pods were chosen for comparison. Scenario 1: Malongo paper pod, Scenario 2: Malongo plastic pod, Scenario 3: aluminium pod, Scenario 4: biosourced plastic pod, Scenario 5: PP/PET (Polypropylene/Polyethylene terephtalate) pod, Scenario 6: PP soft pod and Scenario 7: PP hard pod.

ReCiPe V1.07 (H) methodology was used for this LCA according to ADEME (French environment agency) and European Commission recommendations. Calculation was realized with midpoint and endpoint model and a single score was calculated. A consistency check was realized with Impact 2002+ model in order to confirm the less impacting pod system.

Production relocation

Designing a new pod and new coffee maker, forced Malongo to rebuild all its production line. Moreover, Malongo decided to relocate the production in France, thanks to a partnership with different actors (SMEs in the field of household appliances, researchers in the field of plastic and boilers…).

Ecodesign and ecoinnovation

Many technological and social innovations were made by Malongo in the coffee sector: vacuum-packed metallic boxes, water based decaffeinated coffee, strong partnership with fair trade producers, biodiversity projects (in Haiti, Guatemala, Belize, Salvador, Honduras, Nicaragua, Costa Rica and Panama), NFC technologies (near field communication)…

Ecodesign takes both in account, coffee makers and pods.

This snap-on assembling enables a high reparability of the machine. As the LCA study pointed out some parts of the machine – such as the over-consuming boiler, Malongo has been able to radically minimize the environmental impact of a coffee cup. The start-and-stop boiler introduced by Malongo in its last machine is one of the most sophisticated boiler and lead to a tenfold difference in use-phase electricity consumption.

Malongo was thus able to design an innovative coffee maker, totally dismountable, reparable and recyclable. In order to make it easier to repair the machine, a screwless design has been worked out.

The plastic pod was also redesigned in collaboration with Nordic companies (Korsnäs and Walki). For the first time on the market, a paper based solution was developed, offering a new way to decrease environmental impacts associated to packaging and pod. That paper is also FSC and PEFC certified, and the pod keeps intact flavor and aroma of artisan roasted coffee.

RESULTS

Life cycle assessment

A comparative LCA was carried out on seven B to C products and the study on the coffee makers permits to redesign the coffee maker 1.2.3. Spresso and ecodesign Malongo *Ek'oh!* new coffee maker.

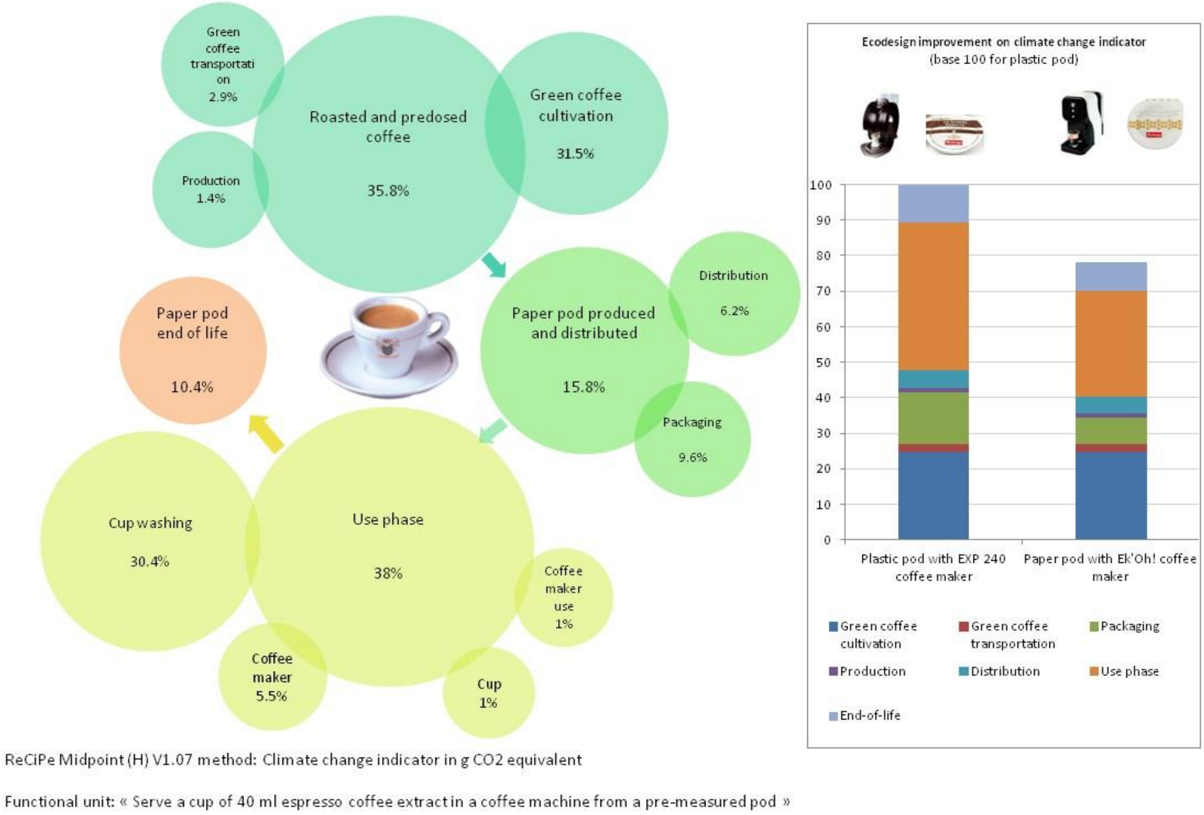


Figure 1 : Malongo natural fiber pod LCA results

Figure 1 permits to compare Malongo pods scenarii for climate change. The pods comparative LCA realized with ReCiPe (H) methodology permits to calculate an environmental single score. The new paper pod comes with the minimum, meaning it is the more environmental friendly package. From the cradle – including organic and fair trade coffee – to the grave – end of life of the coffee pod machine and the packaging – it gave priority to sustainability.

Production relocation

Pods production has always been realized in France.

In order to increase our coffee pods system sustainability, Malongo works with a French SME to produce *Ek'oh!* its new coffee maker. That relocation enables to ensure reactivity and reliability of the coffee maker. It reduces upstream and downstream transports and it provides a better after sales services.

Ecodesign and ecoinnovation

With the LCA studies results, Malongo R&D team ecodesigned pods and coffee machine. Replacement of plastic pods by paper, coffee pods become recyclable and oxo(bio)degradable, and coffee machine become reparable, more recyclable. Life span of the coffee maker had been increased by adding a 5 years warranty. Paradigm shift is also being thanks to lease purchase contract and associated after sales service. Moreover, that ecodesign enabled Malongo to file some 40 patents.

DISCUSSION

This study point that Malongo thanks to its life cycle management strategy is a driver of ecoinnovation in coffee sector. Innovations carried out by the company impact every sustainable development pillars and stakeholders of the coffee life cycle.

CONCLUSIONS

From a production perspective, all these improvements redesigned the production lines, and are offering to Malongo a clear advance and coherence in the coffee sector. The new factory will be completely built according to the highest environmental standards, in the next months.

LCA study permitted to demonstrate the lowest impact of new paper pod versus plastic one and five other capsule system.

REFERENCES

Goedkoop M., Heijungs R., Huijbregts M. et Al. (July 2012). ReCiPe V1.07 (2008) Revised (2012).

Responsabilité éthique d'entreprises 2011. (2011). Compagnie Méditerranéenne des Cafés Malongo.

Schiesser P., Grelet S. (2013). Analyse de cycle de vie d'une tasse de café pour le particulier. Comparaison de sept systèmes différents.

Schiesser P. (2012). Pratique de l'éco-conception en 53 outils. Dunod, 208 pages, ISBN 978-2-10-056518-4.

Schiesser P. (2011). Eco-conception Éco-conception: Indicateurs.Méthodes. Réglementation. Dunod. 198 pages. IBSN 978-2-10-053378-7

LCA FOR LIFT SYSTEMS

*Fredy Dinkel * and Cornelia Stettler, Carbotech AG, Switzerland.*
Carbotech AG, Postfach, 4000 Basel, Switzerland f.dinkel@carbotech.ch.

Keywords: LCA, Lift, Elevator, Relevance; eco design, EPD.

ABSTRACT

In the late Nineties Schindler had conducted a LCA to evaluate the relevant environmental impacts and find improvement potentials of their lifts. One important result was that the main environmental impacts don't result from the material production, processing and logistics but during the use phase and depending on the type of disposal. These results as well as eco design tools were used to improve the lift system and a recent LCA showed that the environmental impacts per functional unit could be halved compared to the old lift. LCA is still used for environmental decisions. This year, for example, the use of neodymium for motors was analysed with a LCA. Furthermore the LCA information is used for costumer information given as EPD type III declaration.

INTRODUCTION

In the Nineties the focus of ecological decisions was often on single pollutants or specific materials known to be problematic in regard to a specific aspect. In the late Nineties Schindler elevator Ltd wanted to know the comprehensive environmental impacts. So they conducted a LCA (Schindler, 1999) to evaluate the relevant environmental impacts on a sound base and find improvement potentials of their systems. For the disposal taking place in the future different scenarios were calculated. An adequate disposal and a worst case scenario were chosen taking into account the estimated percentages for recycling, incineration and landfill for the different materials and components. For the electricity in the use phase the European electricity mix was used. Different environmental indicators such as GWP, acidification, CED were calculated as well as single score indicators such as ecological scarcity (UBP 97) and eco indicator. The results of this old study are given in this paper, taking into consideration that UBP 97 was the most current method at that time.

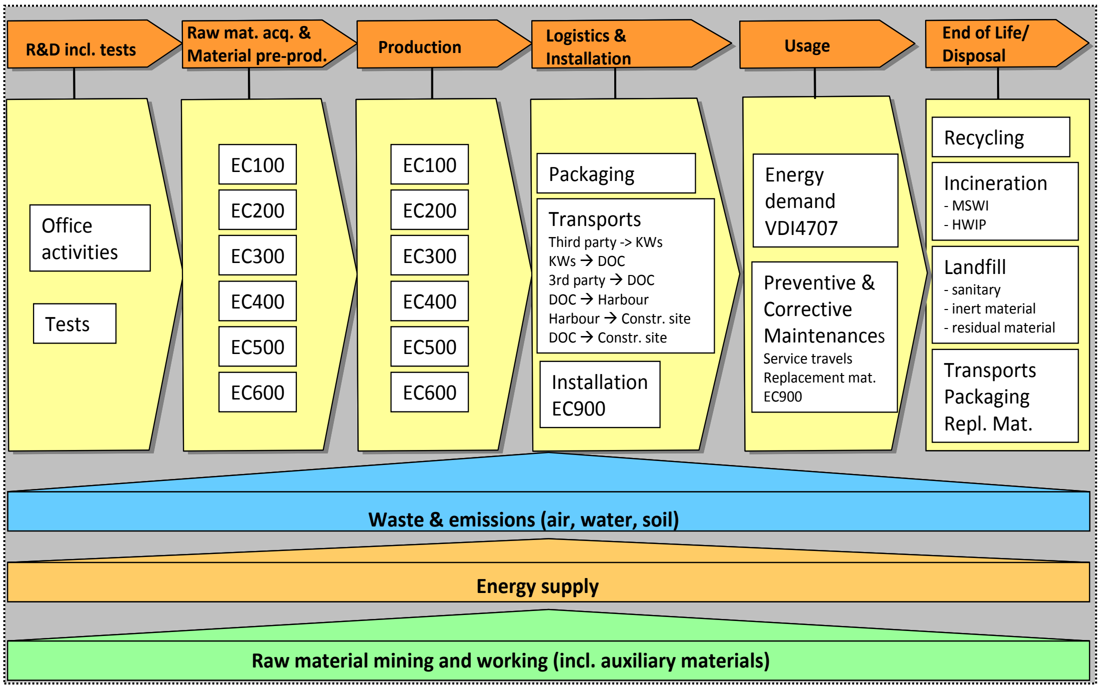


Figure 1: Life Cycle model for an lift used in the LCA.

LESSONS LEARNT FROM THIS FIRST LCA

At that time these results were more surprising for the environmental manager than they would be from today's perspective. The main environmental impacts arise during the use phase and in the worst case of disposal on the end of life treatment. The production of the materials, the processing and the logistics are of minor relevance. To improve the end of life impacts the customer care provided services for redemption and informed the customers about the importance of end of life. Concerning the use phase another astonishing result was that the impacts from the drive were less than 50%. The other impacts came from standby, ventilation, lighting etc. The R&D department was asked to reduce the impacts of the use phase. The environmental manager developed an easy to use eco design tool for the developer containing LCA indicators for the most relevant materials and possible alternatives enabling them to make their choices of the materials accordingly.

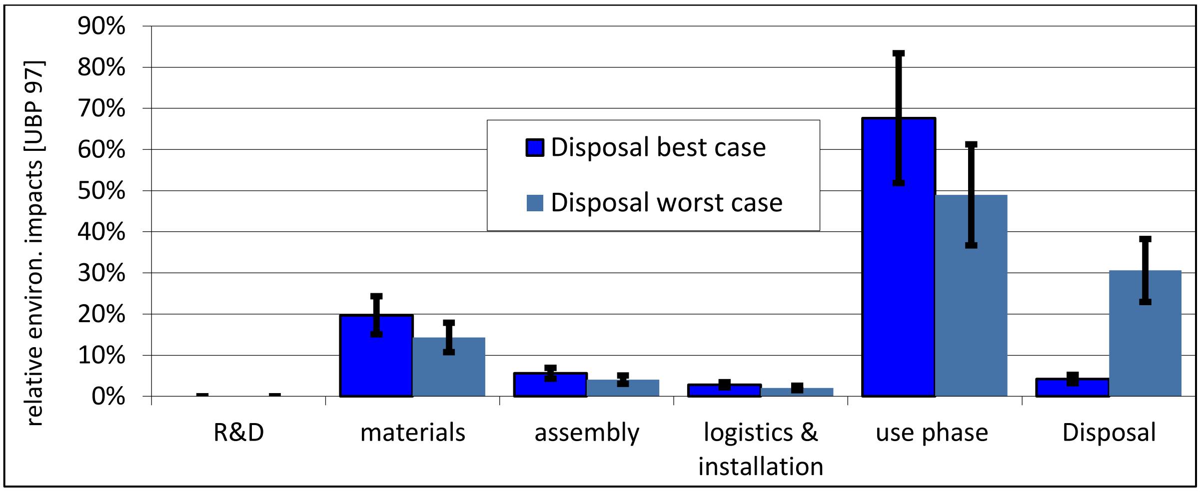


Figure 2: Environmental impacts of the main life cycle phases of the lift S100T in the year 1999 measured with the method ecological scarcity 97, life span 30 years. The black bars give the uncertainties as s.

RESULTS

In the year 2011 a full LCA was conducted on the follow up lift system (Schindler, 2011). For this LCA the eco design tool was used to provide the amounts of the relevant materials and processing steps.

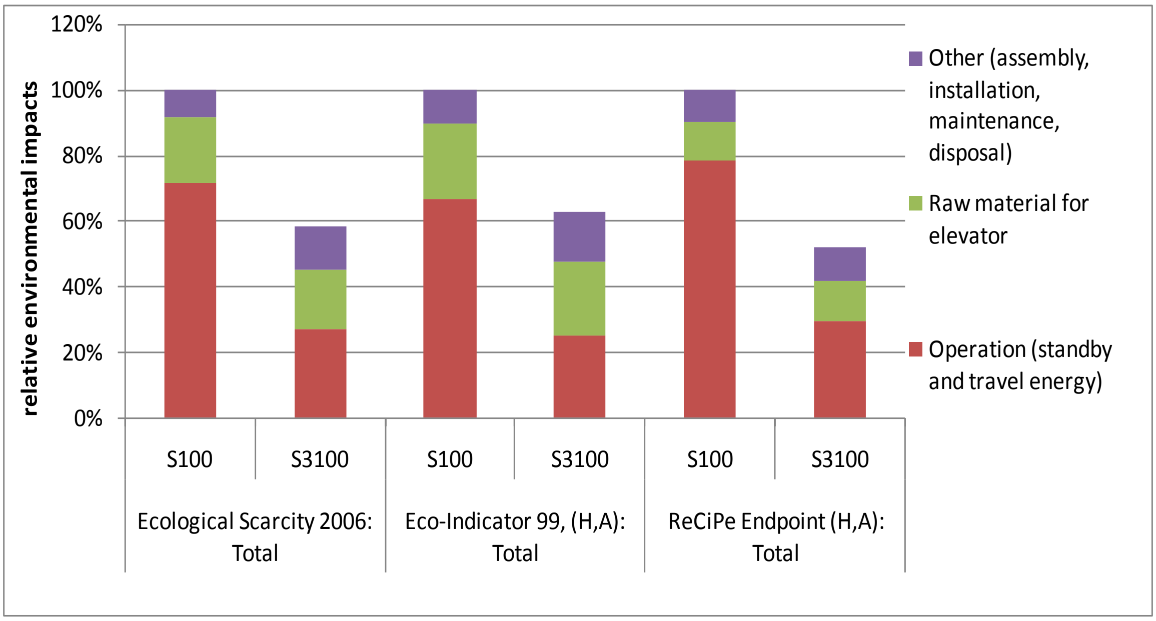


Figure 3: Comparison of the environmental impacts from the old lift (S100) and its successor (S3100)

This full LCA has shown that the environmental impacts per functional unit (t km) could be halved compared to the old lift system. This LCA also indicated the current hot spots. Now, because of the reduction in energy use the environmental impacts of the materials become more relevant.

DISCUSSION AND CONCLUSIONS

The LCA approach is still used for important environmental decisions because it is a powerful tool giving insights into the whole life cycle. This year, for example, a LCA was conducted to analyse whether from an environmental perspective, the use of neodymium for the motor is a good choice. This question rose because of the fact that synchronic motors with neodymium are more efficient on one side, while on the other side the production of neodymium is related to a variety of environmental impacts. For this purpose the production of neodymium metal from neodymium oxide, the magnet and the motor production were analysed using LCA and compared to an asynchrony motor as well as a synchronic motor with ferrite. This analysis showed that the production of 1 kg of Neodymium metal has higher impacts than other used metals. However because of the fact that the overall material use for a synchronic motor with neodymium is lower than an equal, synchronic motor with ferrite does not lead to higher environmental impacts. On the other hand the asynchronic motor tends to have lower impacts than the synchronic motor but also lower energy efficiency. So the overall analysis showed that the results depend mainly on the utilization and the electricity mix. The synchronic motor with neodymium is the better solution for lifts in the high rise segment. The asynchronic motor has advantages for small lifts with low trip numbers especially if the electricity mix used does not have high environmental impacts (Beuret, 2013).

Furthermore the LCA information is used for costumer information given as EPD type III declaration according to ISO 14’025.

REFERENCES

Beuret, R. (2013). Ökologischer Vergleich: Asynchronmotor versus Synchronmotor. *Internal document.*

The Eco-indicator 99. (2001). A damage oriented method for Life Cycle Impact Assessment. *Methodology Report, Third edition, PRé Consultants B.V., Amersfoort*.

Ecoinvent. (2010). Ecoinvent Data v2.2, *Swiss Center for Life Cycle Inventories, Dübendorf.*

Frischknecht R., Steiner R., and Jungbluth N. (2008). Life cycle analysis: methode of ecological scarcity. *Ökobilanzen*. Original title: Methode der ökologischen Knappheit – Ökofaktoren 2006. Methode für die Wirkungsabschätzungen in Ökobilanzen. *Öbu SR 28/2008*.

Goedkoop M. et al. (2012). ReCiPe 2008, a life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. http://www.lcia-recipe.net.

Häcker, J. (2013). Life cycle assessment PM-FM motors, *Master thesis at university of applied science North Western Switzerland, Muttenz* .

Schindler AG, Iqbal S. and Knöpfli M. (1999). Ökobilanzierung ausgewählter Standardaufzüge. *Internal document*

Schindler AG, Stettler C. and Dinkel, F. (2011). Life Cycle Assessment of elevators system S3100 EU.

REALIZATION OF LCA IN BUSINESS – LIFE CYCLE SIMULATION MODELS FOR PRODUCT OR TECHNOLOGY DESIGN

Julian Maruschke, Matthias Harsch, Judith Schnaiter, LCS Life Cycle Simulation GmbH.*
**Aspacher Str. 9, D-71522 Backnang, Germany; julian.maruschke@lcslcs.de*

Keywords: spreadsheet; models; LCA; LCC; business

ABSTRACT

The life cycle of products or technologies can be very complex and therefore the LCA approach is comprehensive. Hence, it is still a challenge to make LCA accessible to a broader range of practitioners in industry in order to integrate sustainable thinking in product development. Experience shows two main obstacles that prevent companies from applying LCA internally: the cost for specific software and the almost permanent demand of human resources. This paper describes how LCA can successfully be realized in any business by using life cycle simulation models based on spreadsheet software. Detailed life cycle models allow the ISO compliant calculation of a product LCA but can also be used to compare technologies or monitor and optimize processes.

INTRODUCTION

It is always emphasized that the LCA method is a scientific tool. Taking shortcuts must not dilute the high representativeness and robustness of results. Similarly, it has always been a vision to make LCA accessible to a broad range of practitioners in the industry. However, todays' business reality shows that it often takes profoundly trained and experienced experts and professional software tools to execute high quality LCA studies and establish life cycle thinking in business processes in a meaningful and profitable way. High cost for software and databases as well as the lack of capable in-house specialists are considered to be the main barriers for LCA to be a steadily integrated part of product development and design.

As a solution, the LCA community is discussing streamline LCA approaches for years and consultants are offering simplified LCA tools to be seamlessly integrated in product development processes. However, when applying such tools, it has to be guaranteed that simplification is not only realized at the expense of quality, transparency and meaningfulness of results. Beyond, streamline approaches must not simplify one part of the LCA but simultaneously adding complexity to another part of it. Practitioners still have to be able to sufficiently differentiate between alternatives (no over-generalization) and to trust in the comparability and appropriateness of used environmental background data (transparency).

This paper presents a solution that fulfills the high requirements of a scientific tool but still enables non-LCA-experts in companies to carry out LCA studies for their respective products, processes or technologies in reasonable expenditure of time and cost.

SPREADSHEET-BASED LIFE CYCLE SIMULATION MODELS

In order to come up with a practical solution for the above described situation it is crucial to recollect what is really essential to execute a high-quality LCA according to today's standards: The tool has to be flexible, transparent and easy to use in order to gain meaningful LCA results in adequate timeframe and at reasonable cost.

The execution of a LCA study is a well-structured and straightforward process. The essence always is a matrix, which combines the quantitative information of the life cycle inventory analysis with environmental impacts. The practitioner has to keep this matrix as small and transparent as possible. Most companies only produce few products or run only few processes, which are more or less comparable. This means that the matrix already is naturally limited. The solution is not a simplified general tool but a finite customized tool. Such a tool therefore can't cover anything, but if used for the target system, it guarantees highest transparency, representativeness, accuracy and quality. Spreadsheet-based life cycle simulation models represent successfully realized implementations of suchlike finite customized LCA tools.

The structure of spreadsheet models is kept simple and is strongly guided by the customers' needs. Depending on the scope, the system under study is categorized in reasonable subassemblies or subsections. For each of those there are reasonably parameterized product and/or process models created based on input-output analysis. This part of a spreadsheet model defines quantity and quality of involved materials, waste, emissions and kinds of energy and hence represents the life cycle inventory analysis. The information that feeds the quantitative life cycle inventory is primarily coming from bills of material, drawings, facility layouts, bills from the purchasing department and actual metering but also is extrapolated from external sources like patents and relevant literature. Raw data is reviewed according to goal and scope of the study and combined at the same level of detail and quality.

Then the resulting mass balance is linked to respective LCI datasets in order to calculate life cycle impacts. The chosen ecoprofiles originate from publicly available industry data, patents, literature, commercial and open source databases and internal calculations. If customers can provide specific datasets e.g. for onsite electricity generation, this will be preferred.

The interpretational part of the model usually consists of a spreadsheet summarizing the results and presenting customized charts for visualization. Optionally a normalization step can be included.

Using the capabilities of parameter variation, sensitivity analysis, scenario technique and dominance analysis, the models are fast and flexible tools for management and improvement decisions.

The benefits are obvious:

- Common spreadsheet software, which usually is already available in any company, can be used. This highly contributes to the models' transparency, easiness of use and adjustability. Also there is no additional cost for purchasing special software.
- Employees do not need extra training but can just start working with the tools right away.
- Since the tools are not bound to a specific database, the most appropriate available

LCI datasets can be used. LCA experts just have to make sure that only comparable datasets (in terms of quality, cut-off criteria, representativeness, etc.) are combined in one tool.

- The spreadsheet-based LCA tools are in compliance with ISO14040/44. They meet the criteria of an external review by an expert panel.
- The tools are highly flexible and thus extensible. In case a model was initially created to only cover essential parts of a system, more detailed sub-models can easily be added after a hot spot analysis. Also, models can be equipped with any desired impact categories and even with life cycle cost or social aspects (depending on available LCI data)

Those simple yet powerful and accurate tools are applied to almost any system (product LCA, process LCA, production site LCA) and serve individual purposes (product comparison, holistic technology benchmark, scenario analysis, analysis of optimization potentials, etc.).

IMPLEMENTATION IN BUSINESS - CASE STUDIES

LCS Life Cycle Simulation GmbH was founded in 1999 due to the growing demand for innovative holistic service concepts. The methodology – life cycle simulation – combines holistic and sustainable thinking with transparent spreadsheet-based simulation tools and internationally accepted standards. It can be used for any kind of system and is not restricted to a specific industry sector. LCS serves to a wide base of national and international clients in large enterprises, small and medium enterprises, research institutes and associations.

Product LCA at BSH Bosch und Siemens Hausgeräte GmbH, Munich, Germany
In 2005 LCS developed the first product LCA tool for BSH Bosch und Siemens Hausgeräte GmbH (http://www.bshg.com). This tool comprises the four main lifecycle stages – production, transportation, use and end-of-life (Saunders, 2013). The tool consists of a manageable, flexible spreadsheet-based set of tables. BSH Bosch und Siemens Hausgeräte GmbH uses the tool for retrospective and descriptive LCAs of existing products but also for quick scenario analysis to estimate impacts of future products. Although the resulting data are not published, they are available on request for customers and retailers. Starting to work with the tool and creating more and more LCAs for various products the practitioners gained knowledge with regards to absolute greenhouse gas emissions as well as the relative contribution of the four main life cycle stages. This awareness is constantly influencing the company's sustainability strategy (BSH Bosch und Siemens Hausgeräte GmbH, 2012).

The tool is currently updated in order to allow for adjustments with respect to product technology, LCA databases, materials and production techniques.

Production-site LCA/Process-LCA at Richard Henkel GmbH, Forchtenberg, Germany
Within the scope of the BMBF-funded project "Ehoch3" LCS built-up a spreadsheet-based LCA tool for Richard Henkel GmbH (http://www.metall-pulverbeschichtung.de). The model covered the entire powder coating facility i.e. pretreatment, adhesive water dryer, cooling zone 1, top coat application, top coat oven, cooling zone 2. Crucial parameters are consumption of gas, electricity and powder coating. In this case the LCA tool was linked to a Life Cycle Costing analysis. Within the project several measures to enhance resource

efficiency have been evaluated with the tool. CO2 and cost savings as well as pay back periods for investments have been verified.

After finalization of the “Ehoch3” project, the tool now serves Richard Henkel GmbH to monitor energy and material consumption and can be the basis for the ISO 50001 certification.

Future Technology LCA/Technology benchmark for Innoshade Project, EU Com. - FP7
Innoshade (www.innoshade.eu) is concerned with an innovative, nanocomposite-based switchable light transmittance technology, applied in various technical environments (Posset et al., 2005). LCS investigated the LCA of five electrically controlled state-of-the-art transmittance modulation devices including their production routes, ‘from cradle-to-gate’. Environmental strengths, weak points and optimization potentials in the industrial up-scaling process were identified. Ecoprofiles for relevant substances have been created from scratch with commercial LCA software and then implemented in spreadsheet-based LCA models for the various industrial applications. This allowed the entire project team to conduct an instant scenario analysis and to receive feedback of any changes in the environmental performance of the process after adjusting parameters.

CONCLUSIONS

Spreadsheet-based LCA tools include many advantages. However, the customization also bears a certain amount of limitation and rigidity. The initial effort of building the unique models has to be executed by experienced LCA experts before they are delivered to practitioners in companies. In terms of timeliness of LCI data the spreadsheet-based LCA tools are considered equal with commercial LCA software. The effort for model maintenance should be lower due to a limited scope and higher transparency.

The key to implement LCA in business is to recollect what is really essential to execute a high-quality LCA according to today’s standards. Practitioners need a flexible, transparent and manageable tool to handle LCA in adequate timeframe and at reasonable cost. Spreadsheet-based, customized LCA tools represent a practicable, proven solution for any life cycle related investigation.

REFERENCES

BSH Bosch und Siemens Hausgeräte GmbH. (2012). *Sustainability report 2011. Top performance. With responsibility.* Munich, Germany: Author. Retrieved from http://www.bsh-group.de/presse/fileadmin/publication/Englisch/BSH_Sustainability-Report_2011_english.pdf

Posset, U., Harsch, M., Rougier, A., Herbig, B., Schottner, G., & Sextl, G. (2012). Environmental assessment of electrically controlled variable light transmittance devices. *RSC Advances, 2012, 2, 5990–5996.* DOI: 10.1039/C2RA20148H

Saunders, K. (2013). Realisation of LCA in business- lifecycle simulation models for product design or technology. How does Bosch Siemens Hausgeräte’s improved LCA methodology compare with existing international LCA methodologies. *Internal document of BSH Bosch und Siemens Hausgeräte GmbH, Munich, Germany.*

TARGET THE USE PHASE! DESIGN FOR SUSTAINABLE BEHAVIOUR

Renström, S., Selvefors, A., Strömberg, H., Karlsson, I.C.M., Rahe U.*

*Division Design & Human Factors, Department of Product and Production Development, Chalmers University of Technology, SE-412 96 Gothenburg, *e-mail: mak@chalmers.se*

Keywords: design; behaviour; sustainability

ABSTRACT

One approach to further decrease the environmental impact of products is to target the use phase. According to the Design for Sustainable Behaviour approach different design strategies can be used to enable a more sustainable use of products by influencing the user's behaviour. The strategies suggested include matching products to users' current behaviours, enlightening users, spurring or steering the users towards more sustainable behaviours, and applying a force dimension to the products. Empirical studies demonstrate the feasibility of different strategies. However further knowledge is needed on which strategies to apply in which situations and for what problems.

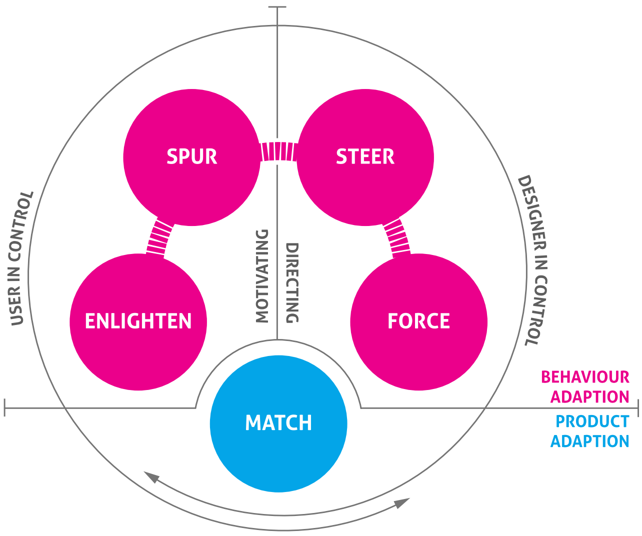
INTRODUCTION

The use phase is a large contributor to the environmental impact in many products' life cycles (e.g. car use). One approach to address this is technological development (e.g. improved fuel efficiency) but this is unlikely to lead to the desired results due to e.g. rebound effects (e.g. the car is driven faster and further). Another way forward is to change people's use behaviour through changing their attitudes but recent research has shown that the relation between attitude and behaviour is weak. Yet another approach is to influence behaviour by education (eco-driving) but it has also been found that users often find it difficult to turn theoretical knowledge into actions. The Design for Sustainable Behaviour (DfSB) approach suggests that different design strategies can be used to enable a more sustainable use of products by influencing the user's behaviour at the point of interaction and hereby bridging the intention–behaviour gap.

DESIGN FOR SUSTAINABLE BEHAVIOUR

Different DfSB strategies have been brought together in a model including five main categories (Lidman & Renström 2011): Match, Enlighten, Spur, Steer and Force (see fig).

The category *Match* contains strategies for adapting products so that they fit users' existing behaviour and fulfil their goals, but in a less environmentally harmful way. Within this category, frameworks such as Life Cycle Analysis, Cradle-to-Cradle, and Biomimicry can be used in part to address the environmental impact of the use phase. However, *Match* strategies also include more tailored strategies such as functionality matching. An example of functionality matching is automotive so-called start-stop systems, a mild form of hybridisation that shuts off the car's engine when the driver stops at a red light or in a queue, and turns it on again when the driver selects a gear. Depending on traffic and road type, fuel consumption can be reduced by 9-15% along with reduction of emissions of for instance NO_x and CO (Merkisz et al., 2011).



In contrast to Match, the other four categories all contain strategies that aim to change the user's behaviour in some way. The Enlighten category includes strategies that aim to influence users' knowledge, values, attitudes, and norms and hereby motivate them to change their behaviour. Users can be influenced for example by being informed about environmental issues, by being instructed on how to behave in a less resource consuming way, by making them reflect on the consequences of their behaviour, or by reminding them of pro-environmental values and norms in particular situations. A commonly used strategy within this category is giving feedback to the users on the consequences of their actions. In a study by Strömberg and Karlsson (2013) 54 bus drivers were supplied with an in-vehicle support system to enhance their adoption of eco-driving. The drivers were given real-time feedback on their performance on five driving parameters related to fuel-efficient driving: fuel consumption, speeding, harsh decelerations, idling, and use of momentum, so that they would be able to link what type of behaviour led to decreased fuel consumption. Through reducing for example harsh decelerations by 66% and instances of speeding by over 40% the drivers managed to reduce their total fuel consumption by 6,8% compared to baseline measurements. The drivers had a positive attitude towards eco-driving but because of other factors, such as lack of organisational support, conflicting job requirements, and technical problems with the system, the drivers gradually decreased their use of the system over the three-week trial. Their difficulties with translating knowledge into practice demonstrate the necessity to consider whether users are able to perform the behaviour they are being instructed to do.

Providing feedback on household energy consumption is a similar example of enlightening users that has proven effective (e.g. Fischer, 2008). However, combining enlighten strategies with different ways of spurring users can increase motivation and reduce consumption even further (Dwyer et al., 1993). Strategies that *Spur* more sustainable behaviour include for instance incentives and competitions that encourage and tempt users to perform a specific behaviour. During a six-months field study Selvefors et al. (2013) studied a web portal that combines enlighten and spur strategies to assess the effectiveness of this solution in influencing the electricity consumption of 23 households. The web portal aimed firstly to enlighten the users by providing real-time feedback and historical comparisons, and secondly to spur the users by including normative comparisons and goal setting incentives through energy challenges. Furthermore, the social incentives to reduce consumption were strengthen by enabling the users to post comments on the web portal and discuss energy conservation measures. The households that used the portal more regularly managed to reduce their electricity consumption by an average of 9% compared to their consumption during a corresponding period the previous year.

The study suggests that these types of solutions can motivate and spur people to reduce their consumption but there are also other influencing factors. The findings reveal that personal capabilities (e.g. financial situation) and contextual factors (e.g. available technology) impact the households' actual possibility to change their habits and reduce their energy consumption long-term.

One way of addressing the contextual factors and to *Steer* behaviours in a more sustainable direction is to consider the resource using product itself. To achieve this, the sustainable behaviour should be facilitated and be the most apparent way of using the product, for instance through clear affordances (Norman, 2002; Wever et al., 2008). More resource consuming ways of using the product should instead be made more difficult. To explore the possibility of steering through product design, two different washing detergent packages were designed with the purpose to induce moderate dosing and then evaluated in a four months field trial involving eight households (Lidman et al., 2011). The first package had an inner construction so that only a fixed amount of washing detergent poured out each time the package was tilted. For a standard wash, three such tilts were needed. This way, the users were steered and correct dosing was facilitated as the users could easily count the number of tilts. The second package contained washing detergent tablets (unavailable where the evaluation was carried out). The washing detergent tablets gave the users a simple cognitive script to follow when dosing and made it impossible to thoughtlessly pour washing detergent. In the field trial, the users of both types of washing detergent dosed as recommended. Ten participants adopted the products as they appreciated being steered towards moderate dosing and that no mental effort was needed in the procedure. However, one participant rejected the tablets, as she did not accept being steered and losing control. Thus, the findings indicate that when applying steer strategies the person's wish for control must be considered.

In the category *Force* all strategies compel the sustainable behaviour upon the users by making the undesired behaviour impossible for instance through limiting a product's functionality. An example is a washing machine that automatically adds a suitable amount of washing detergent. The difficulty with applying these types of strategies is not to make them efficient, but rather to render acceptance from users. Some users might find such a washing machine too controlling while others will accept the functionality and even find it convenient. An opportunity to acquire acceptance for products with a force dimension is to introduce innovative products with new use principles as a novel use situation may make it easier to accept that new behaviours are required.

DISCUSSION AND IMPLICATIONS

Several studies have concluded that the use phase is a significant contributor to the environmental impact in a product's life cycle. Additional studies have demonstrated the difficulty associated with changing users' behaviours. The DfSB approach offers a range of different strategies that add to the development for sustainability toolbox. The examples provide evidence of how a product can be designed to enlighten or spur a more sustainable use behaviour as well as how a particular product's design can enable or steer a user to behave in a less environmentally harmful way. The proposed model (Lidman & Renström 2011) offers a tool when designing solutions. However, in order to increase its usefulness a key issue for the future is to develop further knowledge on which strategies are most efficient in which situations and for which problems. Such a model has been proposed by Zachrisson and Boks (2010) but it has limitations as it is primarily based on user attitudes towards the specific behavior of interest and does not consider the situational and contextual factors which have been identified as important. Ölander and Thøgersen (1995) conclude that otherwise motivated and able people will not perform a specific behaviour if the contextual factors do not provide the opportunity to perform or enable the desired behaviour.

The examples illustrate the importance of a more holistic perspective and use and user-centred approach. When designing for a certain behaviour a thorough understanding of the users, their attitudes and values, behaviours and habits is fundamental but investigations must reach the 'point-of-interaction'. Such in-depth user studies were for instance able to demonstrate how a certain principle for heating water in a coffee maker triggered a use behaviour that resulted in the water being heated not once but several times before the coffee was consumed (Thornander et al. 2011). Equally important is to understand the contextual factors that influence the users actual or perceived ability to behave in the desired, sustainable way.

REFERENCES

Dwyer, W.O., Leeming, F.C., Cobern, M.K., Porter, B.E., Jackson, J.M., 1993. Critical Review of Behavioral Interventions to Preserve the Environment. Environment and Behavior 25, 275-321.

Fischer, C., 2008. Feedback on household electricity consumption: a tool for saving energy? Energy Efficiency 1, 79-104.

Lidman, K.M.E., Renström, S. 2011. How to design for sustainable behaviour? A review of design strategies and an empirical study of four product concepts. Master thesis. Chalmers University of Technology, Göteborg

Lidman, K.M.E., Renström, S., Karlsson, I.C.M, 2011. The green user. Design for sustainable behaviour, IASDR Conference 2011, Diversity and unity, Delft, the Netherlands, pp. 1-12.

Lockton, D., Harrison, D., Stanton, N., 2010. Design with Intent: 101 patterns for influencing behaviour through design. Equifine, Windsor, Berkshire.

Merkisz, J., Pielecha, I., Pielecha, J., Brudnicki, K., 2011. On-road exhaust emissions from passenger cars fitted with a start-stop system. Archives of Transport 23, 37-46.

Norman, D.A., 2002. The Design of Everyday Things. Basic Books, New York.

Selvefors, A., Karlsson, M., Rahe, U. 2013. What's in it for the user? Effects and perceived user benefits of online interactive energy feedback. Paper submitted to the ERSCP-EMSU conference, June 4-7.

Strömberg, H.K., Karlsson, I.C.M., 2013. Comparative effects of eco-driving initiatives aimed at urban bus drivers - Results from a field trial. Transportation Research Part D: Transport and Environment 22, 28-33.

Thornander, S., Karlsson, M., Bakker, C. (2011). Predicting Energy Thieves. Proceedings from Conference on Sustainable Innovation 2011, 'Towards Sustainable Product Design', 24-25 October 2011, Farnham Castle, Farnham, UK, 193-201.

Wever, R., van Kuijk, J., Boks, C., 2008. User-Centred Design for Sustainable Behaviour. International Journal of Sustainable Engineering 1, 9-20.

Zachrisson, J., Boks, C. (2010). When to apply different design for sustainable behaviour strategies? ERSCP-EMSU Conference, Delft, The Netherlands, October 25-29, 1-20.

Ölander, F., Thøgersen, J., 1995. Understanding of consumer behaviour as a prerequisite for environmental protection. Journal of consumer policy 18, 345-345.

GOVERNANCE OF CRITICAL RAW MATERIALS

Tuesday, Aug 27: 1:30 pm - 3:00 pm

Session chairs: Maria H Ljunggren Söderman, Chalmers University of Technology, Sweden
Steven B Young, University of Waterloo, Canada

DYNAMIC SUBSTANCE FLOW ANALYSIS OF NEODYMIUM AND DYSPROSIUM ASSOCIATED WITH NEODYMIUM MAGNETS IN JAPAN

Nobuo Sekine, Ichiro Daigo, Yasunari Matsuno and Yoshikazu Goto. Department of Materials Engineering, Graduate School of Engineering, The University of Tokyo. 7-3-1, Hongo, Bunkyo-ku, Tokyo, 113-8656 Japan, email:sekine@mfa.t.u-tokyo.ac.jp*

Keywords: substance flow analysis; neodymium magnet; in-use stock; recycle potential; resource management.

ABSTRACT

The recycling of neodymium (Nd) and dysprosium (Dy) is of great interest to industry because of the rapid increase in demand for Nd magnets and the limited availability of the resource. This study characterized the flows and stocks of Nd and Dy associated with Nd magnets in Japan and then evaluated the economic feasibility of recycling Nd magnets. Dynamic substance flow analysis of Nd and Dy in Japan was conducted using data from 1984 to 2010. A bottom-up approach was employed in the analysis to prepare time series of consumption by end use. The results of this study will contribute to the establishment of better recycling systems of Nd and Dy.

INTRODUCTION

Neodymium (Nd) magnets[1)], a type of rare-earth magnet, are the most powerful permanent magnets. Nd magnets are made from neodymium, iron and boron and are used in many products because of their high efficiency and downsizing potential. Moreover, dysprosium (Dy) is added to Nd magnets to improve their heat resistance. Recycling of Nd and Dy is of great interest to industry because of the rapidly increasing demand for and limited availability of these elements[2)]. However, Nd and Dy are seldom recovered from end-of-life products, and the recycling potentials of Nd and Dy have rarely been quantified.

Material flow analysis and substance flow analysis (SFA) are useful tools with which to determine the flow of materials and substances. Moreover, we can estimate the stock of a material or substance using dynamic models considering product lifetimes. Shi et al. (2010)[3)] conducted dynamic SFA of Dy in Japan by categorizing the end use of Dy into four groups and characterizing the flows and stocks of Dy. The present study determines the flows and stocks of Nd and Dy associated with Nd magnets in Japan through dynamic SFA and quantifies the recyclability of Nd and Dy.

METHODS

Dynamic SFA
SFA is a method for calculating the flow of a specific substance in a defined system. We employed dynamic SFA to calculate the flows and stocks of Nd and Dy in Nd magnets in Japan. The end uses of Nd magnets were categorized as shown in Table 1. We estimated time-series data for the domestic consumption and the entering into use of Nd and Dy in each end-use category for the period 1984–2010 in Japan. A bottom-up approach was employed using the magnet use per product and a range of Nd and Dy contents in the magnets for each end use. In-use stock and discards of Nd and Dy were estimated through dynamic SFA, according to a time series of entering into use and a lifetime distribution for each end use. We did not evaluate acoustic equipment because data were unavailable.

Table 1 Semiproduct and end-use categories

Semiproduct		End use
Motor	Driving motor of HEVs	Automobile
	EPS	
	Other	
		Air conditioner
		Washing machine
		Refrigerator
		Factory automation
Voice coil motor		Desktop computer, laptop computer, cellular phone, camera
MRI equipment		MRI devices
Laser pickup		DVD/BD/CD/ MD recorder/player, CD/MD boom box, micro component system, car navigation system, stereo set, in-car DVD/CD/MD player, desktop computer, laptop computer
Acoustic equipment		Microphone, loudspeaker

*HEV: hybrid electric vehicle, EPS: electric power steering, MRI: magnetic resonance imaging

Evaluation of recyclability
The recycling of Nd and Dy needs to be economically feasible. We evaluated the economic feasibility of recycling Nd magnets. The evaluation considered the costs of recycling processes including collection, separation, degaussing, transportation and refining, and revenues from recovered materials including Nd, Dy steel, and copper. In-use stocks can be regarded as having recycling potential. In-use stocks classified into end uses, which were derived from dynamic SFA, represent the magnitude of recycling potential by end use. We refer to feasible recycling potentials as ‘reserves of the urban mine’. We obtained recycling costs and revenue data and evaluated the economic feasibility of recycling the driving motors

of hybrid electric vehicles (HEVs) and the motors of air conditioners, which account for approximately 50% of the recycling potential.

RESULTS

Dynamic SFA
We characterized the Nd stock and flow for the period 1984–2010 in Japan. The result for 2010 is shown in Figure 1. We estimated the in-use stock of Nd to be between 5200 and 8200 t at the end of 2010; this accounts for about 4%–6% of global in-use stock[2)]. We also found that the amount entering into use (680–1200 t/y) was about half the amount of domestic consumption (1700–2200 t/y) because much of the Nd was in final products exported from Japan. Figure 1 also shows the Dy stock and flow. The Dy stock in use was estimated to be 540–1100 t at the end of 2010; this accounts for about 6%–12% of global in-use stock[2)].

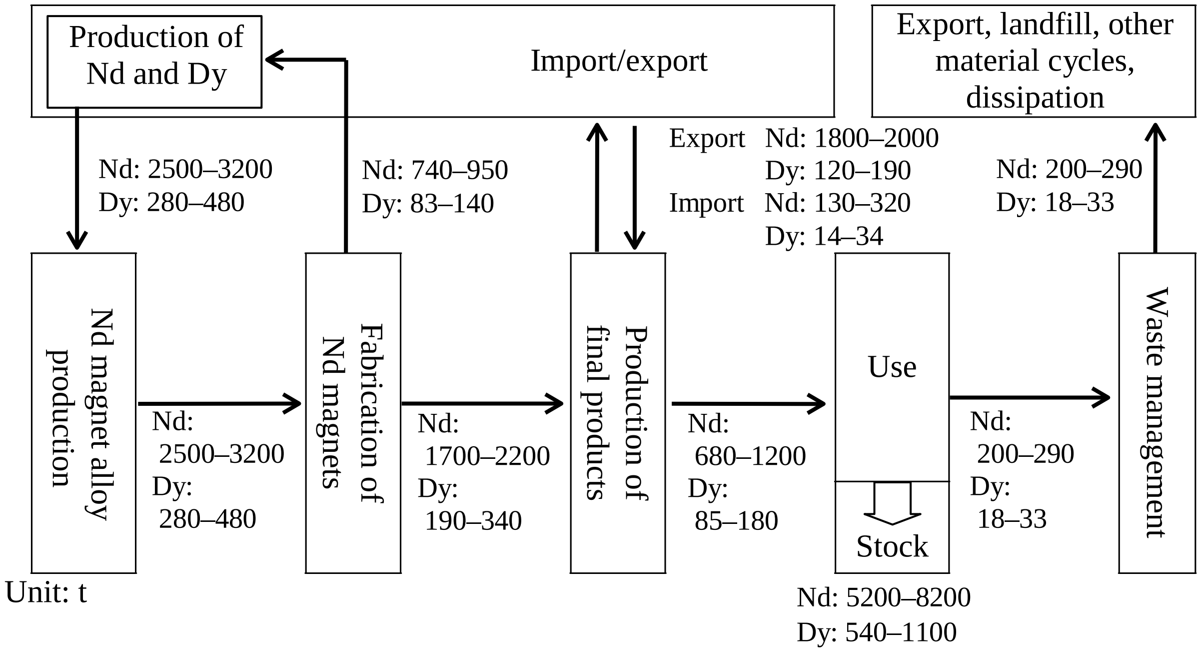


Figure 1 Substance flow of Nd and Dy in Japan in 2010

Evaluation of recyclability
We evaluated the economic feasibility of recycling Nd magnets at the end of 2012 in Japan, as shown in figure 2. We found that recycling the Nd magnets from end-of-life driving motors of HEVs is economically feasible. However, magnets recovered from end-of-life air conditioners cannot be recycled economically. Nd and Dy reserves of the urban mine were evaluated as 290–780 and 100–230 t, respectively.

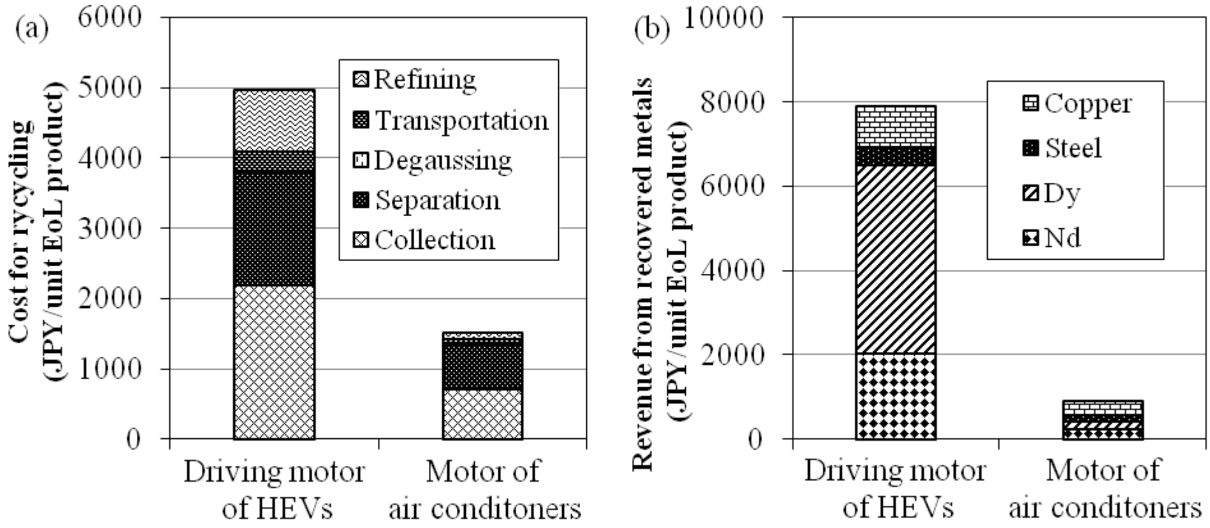


Figure 2 (a) Costs and (b) revenues of recycling products containing Nd magnets

DISCUSSION

Even if all end-of-life Nd magnets were collected and recycled, secondary resources in 2010 (200–290 t of Nd and 18–33 t of Dy) would equate to only about 10% of consumption in the same year. The gap between the consumption and discard may be due to the rapidly increasing demand for Nd and Dy in recent years, with nearly half the consumption of Nd and Dy being in the form of exported semiproducts and finished products.

Nd magnets in end-of-life products are seldom recovered in Japan’s present recycling system, although the recycling of Nd magnets from end-of-life driving motors of HEVs was found to be economically feasible. This is because a recycling market for Nd magnets has not yet been established. In the near future, Nd magnets from some end-of-life products may be recovered with an increase in the discard of end-of-life Nd magnets.

CONCLUSIONS

This study conducted dynamic SFA of Nd and Dy and determined the flows and stocks of Nd and Dy. The recycling of driving motors in HEVs was found to be economically feasible. At present, Nd magnets are not recycled because there is no market for secondary resources, which may be because of the low potential of secondary resources. Nd and Dy may be recovered in the future with an increase in the discard of products.

REFERENCES

1. Sagawa, M., Fujimura, S., Togawa, N., Yamamoto, H., Matsuura, Y. (1984). New material for permanent magnets on a base of Nd and Fe. *Journal of Applied Physics*, 55, 2083–2087.

2. Xiaoyue Du, T. E. Graedel (2011). Global In-Use Stocks of the Rare Earth Elements: A First Estimate. Environmental Science & Technology, 45, 4096-4101.

3. Wei Shi, Ichiro Daigo, Yasunari Matsuno, Yoshihiro Adachi (2010). Substance Flow Analysis of Dysprosium in Japan. J. Japan Inst. Metals, 74, 11, 758-765.

EFFICIENT USE OF CRITICAL METALS IN THE AUTOMOTIVE INDUSTRY - IDENTIFICATION, REUSE AND RECOVERY

Alexandra Pehlken, Carl von Ossietzky University Oldenburg; Chen Ming, Shanghai Jiao Tong University; Kerstin Kuchta, TU Hamburg Harburg; Jorge Marx Gómez, Carl von Ossietzky University Oldenburg*

**COAST, CvO University Oldenburg, Ammerlaenderheerstr. 114-118, D-26129 Oldenburg.*

Keywords: critical metals; automotive; China; rare earth elements

ABSTRACT

The presented case study analyses the resource potential of End-of-Life vehicle recycling in Germany and the PR of China, especially of strategic and critical metals. In the recycling hierarchy the reuse of used parts always achieves the most favorable eco-balance and thus, gains the highest priority. Apart from batteries critical metals can be found in catalysts and neodymium magnets. Besides cobalt and gallium, neodymium, dysprosium, praseodymium and terbium are identified as relevant in the automotive sector and they are all classified as strategic metals.

INTRODUCTION

The EU Disposal of End-Of-Life Vehicle (ELV) Act specifies quotas of material recycling (EU, 2000). The ELV Directive 2000/53/EC established goals to minimize the effect of ELV's by setting recycling, reuse, and recovery targets for the materials used in all manufactured vehicles. The directive requires that 95% of ELV waste must be reused or recycled by 2015, with only 10% of this recovered through energy. In addition to pure recycling of materials, the reuse of components and subassemblies makes sense not only in line with the Lifecycle Management and Waste Act (KrW-/AbfG, 1994) from Germany but also from the economic perspective. This is also in accordance with the „Raw Material Initiative“ that was released in 2008 by the European Commission (EC, 2008). There is high pressure on saving and recovering raw materials in Europe.

The German car market has a volume of around 43 million cars (counting on January 2013) and additional 9 million cars in 2012 for recycling or export (KBA, 2013). The market is nearly stable in terms of the total car volume. At the moment we experience a change in technology since there are strong developments in electric and hybrid cars as alternative engines. Representing only 1 % of the total drive systems in 2011, forecasts are predicting a rise to 25% in total by 2030 (Shell, 2012). This change is related to a significant increase in relevance of strategic and critical metals in the automotive sector, not taken into account that the specific supply might be related to serious risks.

By the end of 2010, China's vehicle population reached 90.86 million, up 19.3% year-on-year, deregistered 3.642 million, recycled 1.479 million ELVs. In China, there are 520 enterprises for dismantling ELVs, with 2,175 take-back stations and more than 30,000 employees. Manual dismantling operation mode guarantees a higher recycling rate. It is expected that by 2020, annual end-of-life vehicle processing capacity will be 13.65 million sets (table 1).

Table 1 Forecast of China's End-of-life Vehicle (2015-2020)

	Vehicle population ($\times 10^4$)	**New vehicle** ($\times 10^4$)	**Scrapped vehicle** ($\times 10^4$)	**Rate of scrapped** (%)
2015	11902	2120	831	7.0
2017	14460	2386	1028	7.1
2020	18841	3055	1365	7.2

China has high ambitions to reach the European recycling quota just 5 years behind the European market in 2020. Their potential of scrap cars in 2020 might equal more than one quarter of the total car market volume in Germany, considering the stable car market development in Germany.

CRITICAL METALS IN AUTOMOTIVES

In the context of lightweight, intelligent and electric automobile, various new materials find wide applications in the industry. Meanwhile, advanced and complicated parts such as power cell, fuel cell, hydrogen storage unit and electronic control unit are constantly emerging, needing new recycling strategy to face the challenge. Counting solely the amount of secondary resources that are going to be available through ELV recycling in China, e.g. scrap steel is estimated to 15 to 22 million tons in 2020. In this context automotive parts will derive great value as resources. Besides, base metals like steel, copper or aluminum automotive parts contain more and more critical metals in future due to the technology change. The waste bulk metal oriented pattern in end-of-life vehicle recycling industry will be hard to ensure realization of 95% actual rate of recycling. Economic value in reutilization of used automotive materials and parts determines future of automobile recycling industry.

Besides cobalt and gallium, neodymium, dysprosium, praseodymium and terbium (rare earths elements) are identified as relevant in the automotive sector and they are all classified as strategic metals. Due to the high criticality of these resources and because of their limited availability, it is important to discover their destiny at the end of their service life, aiming to recover them for further use.

Taking into account the actual situation of the high percentage of combustion engines in cars most critical metals are found in:

- Catalysts
- Neodymium magnets
- Batteries

The percentage of rare earth elements will strongly increase if the electro mobility will show a tendency to hybrid cars. In this case a 50 kg drive battery contents up to 12 kg rare earth metals. This number can change by the coming years since the technology is still in its infancy and more research is needed in this field. There a numerous publications on car batteries and this paper focuses on catalysts and neodymium magnets.

Metals in catalysts

A good example for resource recovery from car parts is given by the potential of motor catalysts: The ELV directive has set clear rules for the handling of automotive catalysts in the EU: In 2007 28t platinum and 31t palladium were recovered from automotive catalysts in a global scale (almost 15% of the global mining production). But despite this development it has to be underlined that even in the EU (especially in the new member states) the collection systems are not yet perfect at all.

Additional elements besides platinum and palladium in catalysts represent also rhodium, cerium and lanthanum. The content of platinum group metals (PGM) was investigated by Hagelüken, Buchert and Ryan (2006) and they could give ranges of PGM between 1 and 5 g per piece catalysts. In commercial vehicles this number could raise until 15 gram per piece.

Since the first use of automotive catalysts in the 1980s the PGM content was decreasing by the half due to more efficient technologies. With the change of the car market to more electric vehicles the number of catalysts will decrease accordingly.

The classical 3 way catalyst is loaded with a 5:1 ratio of platinum to rhodium content.

Numbers for cerium are not available at this moment. Cerium dioxide raises the gas purifying efficiency by storing the oxygen for a very short time and releasing it when needed. Lanthanum assures the temperature stability of the catalysis process and according to cerium there are hardly any reliable numbers to be found in literature.

Metals in neodymium magnets

Considering the high material and energy efficiency in automotives we also observe high quality and safety standards in all cars. This results in more electronic devices, as sensors for distance or light measures for example. Additional the comfort is also increasing and many small motors operate inside our car (seat adjusting, air conditioning, the locking device, window opener, etc.).

On average neodymium magnets contain about 30 mass % of rare earth elements as neodymium, praseodymium and dysprosium. For a higher temperature resistance terbium may be added as well. A study of Mercedes-Benz (2012) states a number of 1 kg rare earth metals for the new A-class. Besides this study hardly any average number can be identified. Maybe this is due to special configurations by each customer. For example 18 motor devices can be necessary for the seat adjustment in specific car brands.

We locate 2080t of rare earth elements by taking into account the use of 10,400 t of rare earth metals for permanent magnets in 2008 (Oakdene Hollins, 2011) and its use by 20% for the automotive industry. Considering the worldwide production of cars (70,520,493) in the same year 2008 provided by the “Organisation Internationale des Constructeurs d’Automobiles” (OICA), a number of 29.5 g of rare earth metals per one single car can be assessed. Due to more electrical components in the cars, this number will increase in future.

CONCLUSIONS

Critical metals are gaining more and more importance in the automotive sector due to the higher content of electrical devices and the increasing usage of batteries. There is still a big lack of data in the amount of critical metals in automotives. Also recycling technologies have to catch up with the rapid change in a car's metal content. More than ever the Chinese car market has great potential for recovering critical metals. A decision tool for assessing the resources in specific car parts available for authorities, governments or industries can support the efficient use of natural resources in automotive industry significantly. The tool should assess the complete material use in automobiles and its life cycle. However, recovering valuable resources from vehicles is crucial for saving primary resources. Additionally, the assessment of cascade use for specific parts must be applied to evaluate the least ecologic and economic burden of further material use. Nevertheless, the general material flow analysis can help to identify and remedy irretrievable losses of critical resources.

REFERENCES

European Commission (2008), The raw material initiative – meeting our critical needs for growth and jobs in Europe, *COM (2008) 699,* Brussels

EU, (2000) Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles - Commission Statements

Hagelüken, C., Buchert, M., Ryan, P. (2006), Materials Flow of PGM in Germany, Life Cycle Engineering, *13th CIRP Int. Conf., J. Duflou, W. Dewulf (eds.),* pp 477-482

KBA, (2013), Kraftfahrt Bundesamt Germany, Statistics, accessed May 2013, http://www.kba.de/cln_033/nn_125402/DE/Statistik/Fahrzeuge/fahrzeuge_node.html?__nnn=true

KrW-AbfG, (1994) Kreislaufwirtschafts- und Abfallgesetz, Germany, 27. September

Mercedes (2012), Study Modell A-Class, *Mercedes Studies*, accessed December 2012, http://www.mercedes-benz.de/content/germany/mpc/mpc_germany_website/de/home_mpc/passengercars/home/world/design/study.flash.html#concept_a

Oakdene Hollins (2011), Investing in Critical Metals, *Research paper June 2011*, accessed May 2013, http://www.oakdenehollins.co.uk/media/999/MetInvest_Report_Final.pdf

Shell, (2012), Mobility Scenario, *Shell Report*, accessed April 17th, 2012: http://www-static.shell.com/static/deu/downloads/aboutshell/our_strategy/mobility_scenarios/shell_mobility_scenarios.pdf

HISTORIC AND FUTURE FLOWS OF CRITICAL MATERIALS RESULTING FROM DEPLOYMENT OF PHOTOVOLTAICS

Till Zimmermann; University of Bremen, Faculty of Production Engineering, Department of Technological Design and Development; artec – research center for sustainability studies. Badgasteiner-Str. 1, D-28359 Bremen, Germany; tillz@uni-bremen.de.*

Keywords: MFA; thin-film photovoltaic; secondary materials; material demand; recycling potential.

ABSTRACT

Within this study, the flows of indium, gallium, cadmium and tellurium used in CIGS, CdTe and a-Si cells are analyzed looking at historic installations and potential future developments. Additionally to the material demand, secondary material flows arising at the cells' end of life are quantified. The study shows that a significant growth in demand resulting from future photovoltaic installations is to be expected. Also, flows of secondary materials will develop to a significant scale showing the necessity of an efficient recycling infrastructure.

INTRODUCTION

Photovoltaic (PV) cells play a central part in most development strategies towards a more sustainable and climate-friendly energy system. Various scenarios regarding future installations of photovoltaic cells have been published in the past years predicting a constant growth of installed PV capacity (e.g., EPIA, 2011; EPIA, 2012; European Commission, 2010; Jäger-Waldau, 2011; Moss, Tzimas, Kara, & Kooroshy, 2011; U.S. Department of Energy, 2011). Among the different photovoltaic cell technologies thin-film cells are of growing importance (European Commission, 2010; Moss et al., 2011; U.S. Department of Energy, 2011). Due to their excellent properties compared to conventional silicon-based PV cells like temperature robustness, versatility and low costs they already gained a significant market share over the past years (El Chaar, lamont, & El Zein, 2011).

Examples for thin-film cells are copper-indium-gallium-(di)selenide (CIGS) cells, cadmium-telluride (CdTe) cells or amorphous silicon (a-Si) cells. These cell technologies require materials like indium, gallium, cadmium, and tellurium that have already been identified to be critical in various studies (e.g. Buchert, Schüler, & Bleher, 2009; European Commission, 2010; U.S. Department of Energy, 2011). These materials might prove to be potential bottlenecks for photovoltaic installations as it has for example been analyzed by Andersson (Andersson, 2000) or more recently by Zuser and Rechberger (Zuser & Rechberger, 2011). At the same time, anthropogenic stocks of these materials will develop and with some delay secondary materials in a significant scale will arise.

Against this background, future demands for critical materials, material flows into use and secondary material flows arising at the modules end-of-life have been analyzed in this study.

METHODOLOGICAL APPROACH AND DATA

The methodological approach centers around the material flows into and out of use. Those depend on the annual installations, the material intensity (critical materials embodied per MW) and the lifespan of the photovoltaic cells.

For the first parameter – annual installations of thin-film photovoltaics – scenarios from the European Photovoltaic Industry Association (EPIA) have been used and combined with historic data from (EPIA, 2012; Maycock, 2007; Maycock, 2005). In (EPIA, 2011) three different scenarios are distinguished: a moderate reference scenario, an accelerated scenario and a paradigm-shift scenario. Based on this, the amount of installed thin-film cells has been calculated using data from (EPIA, 2011; Moss et al., 2011; PHOTON, 2012).

Concerning the second parameter, the material intensity, i.e. the amount embodied in cells equivalent to 1 MW, a literature screening has been performed and completed with expert judgments and manufacturer data. As a result, the material intensity of each considered metal in each thin-film technology could be identified. The respective values are shown in the following table. Potential future developments have been considered, too.

		Lower bound	Mean value	Upper bound
CIGS	Indium	9.8	16.5	23.1
	Gallium	2.3	11.0	19.7
CdTe	Indium	15.4	16.9	18.3
	Cadmium	140.1	153.4	166.6
	Tellurium	93.3	137.7	182.0
a-Si	Indium	5.3	5.3	5.3

Table 1. Material intensity of thin-film technologies Data from experts, manufacturers and literature (Andersson, 2000; Moss et al., 2011; U.S. Department of Energy, 2011)

Regarding life span, it can be said that in LCA studies commonly a life span between 20 and 30 years is assumed (e.g., Azzopardi & Mutale, 2010; Berger, Simon, Weimann, & Alsema, 2010; Raugei & Fthenakis, 2010; Sherwani, Usmani, & Varun, 2010). Other studies indicate that a lifespan of over 25 years can be assumed for thin-film cells (Berger et al., 2010; EPIA, 2011; Kuitche, 2010; Kumar & Sarkan, 2013). Based on this, an average lifespan of 28 years is assumed here. Instead of assuming a simultaneous exit after 28 years, a lifetime distribution is used for analyzing the material flows. The Weibull distribution has been shown to give a good approximation and is most widely applied for such purposes (Cullen & Frey, 1999; Gößling-Reisemann, Knak, & Björn, 2009; Kumar & Sarkan, 2013; OECD, 2001; Oguchi, Kameya, Yagi, & Urano, 2008; Tasaki, Takasuga, Osako, & Sakai, 2004; Wilker, 2010, Wilker, 2010). Additional parameters required for applying the Weibull function in this study have been taken from (Kuitche, 2010).

RESULTS

Based on the approach and parameters described above, the material flows of indium, gallium, cadmium and tellurium connected with the deployment of CIGS, CdTe, and a-Si cells have been calculated. An overview of selected results is given in the following table.

		Reference scenario			Accelerated scenario			Paradigm shift scenario		
Metal	Decade	Flows into use [t]	Material demand [t]	Flows out of use [t]	Flows into use [t]	Material demand [t]	Flows out of use [t]	Flows into use [t]	Material demand [t]	Flows out of use [t]
In	’21-30	307	539	12	2,711	4,720	22	4,130	7,229	34
	’31-40	444	628	89	3,349	4,733	308	5,158	7,293	567
	’41-50	526	606	243	4,166	4,887	1,419	6,494	7,459	2,622
Ga	’21-30	115	211	2	1,005	1,825	6	1,544	2,820	10
	’31-40	158	229	27	1,211	1,755	103	1,866	2,705	193
	’41-50	193	224	91	1,517	1,759	518	2,362	2,733	955
Te	’21-30	747	1,180	50	6,633	10,416	83	9,993	15,740	119
	’31-40	1,168	1,559	279	8,505	11,347	863	13,994	17,472	1,550
	’41-50	1,307	1,479	568	10,515	11,877	3,494	16,416	18,537	6,487
Cd	’21-30	833	1,314	56	7,389	11,604	92	11,133	17,535	133
	’31-40	1,301	1,736	311	9,475	12,640	961	14,587	19,464	1,727
	’41-50	1,456	1,648	633	11,714	13,232	3,892	18,288	20,651	7,227

Table 2: Flows and demands of critical metals in different EPIA scenarios

CONCLUSIONS

It has been shown that a significant additional demand for critical metals will result from increased installations of thin-film photovoltaic cells. Even in the most conservative scenario (EPIA reference scenario) the maximum annual demand for tellurium amount to about 9 to 48 percent of the global 2012 production. In the other scenario the demand even amounts to 257 to 595 percent. A similar situation has been shown for indium where the maximum annual demand increases to – depending on the underlying scenario – between 98 and 231 percent of the global production of 2012.

At the same time a big potential for recovering secondary materials has been identified. Average secondary flows of tellurium between 2041 and 2050 amount to between 29 and 122 percent of the global production in 2012. In the same decade, indium secondary flows amount to between 29 and 122 percent of 2012’s production. Gallium shows a similar situation. Given this, the necessity of an efficient and sustainable metals management becomes clearly evident. A working recycling infrastructure is strongly needed to recover and recycle these critical materials and hereby significantly reduce primary metal demand.

REFERENCES

Andersson, B. A. (2000). Materials availability for large-scale thin-film photovoltaics. *Progress in Photovoltaics: Research and Applications*, *8*, 61–76. Retrieved from

Azzopardi, B., & Mutale, J. (2010). Life cycle analysis for future photovoltaic systems using hybrid solar cells. *Renewable and Sustainable Energy Reviews*, *14*(3), 1130–1134. doi:10.1016/j.rser.2009.10.016

Berger, W., Simon, F.-G., Weimann, K., & Alsema, E. A. (2010). A novel approach for the recycling of thin film photovoltaic modules. *Resources, Conservation and Recycling*, *54*(10), 711–718. doi:10.1016/j.resconrec.2009.12.001

Buchert, M., Schüler, D., & Bleher, D. (2009). *Critical Metals for Future Sustainable Technologies and their Recycling Potential*. UNEP report. Darmstadt.

Cullen, A. C., & Frey, H. C. (1999). *Probabilistic techniques in exposure assessment: A handbook for dealing with variability and uncertainty in models and inputs*. New York: Plenum Press.

El Chaar, L., lamont, L., & El Zein, N. (2011). Review of photovoltaic technologies. *Renewable and Sustainable Energy Reviews*, *15*(5), 2165–2175. doi:10.1016/j.rser.2011.01.004

EPIA. (2011). *Solar Generation 6: Solar Photovoltaic Electricity Empowering the World*. Brussels.

EPIA. (2012). *Global market outlook for photovoltaics until 2016*. Retrieved from http://files.epia.org/files/Global-Market-Outlook-2016.pdf

European Commission. (2010). *Critical raw materials for the EU*. Report of the Ad-hoc Working Group on defining critical raw materials. Brüssel.

Fthenakis, V. (2009). Sustainability of photovoltaics: The case for thin-film solar cells. *Renewable and Sustainable Energy Reviews*, *13*(9), 2746–2750. doi:10.1016/j.rser.2009.05.001

Gößling-Reisemann, S., Knak, M., & Björn, S. (2009). Lifetimes and copper content of selected obsolete electric and electronic products. In L. Hilty, X. Edelmann, & A. Ruf (Eds.), *Resource Management and Technology for Material and Energy Efficiency*. Dübendorf, Schweiz.

Jäger-Waldau, A. (2011). *PV status report 2011: Research, solar solar cell production and market implementation of photovoltaics*. Luxembourg: Office of Official Publications of the European Communities.

Kuitche, J. M. (2010). *Statistical Lifetime Predictions for PV Modules*. Retrieved from http://www1.eere.energy.gov/solar/pdfs/pvrw2010_kuitche.pdf

Kumar, S., & Sarkan, B. (2013). Design For Reliability With Weibull Analysis For Photovoltaic Modules. *International Journal of Current Engineering and Technology*, *3*(1), 129–134.

Maycock, P. (2007). *2006-2015 World PV Market: Technology & Cost*. Retrieved from http://www.ncsl.org/print/energy/PMaycockSolar1007.pdf

Maycock, P. D. (2005). PV review: World Solar PV market continues explosive growth. *Refocus*, *6*(5), 18–22. doi:10.1016/S1471-0846(05)70452-2

Moss, R. L., Tzimas, E., Kara, H., & Kooroshy, J. (2011). *Critical Metals in Strategic Energy Technologies: Assessing Rare Metals as Supply-Chain Bottlenecks in Low-Carbon Energy Technologies*. JRC Scientific and technical reports. Retrieved from http://setis.ec.europa.eu/newsroom-items-folder/copy_of_jrc-report-on-critical-metals-in-strategic-energy-technologies/at_download/Document

OECD. (2001). *Measuring Capital - OECD Manual: Measurement of capital stocks, consumption of fixed capital and capital services*. Retrieved from http://www.oecd.org/std/nationalaccounts/1876369.pdf

Oguchi, M., Kameya, T., Yagi, S., & Urano, K. (2008). Product flow analysis of various consumer durables in Japan. *Resources, Conservation and Recycling*, *52*(3), 463–480. doi:10.1016/j.resconrec.2007.06.001

PHOTON. (2012). Das Solarstrommagazin: April 2012 - Anteile der verschiedenen Zelltechnologien, weltweite Solarzellenproduktion 1999 bis 2011. *Photon Das Solarstrom Magazin*, (4).

Raugei, M., & Fthenakis, V. (2010). Cadmium flows and emissions from CdTe PV: future expectations. *Energy Policy*, *38*(9), 5223–5228. doi:10.1016/j.enpol.2010.05.007

Sherwani, A., Usmani, J., & Varun. (2010). Life cycle assessment of solar PV based electricity generation systems: A review. *Renewable and Sustainable Energy Reviews*, *14*(1), 540–544. doi:10.1016/j.rser.2009.08.003

Speirs, J., Gross, R., Candelise, C., & Gross, B. (2011). *Materials availability: Potential constraints to the future low-carbon economy*. Working paper.

Tasaki, T., Takasuga, T., Osako, M., & Sakai, S.-i. (2004). Substance flow analysis of brominated flame retardants and related compounds in waste TV sets in Japan. *Waste Management*, *24*(6), 571–580. doi:10.1016/j.wasman.2004.02.008

U.S. Department of Energy. (2011). *Critical Materials Strategy*. US DOE report.

Wilker, H. (2010). *Leitfaden zur Zuverlässigkeitsermittlung technischer Komponenten: Mit 86 Tabellen, 86 Beispielen* (2nd ed.). Norderstedt: Books on Demand.

Zuser, A., & Rechberger, H. (2011). Considerations of resource availability in technology development strategies: The case study of photovoltaics. *Resources, Conservation and Recycling*, *56*(1), 56–65. doi:10.1016/j.resconrec.2011.09.004

LIFE CYCLE ASSESSMENT AND CRITICALITY OF RAW MATERIALS: RELATIONSHIP AND POTENTIAL SYNERGIES

Lucia Mancini, Serenella Sala, Małgorzata Góralczyk, Fulvio Ardente, David Pennington*
European Commission Joint Research Centre, Sustainability Assessment Unit

** Lucia Mancini, European CommissionDG Joint Research Centre Via Enrico Fermi 2749 TP270 I-21027 Ispra/Italy* lucia.mancini@jrc.ec.europa.eu

Keywords: Life Cycle Assessment; Critical Raw Materials; product policies; Life Cycle indicators, impact assessment methods.

ABSTRACT

The security of supply of raw materials is a policy priority for the European Union (EU). In this paper, different research activities undertaken by the European Commission's Joint Research Centre (JRC), Sustainability Assessment Unit, and related to Critical Raw Materials (CRM) are briefly described. The potential of Life Cycle Assessment for supporting resource policy needs in business and governance is discussed.

Related research activities addressed in this paper include an analysis of impact assessment methods used for the assessment of resources; the Resource Life Cycle Indicators that provide insights into the total environmental pressures of the EU; the identification of potentially relevant requirements for product policies, and the results of the expert workshop "Security of supply and scarcity of raw materials".

INTRODUCTION

The increasing and volatile trend of raw materials' prices observed in recent times reveals that the competition for resources has intensified during the last years. Often, more than just their availability, the access to resources is the main reason of concern.

The Raw Materials Initiative launched by the European Commission started further addressing the problems related to raw materials in order to achieve the goal of ensuring a secure access to these resources for Europe. A list of Critical Raw Materials (CRM) for EU has been published (EC 2010) considering their supply risk and economic importance.

Pressures related to resource use are already encompassed in Life Cycle Assessment (LCA), generally in terms of depletion potential. Thus, consideration is mainly focused on the potential effect of resource extraction on reserves. The security of supply of resources used along the supply chain is not taken explicitly into account by the current impact assessment methods. However, supply chain analysis using LCA has a potential for monitoring the use of CRM and could provide useful information for decision support in business and governance.

This paper provides an overview of research projects conducted by JRC, Sustainability Assessment Unit and related to this topic.

LIFE CYCLE IMPACT ASSESSMENT METHODOLOGIES

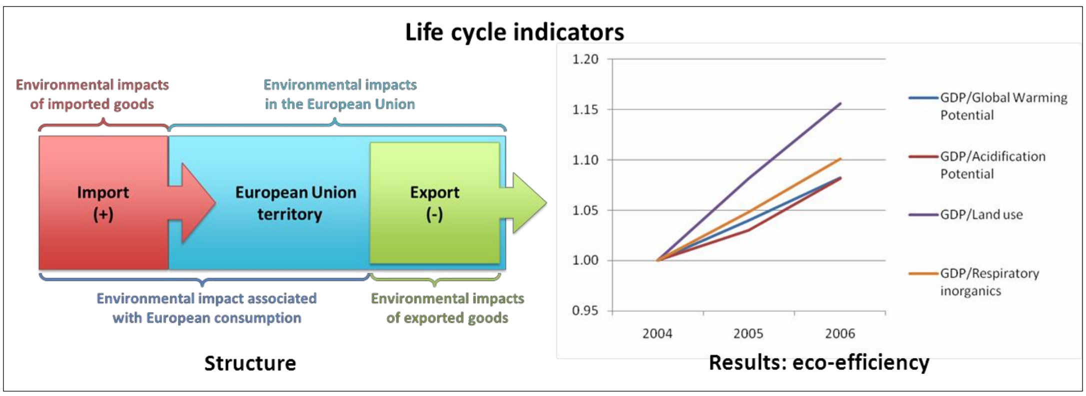
The depletion of abiotic and biotic resources is a fundamental issue for sustainability assessment, entailing and affecting environmental, economic and social aspects. In the context of LCA, resources are already modeled and handled both at the level of inventory (LCI) and at the level of Life Cycle Impact Assessments (LCIA). For inventory, this focuses on the compilation of emissions and resources consumed that can be attributed to specific goods and services. LCIA methods presently consider the resources used in terms of resource depletion in a relatively limited way (Klinglmaier et al 2013): use of natural resources is covered in LCIAs mainly in terms of the relative importance of extraction of a resource from the natural environment that leads to a decrease in its future availability. Amongst the methods used in LCIA, the comprehensiveness in terms of number of resources modeled is also different. The resultant rankings depend on the methods adopted, even within this narrow focus. Additionally, only a few of the CRM are modeled by existing methods, highlighting the difference in focus of resource scarcity and criticality methods in current practice.

There are specific research needs in order to foster the capability of LCA and LCIA models to more fully support decision making in the context of resource efficiency and to interact with methodologies for assessing e.g. CRM. The main elements of such research should be focused towards assessing: i) whether criticality should be part of the area of protection “natural resources” in LCAs; ii) how to use results of LCA for comparing CRMs or for identifying a potential substitute material - having the best environmental profile; iii) whether socio-economic implications should even be a part of an LCA or not; and iv) if current LCA indicators and results for resources provide governments and business with the most appropriate information for decision support regarding resource efficiency.

RESOURCE LIFE CYCLE INDICATORS

Resource Life Cycle Indicators provide a comprehensive, aggregated measure for the EU´s (and of each Member State’s) overall use of natural resources and emissions (EC 2012). Resource Life Cycle Indicators combine macro-level territorial resource extraction and emission inventories with the life cycle inventory data for imported and exported products, drawing on trade statistics (Figure 1). Environmental impacts are assessed using Life Cycle Impact Assessment methodologies; hence these cover burdens on the environment, human health, as well as in terms of resource use. Resource Life Cycle Indicators therefore can provide a basis for the assessment of critical raw materials.

Figure 1. Resource life cycle indicators structure and eco-efficiency



PRODUCT POLICIES FOR CRM

A resource-conscious design of products can contribute to reduce supply risk and to ease the pressure on natural reserves. For example, the improvement of design for recycling of the product can make available larger amounts of recovered materials at the product's End-of-Life (EoL). This can be particularly significant for some relevant materials (including CRM) contained in small amounts in products, which are generally lost when specific EoL treatments are not applied.

JRC recently developed a method to help measure, assess and verify resource efficiency of products based on a set of parameters, as: Reusability/Recyclability/Recoverability; Recycled content; Use of priority resources; Use of hazardous substances; Durability (Ardente and Mathieux 2012). The method has been applied to some case-study product groups (Television with LCD - liquid crystal display and washing machines) (Ardente and Mathieux 2012b). Some key components have been identified as important in relation to the content of CRM as, for example, LCD for the content of indium and washing machine's motors, for the potential content of rare earths. The analysis concluded that a design for dismantling of these key components, preventively to shredding treatments, is essential to allow the recovery of CRM.

Potential requirements about dismantlability of key components could be enforced via e.g. implementing measures set according to the Ecodesign Directive (EU 2009). For example Figure 2 illustrates an estimation of the potential benefits in the EU due to the potential enforcement of an Ecodesign requirement on dismantlability of motor in washing machines (fixing the maximum time for the extraction of the motor) (Ardente and Mathieux 2012b).

Figure 2. Assessment of potential benefits provided by the implementation of a product requirement on dismantlability of motors in washing machines (Ardente and Mathieux 2012b)

	A. Overall quantities of metals used in EU 27 (10^3 kg/year)	B. Quantities of metals used for WMs (10^3 kg/year)	C. Benefit in terms of additional recycled mass (10^3 kg/year) brought by the requirement	Fraction C/A	Fraction C/B
COPPER	3.525.913	20.017	500,4	0,01%	2,5%
STEEL	79.926.821	34.695	867,4	0,001%	2,5%
NEODYMIUM	16.800	331,6	82,9	0,8%	**25%**
PRASEODYMIUM		82,9	20,7		**25%**
DYSPROSIUM		82,9	20,7		**25%**
TERBIUM		41,5	10,4		**25%**

SECURITY OF SUPPLY AND SCARCITY OF RAW MATERIALS: OUTCOMES FROM AN EXPERT WORKSHOP

The Workshop "Security of supply and scarcity of raw materials" brought together experts in LCA and criticality assessment, in order to shed light on the potential of supply chain analysis in supporting resource policy. The state of the art in impact assessment methods for resources and in methodologies for identifying critical raw materials was discussed during the two days meeting.

The discussion held between participants led to conclude that a re-think and re-design of the impact category "Resources" is needed in assessments such as LCA. In particular it was acknowledged that, in addition to scarcity issues, socio-economic factors that can prevent the access to raw materials (i.e. the supply risk) should also be taken into account. However, some mismatches have been identified between methodologies for assessing criticality and LCA, which could make the inclusion of criticality aspects at impact assessment level controversial. For these reasons, the inclusion of criticality aspects in LCA – that has been suggested by workshop participants – could be better placed at inventory level.

However, the consideration of resource security aspects in LCA – which shouldn't be limited to the environmental aspects but should instead capture all the impacts along the supply chain – has been recognized as a relevant development that could enhance the capability of LCA in supporting policy objectives related to resources and that is consistent with some existing elements of e.g. LCA in current practice (Mancini, De Camillis, & Pennington, 2013).

CONCLUSIONS

This paper provides a brief overview of different research activities undertaken by the Sustainability Assessment Unit of Joint Research Centre, and linked to the topic of CRM. The developments highlight the potential of Life Cycle approaches for detecting flows of CRM within economies; identify major research gaps of the current impacts assessment methods used for assessing resource related pressures; suggests how an improvement of design for recycling can support more efficient use of critical resources.

We suggest that approaches such as Life Cycle Assessment are well positioned for a methodological enhancement to better reflect the consideration of security of supply aspects and to give improved support to resource policy. This information could provide governments and business with more appropriate information for decision support and for reducing supply risks associated with materials' provision.

REFERENCES

Ardente, F., Mathieux, F. (2012). Refined methods and Guidance documents for the calculation of indices concerning Reusability/Recyclability/Recoverability, Recycled content, Use of Priority Resources, Use of Hazardous substances, Durability. Joint Research Centre Technical Report. (http://lct.jrc.ec.europa.eu/assessment/projects#d). Doi: 10.2788/42590

Ardente, F., Mathieux, F. (2012b). Application of the project's methods to three product groups. Joint Research Centre. Technical Report. (http://lct.jrc.ec.europa.eu/assessment/projects#d). Doi: 10.2788/75910

EC - European Commission (2010). Critical Raw Materials for the EU. Report of the Ad-Hoc Working Group on Defining Critical Raw Materials. EC. Brussels.

EC - European Commission (2012). Life cycle indicators for resources: development of life cycle based macro-level monitoring indicators for resources, products and waste for the EU-27. European Commission, Joint Research Centre, Institute for Environment and Sustainability

European Union – EU. (2009). Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of Ecodesign requirements for energy-related products (recast).

Klinglmaier M., Sala S., Brandao M. (2013) Assessing resource depletion in LCA: A review of methods and methodological issues *accepted for publication in IJLCA*

Mancini, L., De Camillis, C., Pennington, D. (eds.) (2013). Security of supply and scarcity of raw materials. A methodological framework for sustainability assessment. Joint Research Centre (in press)

LIFE CYCLE ASSESSMENT OF RARE EARTHS UNDER CONSIDERATION OF NEW SUPPLY TRENDS

*Roberta Graf * University of Stuttgart. Michael Held, Jan-Paul Linder Fraunhofer*
**Wankelstrasse 5, 70563 Stuttgart Germany, roberta.graf@lbp.uni-stuttgart.de.* *Keywords:*

Life Cycle Assessment, Production Scenarios, Monazite, Neodymium, Rare Earth.

ABSTRACT

Rare earths contribute as material significantly to the Life Cycle Assessment of green technologies. New mining endeavors are likely to influence the future environmental profile of them. The developed method aspires to enable an estimation of the expected environmental characteristics. Based on a literature research the most influential factors are established. The process steps mining, beneficiation and separation are accounted for. Through a relevance analysis of potential and actual mining projects possible future production scenarios, based on best and worst case assumptions, are developed and reviewed. Their influence on the following parameters: country specific energy provision, type of mining, allocation method, rare earth oxide grade and Neodymium-grade is quantified

INTRODUCTION

Rare earths are 17 chemical very similar elements. Included are all lanthanides with the atomic number 57. to 71. as well as scandium (21.) and Yttrium (39.) (BGS, 2011). Their partial appearing, exceptional characteristics as fluorescence, high refraction index, strong paramagnetic property as well as a high capability to store hydrogen, make them highly interesting for many utilizations. Their field of application is therefore very broad. In many cases a substitution is not possible at all or can only be achieved by a total redesign (Gupta, 2005). An additional aspect is the Chinese monopoly on the supply of the industry with the demanded material. Rare earths are listed as critical raw material, as the supply situation is at risk while the usage has strategic importance (U.S. Department of Energy, 2010). As they are often used for so called green technologies (Schüle, 2011), Life Cycle Assessment (LCA) can be used to verify the environmental friendliness of those, thus enable proper comparison of new and conventional technique.

New mining endeavors globally could assure future provision but also change the environmental profile of rare earths (Graf, 2012). Aim of this study is to achieve a better understanding of the future development of the environmental profile of rare earths, deduced from their exploitation mix. Therefore the state of the art of rare earth production is compiled and transferred into inventory analysis in the LCA software GaBi 5 (PE International, 2012). The model comprises mining, beneficiation and separation into the individual elements. Through an investigation of the producing mines as well as the predicted mine openings, information of production countries, host rock, production rate and grades can be gathered. By linking these findings with each other, a systematic procedure for an estimation of future

LCA results can be developed. By means of different scenarios the tendency of the expected environmental profile of the "rare earth mix" can be assessed. This study focuses on the extraction of Neodymium oxide out of Monazite.

METHOD

How and which deposits will be exploited, will influence the future environmental profile of rare earth. The following aspects are regarded as important parameters for those aspects and will therefore be examined in more detail:

- Host rock, as it defines the way of production as well as byproducts
- Regional factors, which determine the assessed energy mix
- Grades, as they define how much material has to be exploited and how much chemicals and energy are necessary to gain a certain amount of REO
- Grade of the individual REO

In a first step rare earth deposits are investigated. Today available data of production volumes and grades of actual and potential production sites are therefore gathered and evaluated. Via a relevance analysis the mines with the highest potential are then determined. Based on these information scenarios are prepared. With a best and worst case approach five scenarios were created. The designed scenarios assume altered operating mines at different point in time. They cover the time horizon of 2010 as a reference year as well as the years 2015 and 2020. Thereby five different cases were developed (Scenario 2010, Scenario 2015 optimistic, Scenario 2015 pessimistic, Scenario 2020 optimistic, and Scenario 2020 pessimistic).

By using a relevance analysis, the mineral types which have to be taken into account are set. Additionally the five scenarios for the global rare earth mix are examined to evaluate the variations of the key driver named earlier. To quantify the impact of these key drivers on the environmental performance a generic LCA model (see figure 1) was developed which is able to illustrate the influence of the different aspects by using parameters to evaluate the gained information.

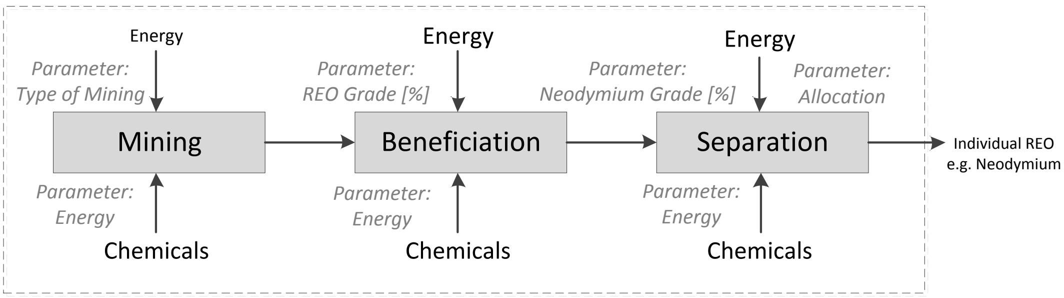


Figure 1. Borders and parameters of the GaBi model

RESULTS

The prime results of the analysis of the evaluated scenarios are outlined in the following. A higher diversity in the rare earth supply is very likely. New exploitation sources might be used in respect of type of mineral and country of production. Those new sources will have an influence on the environmental profile of REO. The importance of Monazite for the global supply will increase. The rare earth deposits which are taken into account for the five different cases (scenario 2010, scenario 2015 optimistic, scenario 2015 pessimistic, scenario 2020 optimistic, scenario 2020 pessimistic) have a very high variation in the REO content of the mined material as well as in the Neodymium grade. For the considered impact categories global warming potential (GWP), acidification potential (AP), eutrophication potential (EP), photochemical oxidant creation potential (POCP) and primary energy demand (PED), reduction capabilities between 10 and 30 percent were detected. In all future production scenarios the environmental impacts seem to be reduced.

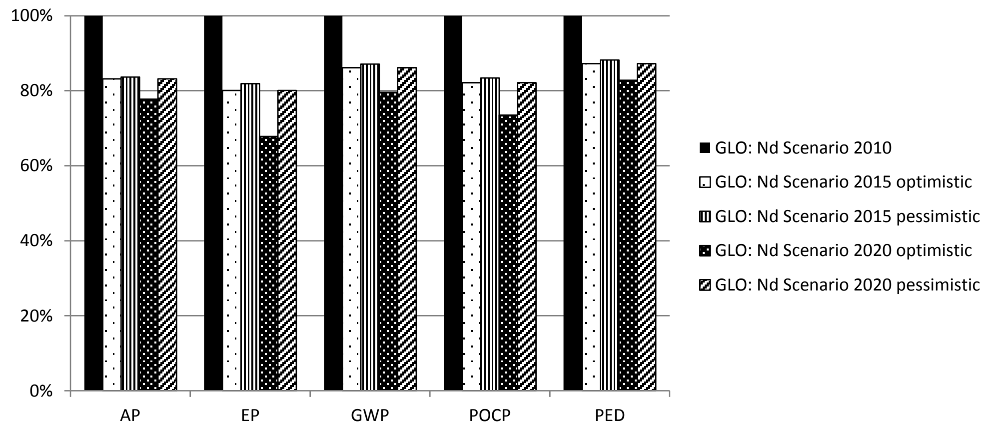


Figure 2. Comparison of scenarios in different impact categories

DISCUSSION

Variation in grade and the site of production is very influential on the environmental profile of rare earth. The latter primarily due to the country specific energy provision. As the host rock determines which process ways are used, as well as the byproducts, adapted LCA models are necessary for every mineral type. The results of the relevance analysis suggest that other mineral types and other REO sources such as Bastnaesite, Ion-adsorption clay and recycling should also be reflected. The model could also easily be expanded to include other rare earth elements besides Neodymium. More work is needed in respect of allocation and efficiency figures.

CONCLUSIONS

The environmental profile of rare earth depends on the supply situation. New mining sites will most likely reduce the environmental impact.

REFERENCES

British Geological Survey (Ed.). (2011). Rare Earth Elements. *Commodity Profile. Available at: www.bgs.ac.uk/downloads/start.cfm?id=1638*

Graf R. (2012). Ökobilanzielle Betrachtung von Seltenen Erden. *Stuttgart, Germany: Universität Stuttgart.*

Gupta C., Krishnamurthy N. (2005). Extractive metallurgy of rare earths. *Boca Raton, USA. CRC Press.*

PE International AG. (2012). GaBi 5 Software-System and Databases for Life Cycle Engineering. *Leinfelden-Echterdingen, Germany.*

Schüle D. et al. (2011). Study on Rare Earths and their Recycling. *Öko-Institut e.V. Darmstadt, Germany.*

U.S. Department of Energy (Ed.). (2010). Critical Materials Strategy.

POTENTIAL FOR RARE EARTH ELEMENT RESOURCE EFFICIENCY IMPROVEMENTS IN PERMANENT MAGNET MOTORS THROUGH AN EXTENSION OF THE ELECTRIC MOTOR PRODUCT GROUP REGULATION UNDER THE EU ECODESIGN DIRECTIVE

Machacek, E., University of Copenhagen and Dalhammar C. J., IIIEE, Lund University.*
**Present address: Øster Voldgade 10, 1350 Copenhagen, erika.machacek@geo.ku.dk*

Keywords: Ecodesign Directive; motor; magnet; resource efficiency; rare earth elements.

ABSTRACT

It has been proposed that the EU Ecodesign Directive can promote resource efficiency through relevant ecodesign requirements. This paper examines the potential for rare earth element (REE) resource efficiency improvements in the event the current regulation for electric motors under the Ecodesign Directive is to be extended to comprise REE-based permanent magnet motors. The research is based on literature studies, questionnaires and semi-structured interviews with representatives from industry and academia. It is found that standards addressing the design and use phase could yield highest resource efficiency improvements of REE in permanent magnet motors. Highly ranked are stricter EU energy efficiency ratings and design for dismantling if and when recycling of REE was to be commercialized.

INTRODUCTION

A diligent use of natural resources is inherent in the Resource Efficient Europe flagship initiative of the Europe 2020 Strategy which aims to facilitate sustainable economic growth. (European Commission [EC], 2011) The aim of attaining higher resource efficiency has been formulated when the criticality of certain resources, such as rare earth elements (REE) was acknowledged. These elements are essential in cleaner energy technologies, which must be applied more widely to achieve stipulated carbon dioxide emission reduction targets. They are also key components in numerous industrial uses and high-tech consumer appliances.

The EU product-oriented environmental policy represents one of several policy options which can facilitate the sustainable use of resources by emphasizing resource efficiency through addressing the entire product life cycle. (Dalhammar, 2007) Multiple instruments work towards this objective, whereby most of them address a specific life cycle phase. Among the mandatory instruments only the Ecodesign Directive 2009/125/EC has an integrated life cycle perspective albeit its primary objective of increasing the energy efficiency of energy-related products. (Official Journal of the European Union, 2009a)

The Ecodesign Directive and its electric motor product group regulation

A vast number of products, classified into 31 product groups, are regulated under the Directive definition of energy-related products and they consume both a significant share of energy and a considerable amount of resources within the EU. (Official Journal of the

European Union, 2009)Recognizing that many issues are product-specific, the study- which formed part of a larger project conducted in 2011-2013 - has been narrowed down to the product group of electric motors, which account for 30 to 40 per cent of the generated electrical energy worldwide. In industry, electric motors are often part of electric motor driven systems which account for about 70 per cent of industrial electricity. The cost-effective improvement of the energy efficiency of electric motor driven systems is estimated at up to 60 per cent whereby the use of energy efficient electric motors accounts for one of the main factors in such improvements. Thus, electric motors demonstrate significant ecodesign improvement potential. (Grundfos, 2008)

The electric motor product group regulation 640/2009 entered into force in July 2009 (Lot 11) and set minimum requirements for the ecodesign of electric motors and the use of variable speed drives. (Official Journal of the European Union, 2009b) The EC regulation is more limited in its scope than the international standard IEC 60034-30. The regulation is not comprehensive enough to account for all efficiency potential savings which could possibly be achieved among electric motors, as not all types of motors are covered. (CEMEP, 2011)

Rare earth element use in permanent magnet motors

Against this background, a preparatory study on lot 30, which aims at identifying the potential for environmental improvement of other motor products outside the scope of Regulation 640/2009 has commenced.(ISR-University of Coimbra and Atkins, 2012)This extension of the current electric motor is envisaged to potentially include permanent magnet (PM) motors. Neodymium-Iron-Boron (NdFeB) and Samarium-Cobalt (SmCo) alloys are prominent in the manufacture of the permanent magnets used in these motors as the magnetic properties inherent to the REE allow for high energy densities in the magnets and thus contribute to make the motors more energy efficient. (De Almeida, Falkner, Fong, and Jugdoyal, 2012)

The aim of this case study was to conduct an ex-ante assessment of whether an extension of the current electric motor regulation to PM motors could foster sustainable product development capable of achieving resource efficiency improvements of REE. Against pressing needs to increase resource efficiency, predominantly of the before mentioned critical REE, the extension of the electric motor group regulation appears to have considerable potential to facilitate product design improvements.

METHODOLOGY

The case study was guided by Geels (2002) Multi-level Perspective on Technological Transitions and innovation drivers selected from Blind (2012), Jänicke (2008), Van den Ende and Kemp (1999). The extent to which these drivers, namely export intensity, price volatility, uncertainty, rule set and anticipation, the Ecodesign Directive, and its potential extension to PM motors affect the development of PM motors and especially the technological transition towards more resource efficiency of REE, has been explored. The data has been collected through questionnaires filled in by representatives of PM manufacturers who attended the first preparatory study meeting in June 2012 for the product group extension. The questionnaire was also sent out to attendants of industry associations and other companies manufacturing motors, however not as a core activity, in order to draw comparisons in the tendencies which were depicted in the responses of PM motor manufacturers. These responses were complemented by three semi-structured in-depth interviews with permanent magnet material experts from academia and a European PM manufacturer. Obtained data was analysed qualitatively according to the selected innovation drivers, which were integrated into the Multi-level Perspective on Technological Transitions.

RESULTS

In summary, the anticipated extension of the electric motor product group regulation to PM motors and its influence on PM motor innovation activities appeared to be of less importance to manufacturers than both the price volatility of the REE-containing-PM magnets and the market demand for them. Despite this observation, it has been noted that the inclusion of new and stricter EU energy efficiency ratings would have the potential to accelerate product innovations and thereby potentially improve resource efficiency in this product group. This finding has been reiterated in the evaluation of the rule set indicator, comprising regulatory standards, which has been pointed out as having the highest influence on innovation activities.

Standards facilitating resource efficiency improvements and perceived feasibility

Potential legal standards and the respective legal instruments, predominantly the Ecodesign Directive, through which these standards could be fostered, were grouped into the product life cycle categories of design, manufacture, use and end-of-life and their perceived feasibility for application on PM motors was discussed. In the design phase of PM motors, legal standards on product composition, which could emphasize the use of the bill of materials and a standard on modularisation which would require design for dismantling, were perceived to be feasible for implementation through the Ecodesign Directive and could potentially contribute to increased resource efficiency of REE in PM motors. Their effectiveness would depend on the development of cost efficient REE recycling methods. The Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) addresses the chemical content of products and has already led to the classification of powder materials used in the production of sintered NdFeB magnets as chemicals. Options for resource efficiency improvement in the production phase of the product life cycle appeared to be rather restricted.

In the product use phase, the enforcement of stricter energy efficiency requirements through the Ecodesign Directive was considered to have the highest potential regarding resource efficiency improvements. These higher energy efficiency class achievements are enabled by the use of REE-containing permanent magnet in motors. The enforcement of stricter energy efficiency standards would, on one hand, continue to promote the use of REE-based permanent magnets in motors but, on the other, if the availability of individual REE was to be restricted in the future and REE market prices are to increase, innovations in permanent magnets would be encouraged which would presumably foster efficient REE use.

Resource efficiency improvements in the end-of-life phase are dependent on the improvement of REE recycling technology which allows for its economically feasible commercialization. Against this precondition, a feasible legal standard in the motor end-of-life phase was seen in a standard requiring the take-back of motors by producers at its end-of-life, which is seen as one of the key pillars in the resource efficiency improvement of REE in PM motors. It is being acknowledged that the long motor lifetime could present a hindering factor in achieving this legal standard which could be jointly facilitated through a closer alignment of the Waste

Electrical and Electronic Equipment (WEEE) Directive with the Ecodesign Directive. The feasibility of other available legal standards, such as a material concentration to facilitate recycling, was viewed as being dependent on preceding innovations in PM manufacturing technology.

CONCLUSION

In conclusion, the potential expansion of the Ecodesign Directive electric motor regulation to comprise REE-based PM motors could possibly achieve resource efficiency improvements of REE through the elaboration of stricter energy efficiency standards in the use phase, and a focus on standards addressing product composition and modularization in the design phase.

REFERENCES

Blind, K. (2012). The influence of regulation on innovation: A quantitative assessment for OECD countries. *Research Policy, 41, 391-400.*

CEMEP (2011).*Electric Motors and Variable Speed Drives. Standards and legal requirements for the energy efficiency of low-voltage three-phase motors*. Frankfurt: CEMEP.

Dalhammar, C. (2007) Product and life cycle issues in European environmental law: A review of recent developments. *Yearbook of Environmental Law, 7,* Oxford University Press.

De Almeida, A., Falkner, H., Fong, J., Jugdoyal, K. (2012).Draft. EuP Lot 30: Electric Motors and Drives. Task 1: Product Definition, Standards and Legislation. ENER/C3/413-2010. Coimbra, Portugal: ISR - University of Coimbra; Atkins.

EC (2011) COM(2011) 571 final.Roadmap to a Resource-efficient Europe. Brussels: EC.

EC (2010).Critical raw materials for the EU. Report of the Ad-hoc Working Group on defining critical raw materials. Brussels: EC.

Geels, F. W. (2002) Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case study. *Research policy, 31, 1257 - 1274*.

Grundfos (2008).Position paper. Enormous Energy Savings to be lost if the EU does not take action: Efficiency legislation for industrial electrical motors. Author: Mads Sckerl.

ISR-University of Coimbra and Atkins (2012).Eco-design of Electric motors. Preparatory study for implementing measures of the Ecodesign Directive - Lot 30. Source: http://www.eco-motors-drives.eu/Eco/Home.html, last accessed: 07.06.2012

Jänicke, M. (2008). Ecological modernisation: new perspectives. *Journal of Cleaner Production, 16,557-565*. DOI: 10.1016/j.jclepro.2007.02.011.

Machacek, E. (2012). Potential Ecodesign Directive Contributions to Resource-Efficient Innovations. A Case Study on the Electric Motor Product Group Expansion and Rare Earth Element Use in Permanent Magnet Motors. Lund, Sweden: IIIEE, Lund University.

Official Journal of the European Union (2009a).Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products.

Official Journal of the European Union (2009b).Commission Regulation (EC) No 640/2009 of 22 July 2009 implementing Directive 2005/32/EC with regard to ecodesign requirements for electric motors.

Van den Ende, J. and Kemp, R. (1999). Technological transformations in history: how the computer regime grew out of existing computing regimes. *Research Policy, 28, 833-851*.

TRACKING ENVIRONMENTAL IMPACTS IN GLOBAL PRODUCT CHAINS – RARE EARTH METALS AND OTHER CRITICAL METALS USED IN THE CLEANTECH INDUSTRY

Alina Pathan[1], Alain Schilli[3], Jens Johansson[2], Iivo Vehviläinen,[1]Anna Larsson[2], Jürg Hutter[3]*

[1]Gaia Consulting Oy; [2]U&We AB; [3]Gaia Global SA

**Bulevardi 6 A, FI-00120 Helsinki, iivo.vehvilainen@gaia.fi*

Keywords: cleantech; Rare Earth Metals; environment; electric vehicles; solar panels.

ABSTRACT

Metals form a central part of the global economy, but their extraction and supply are linked to several environmental and social concerns. The study aims to create a picture of the supply chain of Rare Earth Metals (REMs) and other critical metals used in the clean technology (cleantech) sectors of electric vehicles and solar panels. The study examines how Nordic cleantech companies are aware and acting on the challenges related to the lifecycle of these metals and what are the potentials to minimise environmental and social impacts. Recommendations of the study can be summarised as three initiatives: establishment of an awareness platform and roundtable initiative (short-term), research and information gathering (mid-term), and development of closed-loop solutions (long-term).

INTRODUCTION

Metals in various forms and uses are a central part of the global economy and have become increasingly important. Metals are also needed in the transition to a low-carbon and resource efficient economy.

Despite the fact that many metal extraction operations have become more sustainable over the past 20 years, especially in the developed countries, many environmental problems still exist. Mining sites are an environmental security concern both locally and regionally.

Manufacturers of end products are not necessarily aware of the potential adverse impacts created in the raw material extraction and processing phase. One of the major challenges for companies is tracing the origin of the metals used in their products. Metal supply chains are complex and involve various different actors such as miners, traders, refiners and manufacturers.

Gaia and U&We AB conducted a study commissioned by the Nordic Council of Ministers to create a picture of the supply chain of selected Rare Earth Metals (REMs) and other critical metals used in the clean technology (cleantech) sectors of electric vehicles and solar panels (photovoltaics) and the environmental problems related to them. The final report (Pathan et al, 2013) was published in March 2013.

METHODS

Main methods used in the study were literature review, web survey to Nordic cleantech companies, case studies including in-depth interviews with selected actors, as well as analysis. The survey examined the traceability of metals used in cleantech products, actions to reduce environmental impacts, substitutes and replacements, as well as cooperation with suppliers. The aim of the case studies was to identify the environmental performance of selected companies and their use of critical and rare earth metals. The case study companies were Volvo (Sweden), ABB Finland, Innotech Solar (Norway) and Beneq (Finland).

RESULTS

REMs are used in cleantech applications due to their unique chemical, magnetic and electrical characteristics. Despite their name, they are not actually considered rare but have significant environmental impacts in the raw material extraction and processing phase. (Sadden, 2011). The major negative environmental impacts from the production of REMs stem from the mining and chemical processing of the metals (Majeou-Bettez et al, 2011).

In electric vehicles, REMs are used in many applications, for example in the permanent magnets of electric motors. The use of REMs in photovoltaics is more limited, although electric system components may contain some REMs to a certain extent. (Eriksson & Olsson, 2011).

The PV industry, even when looking at the PV system as a whole does not rely on REMs although system components such as inverters, batteries, and mounting systems might contain some REMs to a certain extent. From the environmental perspective, raw materials used in PVs come with the environmental burden of the mining and production of primary metals (zinc, copper, lead etc.). Current discussions on environmental issues in the PV industry are primarily focused on energy payback times and recycling of PV modules and materials.

Traceability of REMs and critical metals, and accountability for social and environmental impacts in their extraction, is challenging. The metals are often procured through long supply chains and from regions with limited regulatory requirements for transparency. There is also insufficient information on how the impacts of metals extraction are specifically allocated to REMs and critical metals used from a life cycle assessment perspective. Although the supply chain is long, much can be done to make the supply chain more responsible and sustainable both in the raw material phase of the supply chain and in the end-of-life phase by improving the re-use and recycling rates of metals.

DISCUSSION

Cleantech solutions are still under development, and they have been in use for only short periods of time and in limited quantities. As the use of cleantech technologies spreads, so does the importance of developing effective methods for re-using cleantech technologies and recycling materials. Currently, recycling of REMs and critical metals are often not profitable because the substances are found in small quantities and in complex systems. Increasing metal recycling rates is a key part of the path to sustainable metals use.

The recycling of PV modules and materials is already discussed, and recycling of PV modules is becoming mandatory through the European Union Waste Electrical and Electronic Equipment Directive (WEEE Directive). For REMs used in electric vehicles, the recycling requirements come through producers' responsibility that requires certain recyclability for the whole vehicle. However, as the amounts of REMs used are relatively small, they do not necessarily fall under the required recycling rates as they are formulated in current EU directives such as the WEEE-directive and ELV-directive.

CONCLUSIONS

To mitigate the potential problems related to REMs and critical metals companies will need to develop their knowhow and procurement processes. The resource requirements for adequate development can become prohibitive, especially for small and medium-sized companies. In practice, sector wide guidelines or checklists could be developed.

Transparency as well as environmental, societal, and economic impacts over the whole life cycle of current and alternative metals used could be addressed. In the short-term, this can be accomplished through awareness raising activities and information sharing, and in the mid-term through further data gathering and research. The Nordic Council of Ministers and the Nordic governments could also use their influence to increase transparency and sustainable extraction in the countries of origin for REMs and critical metals.

Support could be funnelled through existing industry organisations. Specialist support on developing and following up on requirements to suppliers can be found through membership of organisations specialising in social and environmental compliance in the supply chain such as the Ethical Trading Initiative, Business Social Compliance Initiative and the UN Global Compact's Supply Chain Sustainability Programme.

On the basis of this study, the recommendations to develop sustainable metal use in the Nordic area can be summarised as three initiatives:

1) Awareness platform and roundtable initiative (short-term): Establish an information sharing and collaboration roundtable for interested parties. The Nordic Council of Ministries could support the roundtable directly by providing financial or organisational re-sources for such initiative, or by supporting the establishment of the roundtable. In addition the Nordic countries could use other communication measures to increase awareness on potential issues in the supply chain of REMs. In practice, sector wide guidelines or checklists could be developed.

2) Research and information gathering (mid-term): The use of clean-tech will increase as companies strive to develop effective solutions to meet global environmental challenges. To better understand and to enable the mitigation of the negative environmental and social impacts of REMs, further research and information on the impacts of metals use in the whole value chain is needed. Sustainable REMs and other critical metals use could benefit from a Nordic research project or program.

3) Closed-loop solutions development (long-term): As an alternative, there is at least in theory a lot of potential in the re-use of compo-nents and recycling of materials. A long-term goal would be closed-loop processes, where re-use and recycling completely replace the need for mining and new material intake to the process. The con-crete initiatives could include support for R&D&I activities in re-use and recycling of REMs and other critical metals in cleantech.

REFERENCES

Eriksson, T. & Olsson, D. (2011). The Product Chains of Rare Earth Elements Used in Permanent Magnets and NiMH Batteries for Electric Vehicles. Master thesis. Chalmers University, Gothenburg, Sweden. Available at: https://www.chalmers.se/ee/SV/forskning/forskargrupper/miljosystemanalys/publikationer/pdf-filer/2011_1/downloadFile/attachedFile_4_f0/2011-8.pdf?nocache=1309331810.28

Majeau-Bettez, G., Hawkins, T.R. & Stromman, A.H. (2011). Life cycle environmental assessment of lithium-ion and nickel metal hydride batteries for plug-in hybrid and battery electric vehicles. *Environmental Science Technology. Vol. 45:10, pg. 4548-4554.*

Pathan, A., Schilli, A., Johansson, J. Vehviläinen, I., Larsson, A. & Hutter, J. (2013). Tracking environmental impacts in global product chains – Rare Earth Metals and other critical metals used in the cleantech industry. Nordic Council of Ministers, TemaNord 2013:520. DOI: http://dx.doi.org/10.6027/TN2013-520

Sadden, E. (2011). Rare Earth Metals in the Cleantech Industry. *Cleantech Magazine 2011 Issue 5, pgs 10-12.* Available at: http://www.cleantechinvestor.com/portal/cleantech-magazine/archive/2011-issue-5.html

SUSTAINABILITY DATA EXCHANGE

Tuesday, Aug 27: 3:30 pm - 5:00 pm

Session chairs: Thomas Bley, iPoint-systems/KERP, Austria
Max Sonnen, Ecomatters B.V., The Netherlands
Raul Carlson, Viktoria institute, Sweden

GREENHOUSE GAS MANAGEMENT ALONG THE SUPPLY CHAIN AT SIEMENS

Karin Uebelhoer Siemens AG, Joern Guder, Siemens AG, Dr. Jens-Christian Holst, Siemens AG, Birgit Heftrich, Siemens AG. *Siemensdamm 50, 13629 Berlin, Germany, karin.uebelhoer@siemens.com*

Keywords: EEP4S; Siemens; Supplier; Carbon Management.

ABSTRACT

At Siemens, activities for climate protection address the entire value chain. The supply chain emits four to six times more greenhouse gases (GHG) than its own manufacturing operations. Obviously Siemens has less influence on the GHG emission of the supply chain than on its own activities. To integrate the supply chain in the climate protection activities Siemens supports its supplier to reduce energy consumption and GHG emissions by implementing the Energy Efficiency Program for Suppliers (EEP4S). (Siemens, 2011)

The aim of the EEP4S is to involve suppliers into Siemens' sustainability strategy and help them to conserve energy. Optimization potentials in environmental and energy efficiency summarized in a comprehensive report encourage Siemens suppliers to contribute on a green supply chain.

INTRODUCTION

With the Code of Conduct Siemens lays the foundations for the evolution of a sustainable supply chain. By accepting the Code suppliers have undertaken the commitment to implement an environmental management system to improve efficiency and reduce emissions. The successful Energy Health Check for the own operations was used as blue print for the development of the EEP4S. (Siemens, 2013 a)

The EEP4S is a corporate program aimed at greening Siemens' supply chain and bringing transparence into the suppliers' processes. Transparency and awareness are the pre-condition for energy and environmental optimization. EEP4S provides a vital foundation of knowledge in the form of several questionnaires, methodologies and reports. Taking the variety of our supplier base into account a 4-level concept has been developed. Levels 1 and 2 involve a graded consulting approach in which certified energy consultants examine the energy and environmental efficiency of a production site. Level 3 and level 4 form the sustainability approach with a web-based self assessment and is also part of the supplier development process. Both levels (3 and 4) determine the GHG emissions of the location for a certain reporting. In addition, the result of level 3 contains a star evaluation (from 1-5 stars) and a top measure report which gives a statement of an average energy saving potential in percent. Level 4 provides an Eco-Care-Point ranking (1-10 points). In the following sections, levels 3 and 4 are described.

MATERIALS AND METHODS

For the implementation of the supplier development and self-assessment levels 3 and 4, the sustainability and reporting software "SoFi software package" from PE-International is used. SoFi is a sustainability and reporting software which has been customized for the EEP4S program. Siemens has integrated the questionnaires, the methodology, the reports, workflow management and the look and feel based on the framework prepared by SoFi. Selected strategic suppliers are provided with a login. Before the suppliers can start with the data acquisition they have to accept the terms of use. The finished data acquisition triggers a comprehensive report which is created and published online. A YouTube video, manuals, embedded explanations and a contact email address are provided as supporting documents.

Level 3 consists of four questionnaires, three qualitative questionnaires and one for GHG calculation: The GHG Questionnaire captures GHG-relevant sources e.g. energy consumption, input materials and waste. Based on the input figures given by the supplier, Scope 1, 2 and 3 GHG emissions are calculated according to the GHG protocol (WRI, 2004) considering different regional CO_{2e} factors, and reported to the suppliers. Due to the fact the main focus is on reduction of emissions and energy, three different regional GHG emissions factors are considered as sufficient: Europe, Asia and the Americas. In this way CO_2 emissions can be compared within one commodity and one region. The CO_2 factors are taken from the life cycle assessment software, "GaBi" (PE-International, 2013) from PE-International and are weighted according the regional split of Siemens suppliers. Scope 1 and 2 related emissions are mandatory fields in the questionnaire, whereas Scope 3 emissions related input and output materials are optional. The results are the GHG emissions separated into the appropriate scopes for the specific location and reporting period. The Energy Management Questionnaire addresses categories of energy policy, controlling and reporting. Energy consuming utilities for the production and administration are considered in the Energy Technique Questionnaire. The Environmental Questionnaire takes GHG reductions strategies into account. As a result of all qualitative questions, the supplier receives a 1-5 star rating. Every star's value represents a certain amount of a saving potential. Finally, the suppliers receive a report of their environmental and energy performance with recommendations to improve their performance.

Level 4 is a basic environmental-only assessment which consists of 2 questionnaires: the GHG questionnaire which covers Scope 1 and 2 emissions and 10 environmental related questions. The level 4 results contain the GHG emissions and an Eco-Care-Point-ranking (1-10 points).

The assessment is valid for a specified reporting period defined by Siemens. The Stars Evaluation and the Eco-Care-Points are a Siemens patented methodology. The methodology considers plausibility checks. In some places plausibility checks are partially integrated into the methodology while others are done additionally after the data acquisition. In some cases answers have to be backed up with corresponding documents, for example certificates, guidelines, otherwise evaluation cannot be completed. In the technical energy questionnaire, the methodology considers an automated and integrated plausibility check. Additionally, at the end of each data acquisition process, a plausibility check with a defined range of minimum and maximum values visualizes potential out of reasonable range. In this case, the supplier is asked to edit or confirm the figures. To generate the report is only possible if all values have passed the plausibility check.

Afterwards the reports are sent to the supplier. Two reports (stars evaluation and GHG report) are generated online the third (top measure report) is generated by an internal Excel-VBA-tool. The report contains recommendations for actions which help the suppliers to improve their energy and environmental performance. Furthermore the potential savings are presented in concrete percentages and ranked into low, medium and high impact.

RESULTS

By the end of 2012, more than 1000 suppliers had finished a self-assessment for one production site and/or building infrastructure each. The potential savings identified speak for themselves: Roughly 18% of the self-assessments have potential to save 14 to 20% energy and another 56% show potential for a 9 to 14% reduction potential for energy saving. Another 1,000 suppliers are due to be integrated into the program in fiscal year 2013. Siemens continues the assessments for the remaining suppliers and will repeat the assessment every two years, which enables Siemens and its suppliers to analyze a time series of energy efficiency increase.

In the next step Siemens will convene about 60 suppliers for supplier meetings to discuss and assess the achieved results together. Aim is to define objectives for improvement and where necessary or requested make contact with Siemens specialists whose experts can help the suppliers to analyze results in detail and implement the ensuing measures. These activities will be embedded into the standardized Siemens supplier management system. Facing an all over savings potential of approximately 5 million tons of CO_2 equivalents relating to 1000 suppliers it is obviously worthwhile to encourage and to force our suppliers to implement suitable measures. (Siemens, 2013 b).

The GHG emissions from the supply chain can be disclosed as part of Siemens Scope 3 reporting. For that reason, Siemens asks for the suppliers' revenue in order to determine and report the equity share. Furthermore, the GHG Emissions per Euro can be used for benchmarking within a region and commodity for plausibility checks.

DISCUSSION

The self assessment itself is holding uncertainty in the process of data acquisition. Encountering wrong answers, typing mistakes, misunderstanding questions can lead to faulty determining factors, not to be detected by the automated and final plausibility checks. Siemens is pretty aware of these uncertainties as well as of its chances and is continuously working on improvements and wherever meaningful seeking the dialogue with suppliers and stakeholders deliberately.

The actual energy saving potential will be visible after the second reporting period when a time series can be displayed and actual improvements can be estimated based on the answers in the qualitative questionnaires.

In the first step Siemens focused on creating transparency knowing well this does de facto not save any kg of CO_2e. Having started a development program for suppliers and working hard on improving the self-assessment tool Siemens can accept the described uncertainties for the time being. Keeping the enthusiasm on a high level Siemens internal and at our suppliers will be the future task since Siemens do not only want to create transparency but also actively reduce emission in our entire supply chain.

Filling in the questionnaires and discussing results with the involved suppliers is very time consuming. Siemens have to accept that it is not possible to involve the entire supplier base into the program. Selecting and focusing on suppliers with significant footprint is a challenge. Further stage of development is to involve not only first but also second to n-tier within specific supply chains.

CONCLUSIONS

Energy efficiency has always been of great significance for Siemens. With the Energy Health Check in our own production facilities potentials up, to 20% were identified. With the launch of the Energy Efficiency Program for suppliers in 2011 we aim to promote an approach in which the entire supply chain is based on well-planned, economical management of resources.

The program enables selected strategic suppliers to determine the energy and economical efficiency of their production and thus find potential for improvements. A free, -web-based tool is available where several questionnaires are implemented in order to evaluate the environmental and energy efficiency at a suppliers' location. There are two different levels available for the sustainability approach: Level 3 for production facilities covering Energy Management, Technical Energy Equipment, and Environmental Management and Level 4 mainly dedicated for non-producing facilities covering pure environmental aspects. Both levels determine the GHG emissions for a selected site. The result of level 3 is a 1-5 Star evaluation and a top measurement report with recommendations to improve energy and environmental efficiency. Level 4 gives a ranking of 1-10 Eco-Care points and covers basically environmental aspects. The methodology is patented by Siemens. Based on the evaluation, a statement of average possible optimization potential (up to 20%) is given. EEP4S creates transparency and tends to arouse and increase awareness for resource efficiency at our suppliers and along with that within the supply chain. Currently, more than 1300 suppliers are using the tool. The self-assessment is intended to be carried out every two years and the results will be monitored as part of the Siemens supplier management system.

The good feedback and valuable comments we have got via a conducted customer satisfaction survey encourage us to keep at the topic.

REFERENCES

Siemens. (2011). Sustainability Report 2011. CO2 management along the value chain, 1. *Retrieved from* http://www.siemens.com/sustainability/pool/en/current-reporting/siemens-sr-co2.pdf.

Siemens. (2013 a). Efficient use of resources. Management Approach. *Retrieved from* http://www.siemens.com/sustainability/en/core-topics/suppliers/management-approach/resource-efficiency.htm

WRI. (2004). Greenhouse Gas Protocol. *Retrieved from* http://www.ghgprotocol.org/files/ghgp/public/ghg-protocol-revised.pdf.

PE-International. (2013): GaBi Software. Product Sustainability Software. *Retrieved from* http://www.gabi-software.com/deutsch/index/

Siemens. (2013 b). Sustainability Report 2012. Suppliers, 3. *Retrieved from* http://www.siemens.com/sustainability/pool/en/current-reporting/siemens-sr-suppliers.pdf.

IMPLEMENTATION OF LCA DATA EXCHANGE SYSTEM: ACHIEVEMENTS AND CHALLENGES

Katsuyuki Nakano, Wataru Koike, Japan Environmental Management Association for Industry (JEMAI)*

Takuma Sugimoto, eagif

Kiyotaka Tahara, National Institute of Advanced Industrial Science and Technology (AIST)

** 2-1, Kajicho 2- chome, Chiyoda-ku, Tokyo, 101-0044. E-mail: nakano@jemai.or.jp*

Keywords: data management; inventory data; software; review; data exchange

ABSTRACT

To increase reliability and sustainable growth of LCA data such as process dataset and LCA case study, there is a necessity of a number of experts' involvements and data exchange beyond organization's boundary. It must be achieved without disclosing confidential information. Therefore, we developed and released LCA data management system to address this issue. A user of the system can publish and use LCA data in the library of the central server freely. Each uploaded LCA data can be marked of their review status to show their reliability. A specific review status can be added by a user who has a specific corded reviewer key in the system. As of January 2013, dozens of LCA data are uploaded to the central server voluntarily.

INTRODUCTION

To improve reliability and sustainable growth of LCA, database involvement of a number of experts and data exchange beyond organization's boundary are needed. As infrastructure of LCA data exchange, database management systems have been developed, such as the ELCD Database developed by Joint Research Centre of European Commission and JLCA-LCA database system developed by LCA Society of Japan (JLCA). In these systems, process dataset is registered after the database management body reviews the process. There are sometimes different datasets for the same process, but the management body manages them to avoid overlap of data item. Therefore, a user is able to use the LCA data with feeling of trust. However, the immediacy is low. Timing of database revision is controlled by the management body. The openness is also low. This type of data management style is categorized by the Shonan Guidance Principles for LCA database (UNEP/SETAC Life Cycle initiative, 2011) as the Scenario L.

On the other hand, data exchange system using Peer to Peer technology was proposed (Mstafa and Wigren, 2004). Norris (2008) suggested Web-based system to which anybody can upload their calculated result. Srocka and Ciroth(2011) presented system that can upload/download LCA data to commercial software. These concepts were categorized as the Scenario I in the

Shonan Guidance. An open system, such as the Scenario I, is said that it encourages data creation activities from the bottom-up with crowd-sourcing or collective wisdom. However, reliability is relatively low. It is concerned that worthless LCA data may overflow on the central server because anyone can publish their data on the cloud. Additionally, keeping consistency among LCA data is difficult in this case.

Therefore, ensuring compatibility with reliability, consistency, immediacy, openness and user-friendless is important for data management system. To address this issue, we developed and released system as an additional function of LCA system “MiLCA” (JEMAI, 2013), and we report this solution.

METHODS

Outline of the proposed system is shown in Figure1. Procedures of data exchange and function follow.

1. A provider of the LCA data registers his/her “Team”. An aim of “Team” function is to manage a data editor. Each LCA data automatically belongs to a team of a data creator, and a user who is in the same team can edit this data. A team ID and password is required to join the team, so an origin of LCA data can be managed by this function in the system. If LCA data is published on the MiLCA Library without team registration, anybody can modify it. It is able to be used this function like “Wikipedia”.
2. A LCA data provider produces a unit process dataset and may link to upstream processes. In this system, process-based inter-linked inventory database “IDEA” including about 3000 datasets (Tahara et al, 2008) is installed as a default database.
3. Each LCA data can be marked of their review status. A specific review status can be added by a user who has a specific corded reviewer key. We issue this key for a person who passed the LCA expert examination (Institute of LCA, Japan and JEMAI, 2013) or the LCA Certified Professional examination (American Center for Life Cycle Assessmen, 2013).
4. A LCA data provider may convert their LCA data to calculated data using the default IDEA database for keeping a secret of intermediate flows.
5. The created LCA data is exported based on ISO TS 14048 format.
6. A provider uploads LCA data to the MiLCA library in the central server freely by using Application Programming Interface (API). To avoid unintended disclosure of LCA data, a provider can upload LCA data only belonging to their team. For example, it should be avoided a provider uploads LCA data reported from their supplier without a permission of them.
7. A user may utilize filtering function based on a review status as shown in Figure 2 if a user prefers to find a relatively-reliable LCA data.
8. Downloaded data is imported to LCA software MiLCA and used for a user’s LCA study.

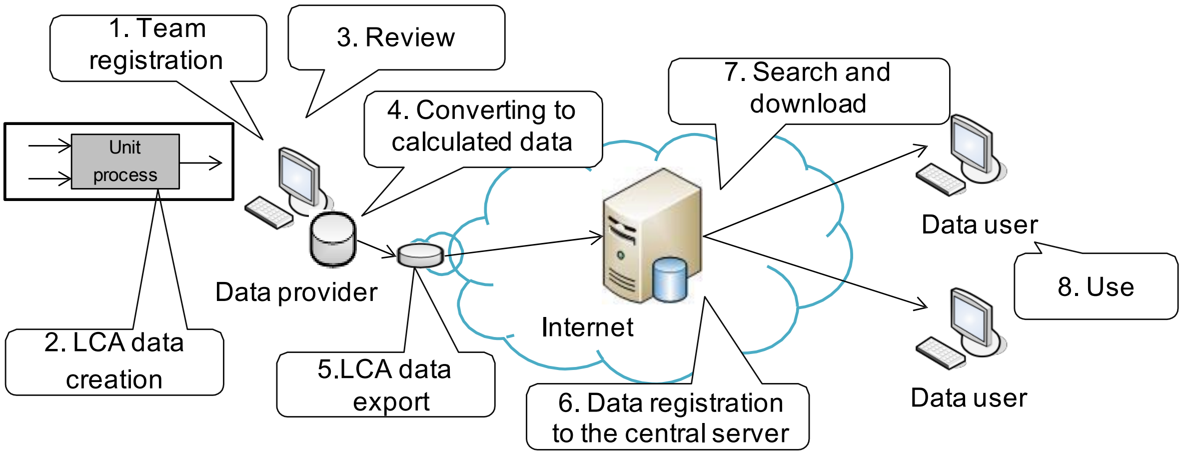


Figure 1. Outline of the proposed LCA data management system

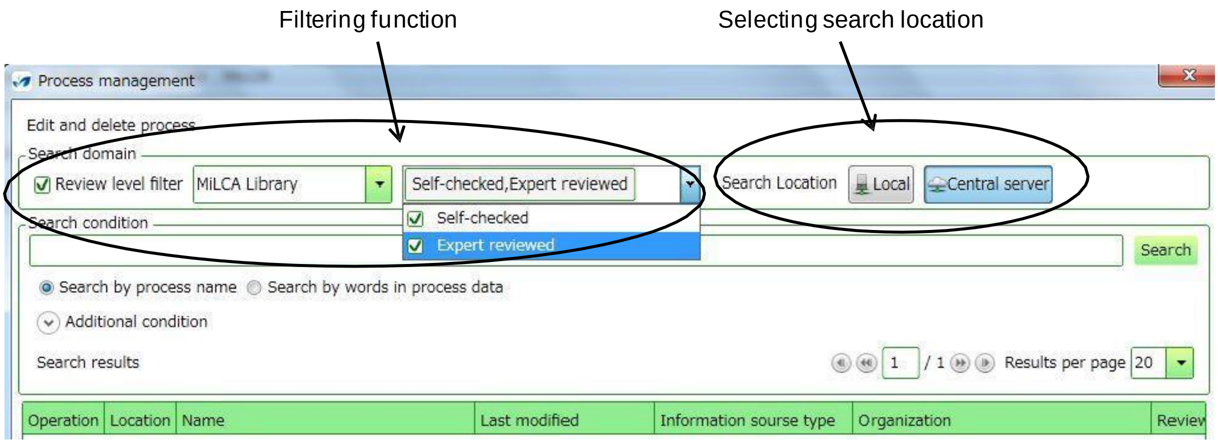


Figure 2. Search Outline of the proposed LCA data management system

RESULTS AND DISCUSSION

These functions were implemented and released as the default functions of MiLCA. The Team function prevents from unintended modifications of published LCA data. To support keeping consistency among LCA data, the existing LCA software and LCI database are used as infrastructures. The Review function clarifies reliability of each LCA data, and a user may utilize it for distinguishing a quality of the data. As of May 2013, dozens of LCA data are uploaded to the central server voluntarily. As seen above, an infrastructure for encouraging LCA data exchange among LCA practitioners is made. However, following issues still exist.

-Good-governance of default database and library: a default database is used as background database for published LCA data, so continues improvement of the data quality is essential. Incentives for publishing LCA data are needed. Furthermore, an appropriate standard to select "best available data" from a number of datasets expressing same process are required.

-Copyright protection and clarification of various contributions: keeping the right of a first unit process data producer is important, but a lot of third parties' contributions, such as pointing out a mistake, linking to upstream processes and review, are also precious contribution to the LCA community. These contributions must be clarified and respected.

-Revision of calculated data: when the default database is updated, a calculated dataset also must be revised. However, revision of published calculated data must be done by the original data provider. If the data is already distributed in long supply chain, updating all data and keeping consistency is a challenge.

-Security: as same with internet bulletin board system (BBS), surveillance of published data is needed.

CONCLUSIONS

We designed and released data management system ensuring compatibility with reliability and openness. However, there are still a lot of issues remained, such as producing good-governance body of the data management system and incentives for contributing the system.

REFERENCES

American Center for Life Cycle Assessmen (2013). LCA Certified Professionals http://lcacenter.org/1certification.aspx <viewed 2013-5-23>

ILCAJ and JEMAI (2013). LCA Expert Examination. http://www.biz.jemai.or.jp/lca-kentei/ (In Japanese) <viewed 2013-5-23>

JEMAI (2013). LCA software MiLCA. http://www.milca-milca.net/english/ <viewed 2013-5-23>

Mstafa, M. and Wigren, P. (2004) . Secure XML file sharing in a JXTA P2P network for inter-organizational industrial collaboration. *Master's Thesis of Computer Science and Engineering Program*, Chalmers University of Technology, Gothenburg.

Norris, G. (2008): Earthster, an Open Life Cycle Inventory Database, presentation, *Life Cycle Assessment VIII* Seattle, USA, 30 Sep – 2 Oct.

Srocka, M., Ciroth, A. (2011). Web-based exchange of LCA data from the client side perspective, presentation, *EnviroInfo 2011* Ispra, Italy, 5 - 7 Oct.

Tahara, K., Kobayashi, K., Onoue, T., Kanzaki, M., Nakano, K. (2008). Development of Inventory Database IDEA based on Process Analysis. *Proceedings of the 8th International Conference on EcoBalance*, Tokyo, Japan

UNEP/SETAC Life Cycle Initiative (2011). Chapter 7 Outlook: Future Scenarios for Knowledge Management. *In Global Guidance Principles for Life Cycle Assessment Databases* (pp. 113-124). United Nations Environment Programme

MANAGING SUSTAINABLE PRODUCTION THROUGH BUSINESS PROCESS-DRIVEN INFORMATION SYSTEM DESIGN

Raul Carlson, Lennart Swanström[1], Richard Watson[2], Thomas Baumgartner[3]*

[1]ABB Corporate Research, [2] The University of Georgia; [3]ABB Ltd,

**Viktoria Swedish ICT, Lindholmspiren 3A, 417 56 Göteborg, Sweden, raul.carlson@viktoria.se*

Keywords: information; management; requirement; multi-stakeholder; conceptual.

ABSTRACT

The use of corporate sustainability information tools and systems has grown organically to include a wide variety of solutions, from dedicated LCA tools to integrated, enterprise-wide sustainability systems. The discussion in this paper is based on an ABB Group internal case study of sustainability related information systems and ABB's business needs. The study concludes that to effectively manage sustainable production, all business process aspects of sustainability information management need to be taken into account, including a multi-stakeholder perspective and the cradle to grave life cycle of products. This paper discusses how to meet the information requirements for managing sustainable production by better integrating sustainability information systems and data with business processes and needs.

INTRODUCTION

ABB, a global leader in power and automation technologies based in Zurich, Switzerland, employs 145,000 people in about 100 countries. ABB's business is comprised of five divisions organized by customers and industries served. ABB was given its current form in 1988, but has an over 120 year long history. ABB is driven by a strong focus on technology and innovation, and therefore maintains seven corporate research centers around the world, and has continued to invest in R&D through all market conditions.

This paper presents results from a case study that has been performed within ABB to prepare the improvement of the information systems used to manage the sustainable production of the ABB business and business processes. The case study resulted in an extensive amount of information about both the current system and about the requirements on the new system and the processes that need to be executed to develop the new system. As an aid to interpret the results from the case study and to suggest a next step, an external expert was commissioned.

The background to this case study and the future development of the information system is that ABB has developed and used sustainability information system since the early 1990s. This includes life cycle based environmental information tools, ranging from dedicated life cycle analysis (LCA) tools and streamlined eco-design software to enterprise business integrated systems including life cycle management (LCM) functionality. The case study addressed the full range of information systems used by ABB for sustainability management. The main sustainability information systems are the environmental information systems, occupational health and safety information systems, and the Corporate Responsibility information systems for decisions and reporting within these specific areas. Some specific information systems such as the Travel Information System, used globally to monitor the travel security of ABB employees, are not included in the discussions in this paper.

METHODOLOGY

A mainly qualitative and thorough case study was performed globally and internally within ABB, investigating performance aspects of the current sustainability information systems (Baumgartner, 2012). This was based on interviews and their consecutive after-analysis. Interview targets included the ABB Group Function Sustainability Affairs, the ABB Sustainability Network (employees in the countries and businesses with a sustainability-related job role), and other ABB Group Functions such as Quality and Operational Excellence, Supply Chain Management and Information Systems. Due to the exploratory nature of the case study, an open and flexible approach was chosen for the interviews, with open-ended questions that gave freedom to interviewees to express diverse views, and to researchers to react and follow up on answers. The open-ended questions also allowed interviewees to freely voice experiences and views with less bias due to guiding questions. In addition to the interviews many related documents were reviewed, to explore further views and aspects of the current ABB sustainability information systems. To facilitate the drawing of conclusions from the extensive result from the case study, an external expert was commissioned to investigate suggestions for how to move ahead. This was mainly based on the case study report but also on other internal ABB sustainability strategy reports.

RESULTS

The findings of the case study (Baumgartner, 2012) indicate that the current ABB sustainability information management works well for the targeted audience, but a wider audience for sustainability information has grown over the years. The system therefore needs to be improved and further developed. Previous incremental improvements have focused mainly on data collection, but the case study results show that a more holistic approach is needed. For example, there are issues with data completeness, consistency, intelligibility, validity and accuracy, as well as with timeliness of reporting, which compromises the usefulness of the information. Also, there are issues with data transfer between different parts of the system and the sustainability information could be better integrated into the plan-do-check-act loop of the sustainability management system. The case study results continue with that when developing the sustainability information system it is important to not only focus on the technical development, but to also look at the information itself, such as the processes to define, collect, report, validate, analyze, distribute and follow-up actions on data, as well as on how to educate people to govern the system. Key requirements on the new system should be flexibility and resilience, as well as integration of workflow and document management. Since sustainability is a wide area, there is also a need to define the scope of the sustainability information management, its data model, and of the sustainability reporting rules, roles, and responsibilities. As basis for a redevelopment and redesign of the system, it is necessary to improve the understanding of the many different requirements within the ABB group. It is suggested to redevelop the system evolutionary rather than revolutionary, since the majority of the improvements need to be related to the integrated system of information, people, and governance of the ABB Group.

Analysis of the case study (Carlson, 2013): The case study was assessed to propose a next step towards implementation and further development of an ABB Sustainability information system. The work was condensed into a short report (Carlson, 2013). A key result from this work was a condensed draft list of information system requirements, together with a conceptual view presented in the discussion section below.

DISCUSSION

The case study shows that the ABB sustainability information system encompasses the framework for an environmental information system, with respect to users, organization and logical and technical content as described in (Carlson, 2010). Hence, as tool for discussing the status and vision of ABB's sustainability information system, a conceptual view of ABB from the perspective of sustainable development and a sustainability information system was developed (Carlson, 2013).

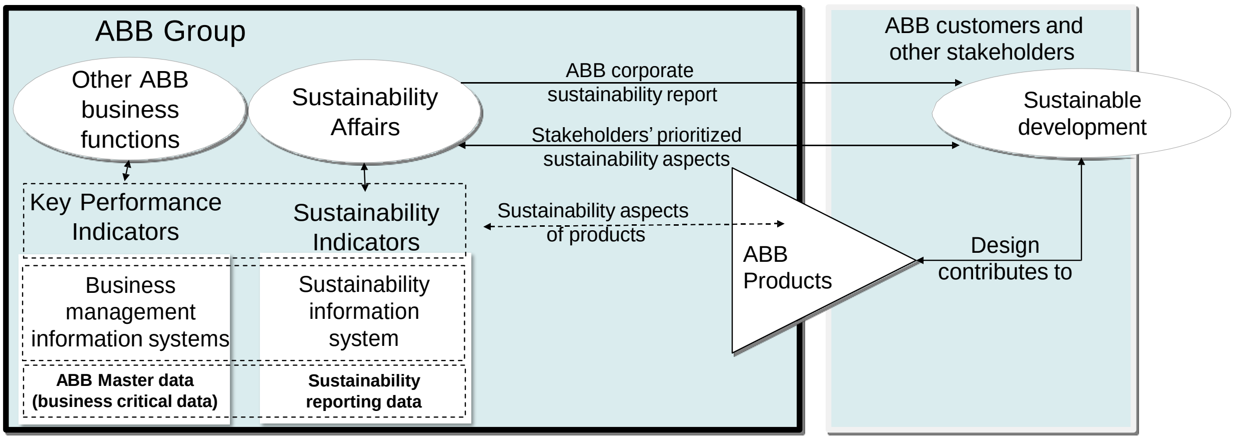


Figure 1. Conceptual view of ABB from the perspective of a sustainability information system (Carlson, 2013).

The conceptual view of ABB in figure 1 describes how the ABB *Sustainability information system* relates to other *ABB Group* and business functions, and the concept of *Sustainable development* at large. The dotted line boxes and the dotted line arrow are areas where integration may be suggested for increased efficiency and effectiveness of the ABB sustainability management. For example, the corporate *Sustainability indicators* and the environmental product design requirements and the product life cycle may be more clearly integrated. Also, the overall *Sustainability information system* may be integrated with the *Business management information systems*. Each of these integration aspects are understood to have many business imperatives, and therefore need careful consideration before implementation decisions are taken. For example, ABB may move more strongly towards an information system design mainly established on the logic dominated by sustainability (Watson, 2012). But regardless of level of ambition, it is suggested that the new system is designed on basis of available standards and guidelines, such as the newly released ISO 14033 – Quantitative environmental information (ISO, 2012). This will provide both a good information system structure and a basis for good quality sustainability data.

CONCLUSIONS

The ABB case study concludes that in order to effectively manage sustainable production, considering its multi-stakeholder perspective throughout the supply chain and life cycle, all business process aspects of sustainability information management need to be taken into account. The case study further concludes that it may be beneficial to hold a much broader approach when considering the sustainability information system, including information needs, technology, people, governance and business processes (including data definition, collection, reporting, validation, analysis, distribution and follow-up actions).

The conclusion from this work is that the task of managing sustainable production through business process-driven information system design is far more multifaceted than just monitoring the production processes. The three main faces of this information system design are, firstly the business processes, and secondly the sustainability management system that sets the aspects and indicators that defines sustainability, and thirdly the data acquisition and communication for measurement, reporting, and delegation of responsibilities.

Today, there is a gap between the information systems that govern business processes and the information systems used for the sustainability management. In the past, many aspects and indicators that guide the way towards sustainable development have been defined externally; by for example the GRI reporting schemes. Reporting of sustainability data from the business processes throughout ABB, have mainly been developed separately from each other, and from the ABB business information system. It has not been a systematic information system in place for target setting and delegation of responsibilities based on the reported sustainability performance data. ABB was a pioneer in sustainability reporting, and now has the opportunity to become a leader in integrating sustainably into business processes and decision making so that it successfully transitions to the era when designing and marketing ecological sustainable products and services will be a necessary core competency for competition.

REFERENCES

Baumgartner T., (2012). GF-SA Sustainability Information Management, 9ADB003049-36, 2012. *ABB Sustainability Strategy 2015+*

Carlson R., (2013). Report and way ahead ABB Sustainability information system, *Viktoria Swedish ICT*

Carlson R., (2010). Structuring information for industrial environmental management. *pp 180-197 in Teuteberg F, Marx Gomez J., Corporate environmental information management systems, Advancements and trends, Business science reference,* IGI Global.

Watson, R. T., Lind, M., & Haraldson, S. (2012). The emergence of sustainability as the new dominant logic: Implications for Information Systems. *Paper presented at the International Conference on Information Systems, Orlando, FL.*

ISO (2012). ISO/TS 14033:2012 – Quantitative environmental performance – Guidelines and examples.

STATE-OF-THE-ART AND REQUIREMENTS FOR COLLECTING AND MANAGING SUSTAINABILITY DATA ALONG TODAY'S SUPPLY CHAINS

[1]Grambow, Gregor, [1]Mundbrod, Nicolas, [1]Steller, Vivian, [1]Reichert, Manfred*

[2]Schiffleitner, Andreas, [3]Bley Thomas, [3]Feick, Christian

[1]Ulm University, Germany, [2]KERP, Austria, [3]iPoint-Systems, Germany

**James-Franck-Ring, 89081 Ulm, Germany, gregor.grambow@uni-ulm.de*

Keywords: Supply Chain; Data Exchange; dynamic, process-aware data collection

ABSTRACT

Today, companies of all sizes need to gather, manage and deliver a wide range of sustainability information due to public demand, regulations and laws. However, in order to calculate reliable measurements, they face the tremendous challenge to gather heterogeneous sustainability information along their dynamic and complex supply chains. As there is no systematic support yet, the EU project SustainHub aims to develop an information system supporting complex sustainability data collection processes along supply chains. Therefore, the project's consortium has established a solid base of requirements and state of the art which are presented in this paper in a consolidated way to enrich the discussion about life cycle management.

INTRODUCTION

Nowadays, there is growing pressure on companies in the automotive and electronics industries to produce and deliver more sustainable products, coming from the customer side as well as emerging laws enforced by national and European parliaments. As a result, companies now face the challenge to gather and distribute sustainability information along their entire supply chains. Thereby, companies are often encouraged to deliver certain computed indicators based on existing regulations or laws that also consider their suppliers. The main issue in this case is the great heterogeneity of supply chain data: some data might be delivered in an unsupported format, some might not match predefined quality requirements, and some might be delivered incompletely or even not at all. So, data collection obviously combines a multitude of manual and automated tasks (e.g., data verification, validation, or authorization) and needs to be synchronized. Furthermore, in some cases, external service providers might also be included in the data collection process, e.g., providing lab tests or assessments regarding important regulations.

As sustainability data collection along supply chains is such a complex endeavor, companies crave for professional support provided by integrated information systems. However, currently available market solutions are fragmented and limited in many respects. They do not satisfy the requirements companies currently have for collecting sustainability data from their various suppliers.

The ongoing research project SustainHub[1] aims to provide a sophisticated platform that supports this scenario. This paper, in particular, deals with the dynamic process of data collection and management of sustainability data in the supply chain. It reviews the state of the art in this sector and elicits important basic requirements for implementing a system supporting automated dynamic data collection from heterogeneous sources.

BACKGROUND

This section briefly gives background information on sustainability indicators and regulations requiring them. Published by different research fields and industries, there is a myriad of possible definitions that can be considered as sustainability indicators. Furthermore, these indicators relate to different phases of the life cycle (e.g., development vs. production) and to different entities, like a produced product, a process or even a whole company. Areas of indicators may include managerial issues, like compliance with regulations, social issues like corruption and bribery, or environmental issues, like the reduction and prevention of GHG (GreenHouse Gas) emissions. There are various initiatives, regulation, and laws covering portions of these sustainability indicators formally or informally requiring companies to comply and report the indicators to customers or legislations. Examples include the ISO 14000 standard environmental factors in production, GRI[2] covering sustainability factors or regulations like REACh (REACh, 2006) and RoHS (RoHS, 2002).

METHODS

To properly elicit requirements for the coming SustainHub platform, the project consortium has taken the following approach: To gather real end-user requirements, two quantitative surveys were conducted with representatives from the electronics and the automotive industry. Furthermore, multiple companies of these sectors are part of the SustainHub consortium for continuous feedback and evaluation.

REQUIREMENTS

In this section, four concrete basic requirements of a platform supporting sustainability data exchange in a supply chain are elicited. These requirements are illustrated in Figure 1 and explained in the following. Figure 1 abstractly exposes the process of requesting a sustainability indicator from one or multiple suppliers.

Requirement 1: Request Variability. In the area of supply chain communication, a multitude of different factors can influence a request for a sustainability indicator. These include, for example, quality requirements of the requester to the indicator data (e.g., age of the data or precision of measurement) and approval processes on the answerer side (e.g., only a specific person can approve the data or the four-eyes-principle). Other data influencing a request includes specific configurations only applying for request made by the requester, properties of the situation (e.g., a newly emerged regulation), or properties of data the answerer has already provided as part of another request. If the meta data of that data matches

[1] SustainHub (Project No.283130) is a collaborative project within the 7th Framework Programme of the European Commission (Topic ENV.2011.3.1.9-1, Eco-innovation).

[2] Global Reporting Initiative: https://www.globalreporting.org

the request, no new data collection is needed. A platform supporting such communication needs to be aware of such meta data and to be able to utilize it for the request. Furthermore, as the large number of parameters implies many different request variants, that system has to be able to efficiently manage and apply these variants.

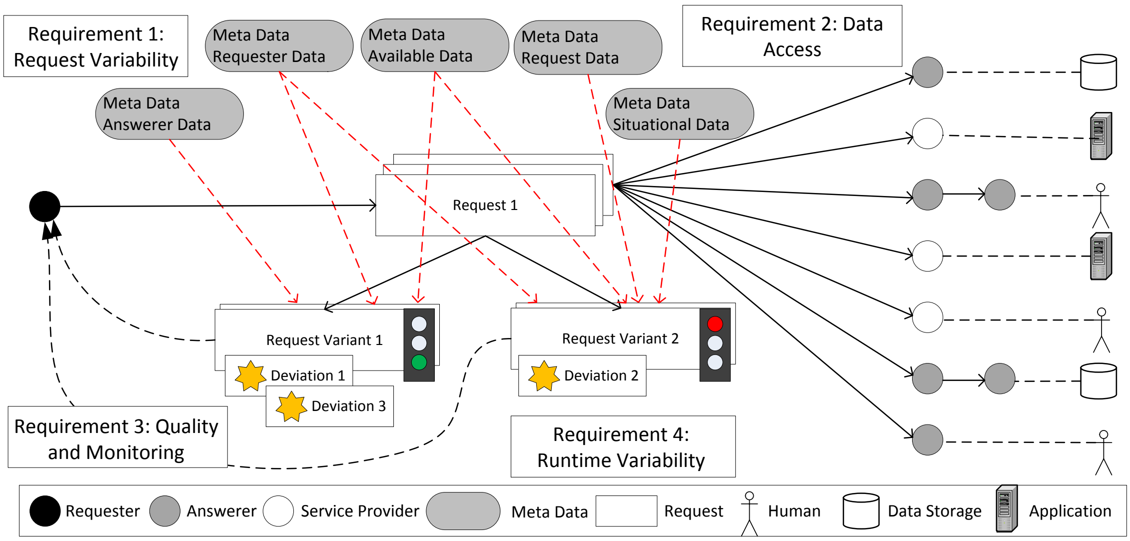


Figure 1. Data collection requirements

Requirement 2: Data Access. As mentioned before, the process of sustainability data collection involves a large number of different manual and automatic tasks. Some requests or parts of them might be answered by humans, some by automated systems. Some might be forwarded by a supplier to his suppliers. For some requests, external service providers might be involved. This implies that many different systems or data formats can be involved and that data could be provided with different calculations or units. A platform supporting such communication must be capable of managing such data as well as the access to it.

Requirement 3: Quality and Monitoring. Due to the heterogeneity in today's supply chains, the quality of data provided by suppliers might differ greatly. This can be of special importance if one request involves multiple answerers. This situation implies another problem: When expecting data from multiple answerers it is difficult for a requester to be aware of the status of his request as they might answer in different ways and with varying delay. A platform supporting such communication must be capable of coping with varying quality levels and be able to monitor request in a way that the requester always has access to up-to-date information regarding the request status.

Requirement 4: Runtime Variability. Sustainability data requests in a supply chain can take a considerable amount of time. This implies the fact that properties important for the request might change (e.g., a new regulation might emerge). Furthermore, various exceptional situations are possible: one or more suppliers might answer with data that does not match the requesters' quality requirements, might answer delayed, or might even not answer at all. Therefore, a platform supporting such communication must be able to cope with such situations and still complete the requests.

STATE OF THE ART

Due to limited space, this section presents a small selection of state-of-the-art solutions and scientific papers on this topic. When it comes to sustainability data communication in supply chains, Environ BOMcheck[3], HP IMDS[4] (International Material Data System), and HP CDX[5] (Compliance Data eXchange) can be considered as market leaders. All of these are platforms that are centrally operated by one company allowing customers to exchange material data. BOMcheck is mainly used in the electronics industry and allows for storing full material declarations. CDX supports the creation of a material management process by enabling the exchange of material data sheets along the supply chain. IMDS offers material data exchange via web interface. It solely focuses on the automotive sector where it has become the de facto industry standard. All of these systems do not meet the requirements for exchanging sustainability indicators along supply chains as they only enable the transfer of directly related product data and none about the companies, or people, or more complex computed values. On the scientific side, there are studies dealing with supply chain communication and information system support for it (Dong et al., 2009; Tseng et al., 2011). Further, there are studies dealing with sustainability reporting and the impact of information systems on it (Melville, 2010). However, these contributions focus on reviewing solutions or theoretical approaches and do not deal with the creation of new supportive information systems.

CONCLUSIONS

In this paper we have briefly shown requirements for platforms that aim at supporting the exchange of sustainability data in a supply chain. Furthermore, we have reviewed the state-of-the-art elaborating that prevalent solutions do not meet these requirements. The latter can be used to create novel systems that automate and thus support sustainable supply chain communication. This is what will be done in the further course of the SustainHub project where we aim at implementing the data collection and exchange process explicitly applying dynamic process-aware information system technology (Dadam and Reichert, 2009).

REFERENCES

Dadam, P., Reichert, M. (2009) The ADEPT project: a decade of research and development for robust and flexible process support. *Computer Science-Research and Development, 23(2), pp. 81-97.*

Dong, S., Xu, S.X., Zhu, K.X. (2009) Research Note—Information Technology in Supply Chains: The Value of IT-Enabled Resources Under Competition. *Information Systems Research, 20(1), pp. 18-32.*

Melville, N.P. (2010) Information systems innovation for environmental sustainability. *MIS Quarterly, 34(1), pp. 1-21.*

Tseng, M.L., Wu, K.J., Nguyen, T.T. (2011) Information technology in supply chain management: a case study. *Procedia-Social and Behavioral Sciences, 25, pp. 257-272.*

REACh: Regulation (EC) No 1907/2006: Registration, Evaluation, Authorisation and Restriction of Chemicals

RoHS: Directive 2002/95/EC: Restriction of (the use of certain) Hazardous Substances

[3] https://www.bomcheck.net
[4] http://www.mdsystem.com
[5] http://www.cdxsystem.com

INNOVATION AND PRODUCT DEVELOPMENT: INTERACTIVE

Time: Aug 27: 3:30 pm - 5:00 pm

Session chairs: Niki Bey, The Technical University of Denmark, Denmark
Mattias Lindahl, Linköping University, Sweden

A PRACTICAL METHOD FOR DFE AT VOLVO PENTA

Eva Axelsson, Volvo Penta Corp, CB82000 Z1.3, 405 08 Gothenburg,
eva.i.axelsson@volvo.com

Keywords: LCA; environment; development; impact; evaluation.

ABSTRACT

When designing a new product, or generation of new products, a lot of decisions are taken regarding choice of materials, energy consumption, pollution from production processes etc. For complex products like engines it is not always obvious from a designer point of view what the best choice from an environmental perspective is. At Volvo Penta a method is used that is based on experiences from Life Cycle Assessments but transformed into a practical methodology.

INTRODUCTION

Volvo Penta produces diesel engines for marine and industrial applications. Environmental care is together with Safety and Quality core values of the Volvo Group.

Volvo has been working very actively in the initial development of LCA methodologies and evaluation methods. Contacts and exchange of competence (Baumann, 1995) with Swedish and international researchers and institutions are frequent. Studies are made both on complete vehicles as well as on different vehicle components. Different LCA methods and assessment models have been used (Steen, 1999 and Finnveden, 2009). These studies have resulted in a lot of new knowledge about where in the life cycle different types of impact occur, relative magnitudes and most important factors to consider in Volvo products and operations. To make the knowledge practically available, a method has been developed for use in the design work.

MATERIALS AND METHODOLOGY

Larger Volvo Penta development projects follow a project model that contains 9 different stages; Pre-study, Concept study, Detailed development, Final development, Industrialisation and Follow up.

During the Concept study a mandatory preliminary environmental assessment is required to be carried out. The assessment is carried out as a team discussion following a standard procedure including a template where all the different life cycle phases are regarded. The technical project leader describes the proposed design and function, project targets relevant for environmental impact as well as production site and suppliers chosen.

Examples of environmental aspects relevant for a diesel engine are: fuel consumption, emissions of PM, NOx and CO_2, interval for oil change, surface treatment, engine packaging size and material, possibility for material recycling, degree of recycled material used etc. Environmental aspects are raised and issues of concern are either put on an action list or decisions are taken directly where possible.

For each component or aspect a check against possible environmental impact, company steering documents and public concern is done. A template is used to guide the discussions and document upcoming issues and decisions.

The composition and skills of the team is of course crucial for the result. An environmental expert is a mandatory participant of the team, ensuring continuous access to updated environmental facts, legislation, new LCA studies etc. Other participants may represent design, purchasing and manufacturing depending on the type of project.

At a later stage in the Final development phase the preliminary assessment is reviewed and actions followed up.

RESULTS

By using the described method, the product under development is evaluated regarding life cycle environmental aspects. Issues and concerns, as well as decisions taken, are documented in the formatted template and added to the rest of the project documentation.

DISCUSSION

By using this procedure for identification and evaluation of potential environmental aspects during the life cycle of a product, better choices of material, assembly methods, surface treatment, transport modes etc can be made. Solutions with higher environmental impact can be avoided and improvement possibilities identified.

Another result from the team discussions and cooperation in evaluating environmental aspects is the continuous training of designers and project leaders in environmental matters. A work has started to further improve the process and tool with adaptation to new circumstances and knowledge.

CONCLUSIONS

Environmental care is a Volvo Penta core value and it is important that considerations are made during product development to constantly reduce the environmental impact through the life cycle. We consider that the method for environmental assessment we use serves as a good tool for that.

REFERENCES

Baumann, H. (1995). Decision making and Life Cycle Assessment. Report - Department of Technical Environmental Planning, Chalmers University of Technology, Göteborg, Sweden, no: 1995:4

Steen, B. (1999). *A Systematic Approach to Environmental Priority Strategies in Product Development (EPS): Version 2000-General System Characteristics* (p. 67). Centre for Environmental Assessment of Products and Material Systems.

Finnveden, G et al, (2009). Recent developments in Life Cycle Assessments. *Journal of Environmental Management, Volume 91, Issue 1, October 2009, pages 1-21*

BARRIERS FOR IMPLEMENTING ECOINNOVATION IN DESIGN FOR ENVIRONMENT: OUTPUTS OF DIFFERENT ECO-DESIGN PROJECTS

Esther Sanyé-Mengual[a,], Sara González-García[b,c], Raul Garcia Lozano[d], Gumersindo Feijoo[b], Maria Teresa Moreira[b], Xavier Gabarrell[a,e], Joan Rieradevall[a,e]*

[a]*Sostenipra (ICTA-IRTA-Inèdit). Institute of Environmental Science and Technology (ICTA). Universitat Autònoma de Barcelona (UAB). Campus de la UAB s/n, 08193, Bellaterra (Barcelona), Spain - *Corresponding author: Esther.Sanye@uab.cat*

[b]*Department of Chemical Engineering, School of Engineering, University of Santiago de Compostela, 15782- Santiago de Compostela, Spain*

[c]*CESAM, Department of Environment and Planning. University of Aveiro, 3810-193 Aveiro (Portugal)*

[d]*Inèdit Innovació, Carretera de Cabrils, km 2 -IRTA-, 08348 Cabrils, Barcelona, Spain*

[e]*Department of Chemical Engineering, Universitat Autònoma de Barcelona (UAB), 08193 Bellaterra, Barcelona, Spain*

Keywords: Design for environment; ecoinnovation; barriers; sustainable manufacturing

ABSTRACT

Barriers for ecoinnovation are quantified in 6 real cases of ecodesign pilot projects. After performing a first viability assessment, between 38% and 56% of the ecodesign strategies were rejected, mainly in Transportation (63%) and Concept (56%) lifecycle stages. Common barriers are economic investment (e.g., new machinery or renewable energy systems) as well as technical constrains (e.g., for using new materials or for improving energy efficiency with new technologies). Social strategies are disregarded if the company personnel believe that the consumer may not value the improvements. For the design of the final prototype, only between 5% and 33% of the proposed strategies were considered by the company. Main barriers include increase of production costs (20%) and low environmental improvement (20%). The inclusion of economic and social indicators in the ecodesign methodology could promote to overcome some of these barriers. More efforts in Transportation, Concept and End of Life stages may be done by encouraging companies to strength their interaction with the value chain suppliers, promoting ecoinnovation and improving communication tools.

INTRODUCTION

Design for Environment (DfE) or eco-design has grown their contribution to sustainable manufacturing during the last decades. This can be observed not only at the business scale but also at the policy and research ones (Boks, 2006). While labelling, sustainable reporting and marketing show the increasing examples of ecodesign products in the market; laws and standards are developed to establish both methodologies and benchmarking frameworks (e.g. Directive 2009/125/EC (European Council, 2009), ISO 14006 (2011)). This growth can be related to the benefits that ecodesign offers to businesses and products, some of which have been reported in the scientific literature under environmental and economic approaches (Borchardt et al., 2011; Knight and Jenkins, 2008; Plouffe et al., 2011). Moreover, social benefits are embedded in a more sustainable manufacturing and in the diversification of products and markets (i.e., additional decision-making criterion). Notwithstanding these positive effects, ecodesign is being implemented progressively and irregular in different products and sectors as environmental strategies can find implementation barriers. Although some studies has analysed the barriers in companies (Boks, 2006; Theyel, 2000; van Hemel and Cramer, 2002), there is a need for further research in this issue. Moreover, no previous studies have evaluated the barriers of projects where research entities have been involved for assessing ecoinnovation in businesses. Finally, although Life Cycle Assessment (LCA) is a common environmental tool used in ecodesign (e.g., González-Garcia et al., 2011), there is a lack of identifying the barriers from a life-cycle perspective while showing the hotspots as a basis for improvement proposals.

This contribution aims to identify the barriers for ecoinnovation in DfE from a life-cycle perspective in real projects developed in collaboration between businesses and research entities. Six real projects were evaluated in the assessment for including different products (wine box, chair, pergola, jacket, trekking boot and knife) from different sectors. Finally, efforts in the implementation of ecoinnovation in DfE and potential methodological improvements are proposed.

MATERIALS AND METHODS

The combined methodology of Life Cycle Assessment (LCA) and eco-design described in Gonzalez-Garcia et al. (2011) was used for the ecodesign projects. After the identification of the hotspots of the initial product (both quantitative and qualitative assessment), ecoinnovative strategies were proposed for improving the product. These strategies were evaluated during all the process and two selective steps were performed. First, a viability assessment (technical, economic and social) allows the company to select some of the strategies for being evaluated for the new design. Second, the prototype design is defined by the company after the selection of the strategies according to environmental (LCA results) and technical (production process) criteria.

The quantification method of the selection and rejection rates of the ecoinnovative strategies was done at different scales; at the project scale, regarding the step where they are selected (viability or prototype), at the lifecycle scale and at the product scale. Finally, global results were also reported for observing common barriers and differences among sectors. For the viability assessment selection, barriers were categorized in technical, economic and social; while for those barriers rejected in the prototype step, categories were defined according to literature (van Hemel and Cramer, 2002) and the criteria used by companies in: increase of production costs, low environmental improvement, influence on the quality and image of the final product, low development of marketing and communication tools, dependence from suppliers, requirement of materials substitution and incompatibility with other strategies.

RESULTS AND DISCUSSION

Common barriers for ecoinnovation

On average, 54% of the proposed strategies are considered viable from the technical, economic and social point of view. Main barriers are due to technical constraints (~46%), such as incompatibility with the current production chain or difficulties for implementing innovative programs (e.g., Collection program of out of use products for material recycling). Economic barriers (~31%) are mainly related to strategies that need investment (e.g., new machinery or renewable energy systems). Finally, customer negative perception is the most common social barrier (~23%). Main barriers in the final selection are related to an increase of production costs (22.5%) or low environmental improvement (20.8%), while incompatibility within strategies and avoiding materials substitution are the least common.

Regarding the sectors analyzed, more strategies were proposed for the urban furniture project (45), where energy was consumed during the use phase, followed by the furniture and kitchenware sectors. The lowest number of strategies was proposed in the packaging sector. The selection rate for the prototype design was the highest in the kitchenware product (33,3%), while the lowest in products tied to design constraints (i.e., furniture with only 5%).

Table 1. Selected strategies and identified barriers by step and ecodesign project.

	Chair	Knife	Trekking Boot	Pergola	Wine woodbox	Jacket	Average
Proposed strategies	39	33	25	45	16	26	31
Viability assessment							
Selected strategies	17	17	11	26	10	16	16
Technical barriers (%)	52,4	38,9	64,3	43,8	33,3	45,5	46,3
Economic barriers (%)	28,6	22,2	28,6	37,5	33,3	36,4	31,1
Social barriers (%)	19,0	38,9	7,1	18,8	33,3	18,2	22,6
Prototype design							
Selected strategies	2	11	5	12	3	5	6
Low environmental improvement (%)	17,6	37,5	0,0	23,1	28,6	18,2	20,8
Incompatibility with other strategies (%)	0,0	0,0	0,0	23,1	0,0	0,0	3,8
Affectation of the product quality and image (%)	29,4	12,5	14,3	15,4	14,3	9,1	15,8
Low development of communication tools (%)	17,6	12,5	0,0	7,7	14,3	27,3	13,2
Avoiding materials substitution (%)	17,6	0,0	14,3	7,7	0,0	9,1	8,1
Increase of production costs (%)	17,6	25,0	42,9	7,7	14,3	27,3	22,5
Dependence from providers (%)	0,0	12,5	28,6	15,4	28,6	9,1	15,7

Barriers from a life-cycle perspective

Concept, Materials and Use were the lifecycle stages where more strategies were proposed in contrast to Transportation. When analyzing viability, 60% of the strategies regarding Packaging (with the lowest barriers number) and Use (with no social barriers) stages were selected. However, Transportation (37.5%) (with no economic barriers) and Concept (44.1%) (mostly due to technical barriers) had the highest rejection rates. For the prototype design, Material and Processing (~26%) ecoinnovative strategies were the most selected as more compatible and that provide some production cost reductions. No strategies were finally applied regarding End-of-life, by avoiding company´s responsibility of this stage, and only 6% of the Transportation strategies were finally applied, due to the low environmental improvement associated. Finally, most strategies are applied in the cradle-to-gate lifecycle stages (~20%) than in the gate-to-cradle ones (~11%).

CONCLUSIONS

Technical, economic and social barriers are common in the development of ecodesign projects. Although usually LCA is used for an environmental assessment, the integration of economic and social indicators in the ecodesign methodology may be key drivers for overcoming some of the barriers (i.e., cost-benefit analysis of a strategy that requires investment). Notwithstanding the development of eco-labeling, the low development of communication tools is an important barrier (13.2% in the final selection), although some communication pathways are low-cost (i.e., business website). Communication should be promoted as a way to include both customers and stakeholders of the value chain in the sustainable behavior of the products. This fact is also important for the lifecycle stages were fewer strategies are finally implemented. Transportation and End of Life stages are the lifecycle stages were less ecoinnovative strategies are applied. Efforts in this area should be done in incorporating the stakeholders of the value chain (e.g., suppliers) as well as incorporating extended responsibility (i.e., end of life).

REFERENCES

Boks, C. (2006). The soft side of ecodesign. *Journal of Cleaner Production*, 14 (15-16), 1346-56.

Borchardt, M., Wendt, M.H., Pereira, G.M., Sellitto, M.A. (2011). Redesign of a component based on ecodesign practices: environmental impact and cost reduction achievements. *Journal of Cleaner Production*, 19 (1),49-57.

European Council (2009). *Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 Establishing the Framework for the Setting of Eco-design Requirements for Energy-related Products.*

González-García, S., F.J. Silva, M.T. Moreira, R. Castilla Pascual, R. García Lozano, X. Gabarrell, J. Rieradevall, and G. Feijoo (2011). Combined application of LCA and Eco-design for the sustainable production of wood boxes for wine bottles storage. *The International Journal of Life Cycle Assessment*, 16 (3), 224–237.

ISO (2011). *ISO 14006: Environmental Management Systems - Guidelines for Incorporating Eco-design.* Geneva: International Organization for Standardization.

Knight, P., Jenkins, J. (2008). Adopting and applying eco-design techniques: a practicioner's perspective. *Journal of Cleaner Production*, 17(6), 549-558.

Plouffe, S., Lanoie, P., Berneman, C., Vernier, M. F. (2011). Economic benefits tied to ecodesign. *Journal of Cleaner Production*, 19 (6-7), 573-579.

Theyel, G. (2000). Management practices for environmental innovation and performance. *International Journal of Operations & Production Management*, 20(2), 249-266.

van Hemel, C., Cramer, J. (2002). Barriers and stimuli for ecodesign in SMEs, *Journal of Cleaner Production*, 10 (5), 439-453.

DEVELOPING, EVALUATING AND ASSESSING ECO- INNOVATIONS BASED ON LIFE CYCLE ASSESSMENT AND QUALITY MANAGEMENT APPROACH

Hildenbrand, J., Gremyr, I., Raharjo, H. and Sarasini, S. Chalmers University of Technology.*

**Environmental System Analysis, Chalmers University of Technology, 412 96 Göteborg, Sweden. E-mail: jutta.hildenbrand@chalmers.se*

Keywords: Eco-Innovations; Life cycle assessment, Quality Management

ABSTRACT

Eco-innovation is seen as a way to contribute to better environment and increased competitiveness. Two problems related to eco-innovations are lack of support for their development and for assessment of their environmental impact. For the first problem one way forward is to integrate sustainability in established toolkits such as quality tools. Turning to the second problem life cycle assessment is well suited if developed to support early stages of development. This paper aims to develop a framework supporting development, evaluation and assessment of eco-innovations based on quality management and life cycle perspectives.

INTRODUCTION

Eco-innovations (EIs) can be described as "new products and processes which provide customer and business value but significantly decrease environmental impacts" (James, 1997: 53). Two areas related to EIs that are in need of more research and developments are tools supporting development of EIs and tools to evaluate actual environmental impact of the EI.

A commonly argued approach to create management support for sustainability is to integrate environmental sustainability into existing engineering practices (Angell and Klassen, 1999). An area in which management support in the form of practices as well as tools is established is Quality Management (QM). A core principle in QM is customer focus; expanding the customer concept to include other stakeholders and society is a means to integrate sustainability considerations with QM (Garvare and Johansson, 2010).

Life Cycle Assessment (LCA) is an approach to evaluate environmental impact of EIs. Arguments are that LCA is a widespread approach to quantify environmental impacts throughout a life cycle (Baumann and Tillman, 2004; Brunklaus et al., 2012). However, LCA requires a rigorous assessment and is most often applied on already developed products (Poudelet et al., 2012). For EIs, LCA is needed in a stage were quantitative details of an offer is not yet available. Hence, an LCA approach applicable in innovative stages is needed. Addressing the shortage of practices and tools for EIs, the purpose of this paper is to develop a framework supporting development, evaluation and assessment of eco-innovations based on quality management and a life cycle perspective.

METHOD

The project is based on state-of-the art reviews of three fields (EI, QM, and LCA) to create a framework for development, evaluation and assessment of EIs. The framework integrates "a number of different works on the same topic, summarizes the common elements, contrasts the differences, and extends the work" (Meredith, 1993). The framework is based on a set of principles linked to practices supportive of EIs.

RESULTS

The underlying principles linked to EI, LCA and QM are elaborated on in the next section, before introducing the framework of practices proposed.

Underlying principles

The first principle is that companies should 'aim to collaborate with diverse stakeholders in order to generate ideas for EI'. This is concluded as literature on EI point to the criticality of collaborations with stakeholders such as key suppliers, competitors, science partners (universities, research institutes, etc.) to get valuable input in terms of knowledge and other resources. It has further been argued that input from diverse stakeholders contribute to more radical innovations (Liyanage, 1995; Baiman et al., 2002).

Second, 'EIs should be both developed and assessed based on life-cycle thinking', as a useful evaluative component of the design process. As argued earlier a complete LCA is infeasible at an innovative stage, due to lack of detailed knowledge of the resulting product. The principles underlying LCA, referred to as life cycle thinking, are still applicable. In short, the life cycle thinking encompasses a systems view on the product and an awareness of environmental impacts throughout the life cycle of a product. Having applied life cycle thinking will nevertheless be a means of addressing actual environmental impact and prepare for more comprehensive LCA in later design stages.

The third principle based on a QM approach is that a 'focus on stakeholders' needs, and translation of those into EI characteristics, must be maintained throughout the design process'. This principle is aligned to two core principles of QM being customer focus and continuous improvements (Dean and Bowen, 1994), and supports the need to assess and ascribe value to different stakeholder needs and demands. The notion of continuous improvement is integrated in this principle by pointing to a continuous process, which is also applied in environmental management (Burström von Malmborg, 2002).

A framework of practices

Based on the principles outlined above, a five-step framework of practices (Figure 1) has been developed to guide designers and developers in developing and assessing eco-innovations. In the following brief summaries of each of the five steps of the framework of practices is presented.

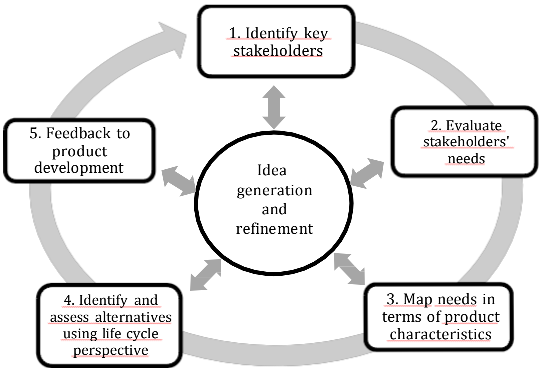


Figure 1: Key practices for our proposed framework (Sarasini et al. 2013)

1. Identify key stakeholders
To identify stakeholders that can either be affected by, or affect, the EI, three guiding questions are proposed: *who is affected; who can contribute; and what is their influence*? Addressing these questions helps in identifying stakeholders, analyse whether they support or oppose the EI, and reflect on what relevant resources they control. One way of mapping their influence is to assess it in relation to the product life cycle stages.

2. Evaluate stakeholders' needs
Having identified stakeholders, this practice moves into evaluating their needs in relation to the EI. A guiding question at this step is: *what are stakeholders' needs in terms of the overall functionality of the product or process*? The needs identified are likely to be of a diverse nature and include similar, as well as contradictory, needs.

3. Map needs in terms of products characteristics
The aim of the third step is to identify critical product characteristics that can satisfy the stakeholders' needs. There are two guiding questions: *how can needs be translated into functional specifications*; and *which product characteristics affect critical functional specifications*? Support for this step can be found e.g. in Quality Function Deployment.

4. Identify and assess alternatives using life-cycle perspective
Having identified potential product characteristics, a range of alternatives of EI characteristics is derived based on environmental assessment. A guiding question for this practice is: *which alternatives provide the greatest environmental improvement from a life cycle perspective*? Support for this practice can be found e.g. in simplified and streamlined LCA.

5. Feedback to product development
The environmental assessment addressed in step four helps to identify 'hotspots', which are aspects of the product life cycle with high environmental impact. It also makes trade-offs between different types of impact visible. In step five this information is fed back to the design team that may choose to develop a particular product or to restart the cycle if more information is needed. In a second cycle new stakeholders might be identified, some of which might become innovation partners given their expertise in a particular area.

DISCUSSION

This paper presents the first step in outlining a framework for development, evaluation and assessment of EIs based on QM and life cycle perspectives. A second step is to refine our ideas based on practical applications of the framework as well as feedback from scholars. The frameworks presented build on previous research and attempts to create synergies between EI, LCA and QM. The key idea is to expand on established QM tools in a way so that it can support development of EIs. Later, LC thinking is applied to assess the environmental impact of the EIs to ensure that options most environmentally benign are developed. The framework places demands on practitioners to involve external stakeholders in early stages of development. A key issue to achieve this is to establish a view on sustainability considerations as creating opportunities rather than imposing constraints (Angell and Klassen, 1999). In the framework proposed this is supported e.g. by the use of life cycles to generate alternatives EIs, thus being part of a creative phase in developing EIs.

CONCLUSIONS

We propose that EIs would benefit from considering and involving diverse stakeholders early in the design process. To support the development of the EIs we suggest integration of sustainability considerations in existing QM practices. Last, by continuously applying a LC perspective the EI can be assessed for its environmental impacts throughout its development.

ACKNOWLEDGMENTS

We acknowledge financial support from Vinnova through the project “A multi-actor tool for creating and evaluating eco-innovations” and from Chalmers’ Sustainable Production Initiative.

REFERENCES

Angell, L.C., & Klassen R.D. (1999). Integrating environmental issues into the mainstream: and agenda for research in operations management. *Journal of Operations Management*, *17*, 575-598.

Baiman, S., Rajan, M.V., & Kanodia, C. (2002). The role of information and opportunism in the choice of buyer–supplier relationships/discussion. *Journal of Accounting Research*, *40*, 247–278.

Baumann, H., & Tillman, A-M. (2004). *The hitch hiker's guide to LCA: an orientation in life cycle assessment methodology and application*. Lund, Sweden: Studentlitteratur.

Brunklaus, B., Hildenbrand, J., & Sarasini, S. (2012). *Eco-innovative measures in large Swedish companies: An inventory based on company reports*, Stockholm. Sweden: Vinnova.

Burström von Malmborg, F. (2002), Environmental management systems, communicative action and organizational learning. *Business Strategy and the Environment, 11*, 312-323.

Garvare, R., & Johansson, P. (2010). Management for sustainability – A stakeholder theory. *Total Quality Management*, *21*, 737-744.

James, P. (1997). The Sustainability Circle: a new tool for product development and design, *Journal of Sustainable Product Design 1*, 52-57.

Liyanage, S. (1995). Breeding innovation clusters through collaborative research networks. *Technovation, 15*. 553–567.

Meredith, J. (1993). Theory building through conceptual methods. *International Journal of Operations & Production Management*, *13*, 3-11.

Poudelet, V., Chayer, J.A., Margni, M., Pellerin, R., & Samson, R. (2012). A process-based approach to operationalize life cycle assessment through the development of an eco-design decision-support system. *Journal of Cleaner Production, 33*, 192-201.

Sarasini, S., Gremyr, I., Hildenbrand, J., & Raharjo, H. (2013). A framework for developing and assessing eco-innovations, *20th EurOMA conference*, Dublin.

LIFE CYCLE MANAGEMENT IN A NOVEL CONSUMER PRODUCT: SELF-CHILLING BEVERAGE CANS

Noemi Arena[1,2] , Philip Sinclair[1], Mitchell Joseph[3], Roland Clift[1], Norman Kirkby[1], Jaqi Lee[1], Mark Sillince[2]*

1. *University of Surrey, Guildford, Surrey, GU2 7XH, UK.*
2. *Joseph Global Interests Ltd., Littlehampton, West Sussex, BN17 7HE, UK.*
3. *Joseph Company International, Irvine, California 92614, USA.*

**Corresponding Author email: n.arena@surrey.ac.uk*

Keywords: consumer product; product design; chilling; desorption; beverage.

ABSTRACT

ChillCan® is a new consumer product launched commercially in 2012 developed by The Joseph Company to chill a beverage on demand: i.e. to cool it to the desired temperature at the point of consumption, avoiding refrigerated storage. In addition to providing convenience, the ChillCan® can also deliver beverages with lower environmental impact, specifically reduced contribution to climate change. The chilling action is provided by utilizing endothermic desorption of carbon dioxide previously adsorbed onto a bed of activated carbon contained in an inner component of the ChillCan®. LCA reveals that the adsorbent dominates the environmental impacts. Life cycle management therefore focusses on the processing and properties of the sorbent, and on recovery, re-use and recycling of the cans and sorbent after use.

INTRODUCTION

The ChillCan®, launched commercially in 2012, is a device and delivery system which provides a service which the beverage industry has long sought: a canned drink which chills at the point of consumption and does not need refrigerated storage. It is evident that this idea could disrupt the beverage market: for instance, it may be possible to reduce or even eliminate refrigerated storage with a consequent revolution in the whole supply chain of beverages. Therefore, it is likely that the ChillCan® system can make a significant contribution to reducing global warming particularly if compared with poorly maintained refrigerated beverage storage cabinets or dispensers which are common in low-income countries, frequently utilized in middle- income countries and encountered under some circumstances even in wealthy countries.

Each ChillCan® is formed by an outer steel can containing the beverage and an inner aluminium can, called the Heat Exchange Unit (HEU), which contains activated carbon (AC) and an amount of carbon dioxide adsorbed onto it. The packed bed of sorbent and the gas have no contact with the 300mls of beverage that are contained in the space between the outer can and the HEU. A button in the base of the ChillCan® allows the carbon dioxide to be released to the atmosphere, releasing the pressure inside the HEU; the desorption of carbon dioxide from the activated carbon is endothermic and provides a cooling action that should ideally lower the temperature of the beverage by about 15°C.

MATERIALS

The principal components of the ChillCan® are listed in Table 1. The carbon dioxide is recovered from the vent gases from a methanol plant; therefore its environmental impacts arise from collection, purification and transport but the gas itself is not included because at the current time it would have been emitted to the atmosphere anyway. The activated carbon adsorbent is produced from waste coconut shells and transported from Indonesia. The impacts are evaluated making the most pessimistic "default" assumption that the carbon will be sequestered if not actually used (BSI, 2011); this assumption has a strong effect on the results and will therefore be revisited in the light of field data on the alternative fates of waste coconut shells. The beverage itself is excluded because it is common to all systems considered. Transport is also excluded although the larger overall can size requires transport to be included in any comparison with a conventional beverage system or in assessing post-use recovery systems. Minor materials – primarily plastic components – contribute much less to the life cycle environmental impacts and have therefore been omitted from this brief summary.

Functional unit	Volume of beverage (ml)	300
Material quantities, kg		
Steel	M_S	0.029
Aluminium	M_A	0.039
Activated carbon	M_C	0.11
Carbon dioxide	M_G	0.055

Table 1. Components of ChillCan® (excepting plastic components).

RESULTS

Life cycle assessment of the principal constituents of the ChillCan® was carried out using the GaBi 4.4 software (PE International, 2013) with primary data for the carbon dioxide (Rice, 1997) and for the carbon adsorbent, covering the most commonly used impact categories (Baumann and Tillman, 2004). Comparing the normalized impact scores showed that the environmental performance of the ChillCan® system is dominated by climate change; this confirmed the results of an earlier study (unpublished) in which the ChillCan® was compared with conventional refrigerated storage and delivery. Figure 1 shows the contributions to climate change of the different constituents, for one scenario of recovery and re-use (see below): the activated carbon sorbent dominates the system even when there is a high level of post-use recovery and re-use.

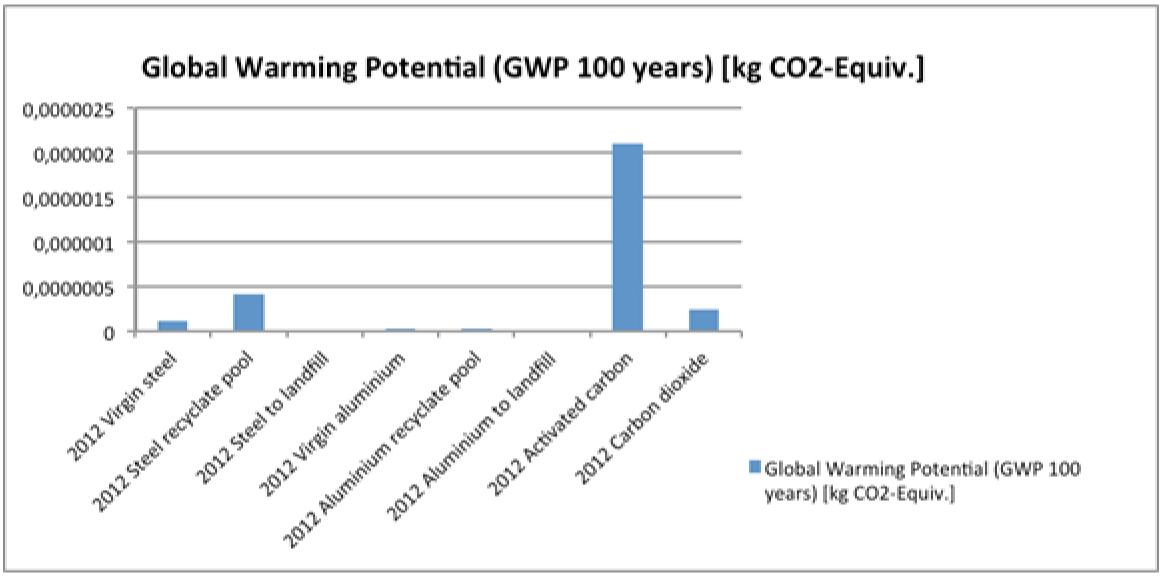


Figure 1. Contributions of constituents of ChillCan® to global climate change (kg CO2-equivalent; 100-year GWP).

System data:
Steel: 80% recycled input; 95% recovered post-use.
Aluminium: 80% recycled input; 90% recovered and re-used post-use.
Adsorbent: 90% recovered post-use; all recovered material re-used.

DISCUSSION

The finding that the GHG emissions embodied in the adsorbent are the dominant environmental impact means, in turn, that management of the life cycle of the ChillCan® must focus on recovering the cans after use and re-using the carbon. Figure 2 shows the overall product system. To have the carbon available for re-use, it is necessary to keep the ChillCans separate from the general waste stream of beverage containers; a specific recovery system from retail outlets is therefore being developed, based on the Swedish RETURPACK system (Pantamera, 2013). Recovered cans will be separated mechanically so that the steel outer can is returned for recycling. The inner HEUs are inspected; if they are undamaged then the carbon can be re-used, although it is not yet clear whether the whole HEU can be re-charged or whether the unit must be opened and the carbon repacked into a fresh HEU. Carbon not re-used is assumed to be sequestered in a land-fill. Aluminium not re-used directly as an intact HEU can be recycled, but the aluminium in HEUs not recovered is assumed to go to landfill.

A simple spread-sheet has been developed, so that the life cycle impacts of the overall product system in Figure 2 can be calculated from the embodied impacts of the four principal material constituents listed in Table 1 allowing for different levels of recovery, recycling and re-use.

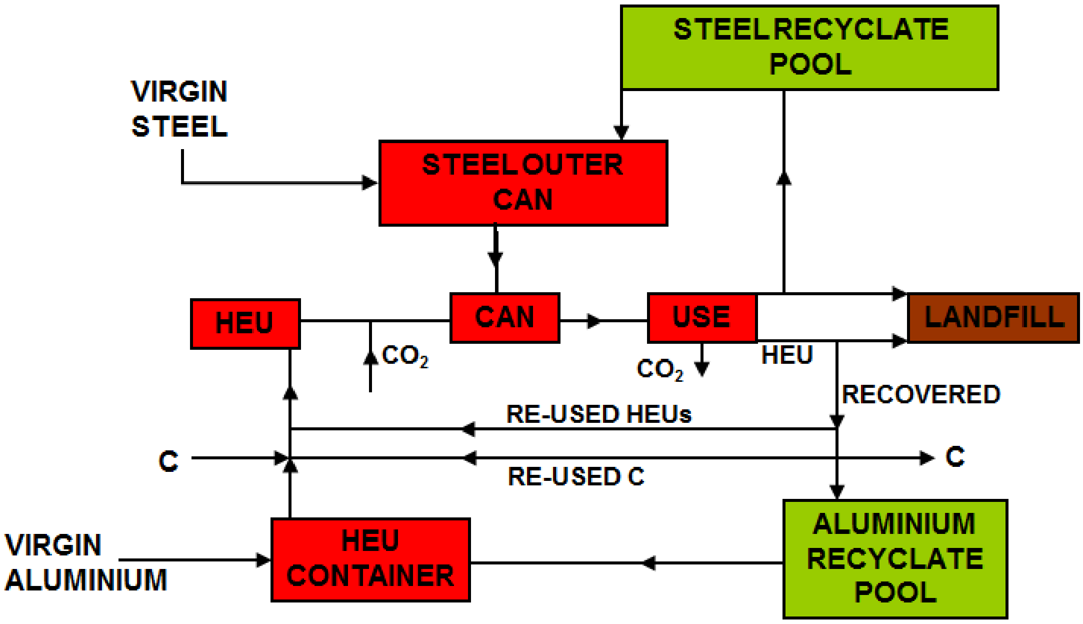


Figure 2. Chillcan® product system.

CONCLUSIONS

The ChillCan® system provides an illustration of a consumer product for which convenience delivered by a more complex device requires a more considered and individually designed system for recovery, re-use and recycling. The delivery system currently being developed, shown in Figure 2, represents a move towards "closed-loop" use of materials. This introduces some further questions and uncertainties. How many times the carbon adsorbent can be re-used without losing its capacity remains to be determined. In any case, the environmental performance will be dependent on consumer behavior: how effectively customers can be encouraged to return their cans after use rather than mixing them with packaging waste or merely discarding them.

REFERENCES

Baumann, H., and Tillman, A. (2004). The Hitchhiker's Guide to LCA: An orientation in Life Cycle Assessment Methodology and Application. *Studentlitteratur*. Lund, Sweden.

British Standards Institution. (2011). Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. *PAS 2050*. BSI, London.

PE International (2013) GaBi 4.4 software, www.pe-international.com

Pantamera (2013). Welcome to Returpack, http://www.pantamera.nu/en/welcome-returpack (accessed 29.5.2013)

Rice, G. (1997). The application of life cycle assessment to industrial process selection. *EngD portfolio*, Univ. of Surrey.

LIFE CYCLE MANAGEMENT IN PRODUCT DEVELOPMENT: A COMPARATIVE ANALYSIS OF INDUSTRY PRACTICES

Kristen Skelton[1], Anna Pattis[2]*

[1]Siemens Wind Power A/S, Aalborg Denmark; [2]Grundfos Holding A/S, Bjerringbro Denmark
[*]Assensvej 11 Aalborg Øst 9220 Denmark; Kristen.Skelton@siemens.com

Keywords: life cycle thinking (LCT); life cycle management (LCM); integration; product development; industry practices.

ABSTRACT

The integration of Life Cycle Thinking (LCT) and Life Cycle Management (LCM) into business operations poses great challenges, as it requires a wider range of environmental responsibility often extending beyond a company's immediate control. Simultaneously, it offers many opportunities such as the reduction of a product's or industry’s environmental impacts, an increase in process efficiency or the interconnectedness within the organization itself or across a supply chain.

Product development has been an area where application of LCM has been discussed most, since most product impacts are determined in the innovation and design phases. This comparative analysis explores the various approaches and challenges two companies are currently facing in their attempts to integrate LCT into their core product development processes.

INTRODUCTION

Inspired by Jensen and Remmen’s (2006) life cycle management (LCM) diagram, this comparative analysis explores the various approaches and challenges two companies are currently facing in their attempts to integrate life cycle thinking (LCT) into their core product development processes (PDP) – those being Grundfos Holding A/S (manufacturer of pumps) and Siemens Wind Power (manufacturer of wind turbines).

Both companies reflect themselves as industry leaders within product innovation and technology. It can be expected that in the future, sustainability must be an encompassed element in this definition of “leader” in order to maintain and/or strengthen both company positions. It has been previously shown that sustainable products via the application of LCM have positively contributed to a company’s competitive advantage and improved its platform for innovation. This has been realized by exemplary companies such as Interface, Philips and Unilever.

The levels of LCM integration will be explored below in order to see if companies from different industries have common challenges and opportunities that can be utilized for mutual collaboration on advancing LCM.

APPROACHES TO LIFE CYCLE MANAGEMENT

Grundfos

Initiating LCT with a focus on energy efficiency

LCT was originally applied in a Grundfos context through the development and participation in an early version of Life Cycle Analysis (LCA) in the mid 90's (UMIP – Udvikling af miljøvenlige Industriprodukter) and was initiated by the Danish Environmental Agency (Hausschild, 1996). The results of this assessment indicated that over 90% of the environmental impacts were generated through the use phase of the assessed products rather than the material selection, manufacturing, logistics or end-of-life phases. This laid part in initiating Grundfos' journey towards a focus on lowering energy consumption of their products. After 20 years of innovation, Grundfos succeeded in leading both industry standards as well as lobbying externally for the importance of energy efficiency in pumps and motors, while actively contributing towards the Eco-Design Directive EuP (energy using product) (Grundfos Holding A/S, 2013). Despite the successful integration, development and deployment of an energy efficiency focus, LCT had not been applied in a systematic fashion. A study undertaken by Holgaard, Remmen and Jørgensen (2007) confirmed that Grundfos had several initiatives that were connected to LCM, yet the concept had been applied in a fragmented manner, with a limited focus on product development.

Expansion of LCM – towards a more systematic integration

It wasn't until 2012 that Grundfos expanded their focus to encompass a more holistic LCM approach, emphasizing integration into their PDP; more specifically, integration by means of their corporate sustainability strategy (Grundfos Holding, 2012) and specific strategies relating to product development. With a broader focus, several life cycle based projects have been launched which are inter-disciplinary and run in parallel to ensure consequent and systematic work with all aspects of sustainability.

Crucial to the future expansion of LCM, Grundfos must adjust its existing core business processes and tools accordingly. Creating and implementing support tools which enable the product development organization to work with a life cycle based product approach will also lend to the organization giving equal consideration to the triple bottom line (TBL) when developing new products. Despite the TBL being a core aspect of Grundfos' sustainability strategy, there is still a misunderstanding that sustainability equates only to environmental aspects rather than on economic and social interests as well. Therefore communication across the company, from top management level to production employees must clarify and align all dimensions of the TBL. All tools and processes, including those that are currently under development and those yet to be developed, must underline the connection between economic, environmental and social aspects. With roughly 80.000 different products, the approach and tools must allow flexibility and adjustment possibilities according to the product characteristics; a "one-size fits all" approach risks compromising the sustainable improvement possibilities of Grundfos' products.

Siemens Wind Power

Looking back at an evolving product standard

As early as 1993 Siemens AG began mapping its minimum requirements, regarding environmentally compatible product and system design with an Environmental Protection (EP) Standard. Valid company-wide, it promotes a holistic and integrated approach spanning the entire product life cycle, from product planning to end-of-life management. It is also continually adapted so company units can continue to satisfy international regulatory requirements, strengthen environmental communication with customers, and broaden environmental awareness among employees (Siemens AG, 2012).

As one of the youngest Divisions of Siemens AG, Wind Power's primary focus has been on its expansion in a growing industry. Internal resource and operating efficiency programs have thus been primarily emphasized for the technology projects (manufacturing life cycle phase). Goals for waste reduction, energy consumption and air emissions were continuously set and reevaluated, while product related environmental management remained less formalized, despite many product improvement projects existing.

Moving forward towards an integrated product management approach

The Wind Power Division is however, working to strengthen its environmental position in the PDP. In 2011 the company initiated a research project involving Design for Environment (DfE) integration in the PDP. One business segment has since implemented DfE requirements and product managers have been trained on the process in addition to various environmental concepts. Furthermore, findings from two investigations resulted in product development and technology departments initiating formal projects for material efficiency and waste reduction.

Wind Power has also begun implementing a program launched under the Global EHS Program of Siemens AG entitled "Product Eco Excellence". One of the key focus areas in this program is about intensifying the production and use of LCAs. The LCA results will be summarized in environmental product declarations (EPDs) to strengthen external communication with customers. Additionally, the results will be used to catalyze discussions with product and technology developers regarding further product improvements.

In a longer perspective, Wind Power must expand on its DfE process to strengthen its LCM approach by further integrating it into all engineering functions, company-wide. It must also incorporate other environmental requirements along the supply chain (e.g. purchasing, projects, service, etc.) while aligning with its business partners (e.g. suppliers). The LCA results should be used internally to communicate LCT and create a common understanding that relates each departmental function to product impacts and associated improvement potentials. Linking the other departmental functions to the PDP and expanding the focus to other responsible functions is critical for integrating LCM into the full PDP spectrum.

The table below summarizes the various decision levels and policies, systems, concepts, tools and data, which are utilized by each company. The difference in approaches indicates that LCM offers a flexible approach for integration.

Table 1: Comparison of LCM approaches (based on Jensen & Remmen, 2006)

APPROACHES TO LCM	GRUNDFOS	SIEMENS WIND POWER
Policies / Strategies	– Energy efficiency → product sustainability	– Corporate environmental product standard
Systems / Processes	– TBL formally integrated (under development)	– DfE formally integrated (under development)
Concepts / Programs	– Sustainable product solutions	– Product eco excellence
Tools / Techniques	– Currently under development	– Waste reviews

Data / Information / Models	– UMIP	– LCAs and EPDs

CHALLENGES AND OPPORTUNITIES INTEGRATING LCM

The table below illustrates the various challenges and opportunities each company currently faces. Common challenges are apparent, despite the fact that both companies operate in different industries, encompass different dimensions in scope (TBL vs. environmental), exhibit different levels of LCM integration and ambition.

Table 2: Comparison of challenges and opportunities

<table>
<tr><th></th><th colspan="2">GRUNDFOS</th><th>SIEMENS WIND POWER</th></tr>
<tr><td rowspan="2">CHALLENGES</td><td colspan="2">– Trade-off issues relating to impacts vs. concreteness in engineering
– Managing complexity and interconnectivity of departmental functions in the PDP
– Clear communication of business potential</td><td>– Formalized DfE process incorporating more departmental functions
– Balanced approach with environment as additional core element of product development
– Multi-criteria decision making support</td></tr>
<tr><td>COMMON</td><td colspan="2">– Company-wide mutual understanding of LCT/LCM
– Moving from initial support to independent practice and tool application
– Evolution from impact assessment to systematic management and reduction of impacts
– Appropriate resource allocation and management commitment needed</td></tr>
<tr><td rowspan="2">OPPORTUNITIES</td><td colspan="2">– Unrealized potential connected to resource efficiency
– Creation of a sharper competitive edge in the market – LCM has proved to be highly beneficial in the case of energy efficiency
– Front runner in a relatively conservative market</td><td>– Flexibility allows various ambition levels across departmental functions
– A multi-dimensional concept of sustainability motivates cross functional collaboration
– Ability to positively influence the industry through application</td></tr>
<tr><td>COMMON</td><td colspan="2">– Large number of methods/tools and case examples for inspiration
– Product LCT can act as facilitator between sustainability dimensions
– Significant innovation potential if existing knowledge is connected to sustainability
– New business model opportunities through circular thinking</td></tr>
</table>

REFERENCES

Grundfos Holding A/S. (2012). Internal sustainability strategy document. Bjerringbro/ Denmark

Grundfos Holding A/S. (2013). Internal interview with Niels Bidstrup on the path to more energy efficient products, Bjerringbro/ Denmark

Hausschild, M. (1996). Baggrund for miljøvudering af produkter. Miljø-og Energiministeriet, Miljøstyrelsen/ Dansk Industri. Copenhagen/ Denmark

Holgaard, J. E., Remmen, A., & Jørgensen, T. H. (2006). LCM – Intentional strategy or a patchwork of practices? Proceedings from *NorLCA - The First Symposium of the Nordic Life Cycle Association, Market Opportunities in Life Cycle Thinking. October 9-10, 2006: Lund, Sweden*

Jensen, A. A., & Remmen, A. (2006). Background report for a UNEP guide to life cycle management – A bridge to sustainable products

Siemens AG. (2012). Sustainability report 2012. Retrieved from http://www.siemens.com/sustainability/en/sustainability/reporting/current-report.htm

The 6th International Conference on Life Cycle Management in Gothenburg 2013

TOOLS FOR SUSTAINABLE PRODUCT DEVELOPMENT: EXPERIENCE AND REQUIREMENTS FROM THE VEHICLE MANUFACTURING INDUSTRY IN SWEDEN

Sofia Poulikidou [a], Anna Björklund [b]*

[a]KTH Royal Institute of Technology, Division of Environmental Strategies Research, Center for ECO2 Vehicle Design
[b]KTH Royal Institute of Technology, Division of Environmental Strategies Research
[*]Drottining Kristinas v. 30, 100 44 Stockholm, sofiapo@kth.se

Keywords: Ecodesign; Ecodesign tools; DfE tools; Sustainable product development

ABSTRACT

This paper presents an empirical study on the use of tools for sustainable product development at four vehicle manufacturing companies in Sweden. Different tools that are used in the studied companies are identified and listed while the obstacles and needs for an increased and successful use of those tools are discussed. The study shows that a limited number the identified tools are used in a systematic way, for instance product specific tools that monitor regulation requirements. Impact assessment tools are applied more centrally in the companies with less integration to the design process. However, interest on the available tools has increased and on the ways that such tools can assist and influence design decisions in a more efficient way.

INTRODUCTION

Incorporating environmental aspects into product development is suggested as the most efficient way to reduce the impact of products on the environment. Along with this strategy, methods[1] and tools have been developed aiming to support companies and product designers in particular, during decision making processes. Previous studies showed that a great number of tools are available while the purpose and objectives of those tools may vary significantly (Baumann, Boons, & Bragd, 2002; Birch, Hon, & Short, 2012; Byggeth & Hochschorner, 2006; Poulikidou, 2012). To simply name a few, tools offer possibilities: to provide design recommendations and guidelines, to evaluate the environmental performance of the product, to identify environmental hotspots, to compare design alternatives and more.

Research on the available tools is expanding while the number of publications on new tools is increasing. On the other hand empirical evidence on the use and diffusion of those tools among product design groups remains limited; an observation stated by Baumann et al.

[1] The terms “method” or “tool” are used interchangeably in this text and can be defined as any type of systematized aid to incorporate environmental aspects in the product development or design process

(2002). Since then, a few studies can be found that investigate and discuss the utilization of tools in industries, for instance (Lindahl, 2005).

The study presented in this paper is part of a project that looks on the integration of environmental aspects during product development processes. This paper presents part of the results concerning the tools that are used in the studied companies to support sustainable product development. The purpose of this paper is to map and show the extent that such tools are used but also to increase understanding on the needs and requirements from a user's perspective. More specifically this paper: lists the most commonly used tools and discuss the purpose of their use, identifies and discuss obstacles and difficulties that are affecting the use of tools and presents needs that were expressed by the studied companies.

To this end the overall aim of this study is to add empirical knowledge on the adoption and diffusion of tools that could assist the development of tools based on the user's perspective. Moreover, improvements for more efficient use of the tools currently used within the studied companies can be suggested.

METHODS

Data for this study was collected through semi structured interviews with employees at four different vehicle manufacturing companies in Sweden. The studied companies represented different modes of transportation which assisted in providing an overview of the sector. Interviewees included: environmental specialists and managers, environmental consultants as well as vehicle designers and product managers. All respondents were related to the product development process but in different ways and at different stages. The process of performing the interviews was based on the stepwise method described by Kvale (2009). The responses of the interviews were then classified in different themes and clusters that were derived according to the research questions of this work (Miles & Huberman, 1994).

RESULTS

Tools were utilized for various reasons in the studied companies and at different stages of product development. The main purpose was to evaluate the environmental performance of the products, collect information and generate ideas about future products, to monitor compliance with regulation and more. Table 1 presents the tools that are common for at least three of the four studied companies and for which more information was obtained during the interview process. Based on the discussion with the environmental experts and design engineers opportunities and limitations of the tools are also presented. It should be mentioned that tools diffusion varied and different maturity levels were identified since some of the companies have greater experience in the use and development of tools than others.

A number of different needs and recommendations were also expressed by the respondents mainly by those involved in tools selection and development. Such recommendations include: more integrated tools that would be able to combine environmental with other design aspects in a reliable way and also tools which information can be easily accessible. A need for standardized and harmonized tools within company was also expressed. A general comment concerned increased education and information exchange about the different tools but also about the outcome of different assessments performed within the companies.

Table 1.List of tools used in the studied companies. Obstacles and limitations based on users' perception.

Tool	***Type***	***User***	***Benefits for the users***	***Obstacles***
Environmental benchmarking	Comparative indicators	Environmental specialists/product developers	• Comparisons with competitors and other industries • Provide incentives for improvements	*No specific comments*
Environmental Design Guidelines	Generic recommendations/ guidance	Designed for vehicle engineer designers	• Helpful recommendations to engineers • Provide basic input on aspects to consider	• Too vague for the designers • No hands on requirements- • Improvements and implementation is more difficult to monitor and may also lead to undesired results if not assessed properly • Generally too many checklists and guidelines exists
Recycling calculation and guidelines	Recycling guidelines	Vehicle engineers and environmental specialists	• Labelling of all materials - easier for recycling processes • Ensure compliance of the product	• Detailed information is needed in order to be able to calculate the exact percentage
Substance and chemical control lists	List of materials, substances and chemicals that are restricted or prohibited to use	Environmental specialists were responsible for customizing the tool, while multiple users were identified for collecting and reporting information. Designers, suppliers and environmental specialists should verify compliance	• Ensure compliance of the product with different requirements (legal, costumer, company) • Easy way to refer and check	• Time consuming to collect information • Resistance and delays from suppliers due to long supply chains and confidentiality issues • Delays lead to not efficient use- late in the process where changes are not possible
Material database systems	Databases with information about the exact composition of all vehicle components	Environmental specialists were responsible for customizing the tool, while multiple users were identified for collecting and reporting information. Supplier should also provide data.	• Ensure compliance of the product with different requirements (legal, costumer, company) • May provide input to other tools e.g. LCA • Labelling of all materials - easier for recycling processes	• Time consuming to collect information • Resistance and delays from suppliers due to long supply chains and confidentiality issues • Delays lead to not efficient use- late in the process where changes are not possible
Life cycle assessment (detailed and simplified versions)	Environmental impact assessment tools	Environmental experts / consultants /researchers	• Robust tool • Suitable to identify key areas of improvements • Provides a complete picture of the product • Supports guidance and decisions • Possibilities to use the results as baseline for future products	• Time consuming- Big and inefficient tool • Need for detailed information to obtain reliable results • Not suitable to implement early in product development • Not easy to connect results with quantitative environmental requirements • Low competence in some of the companies to apply the tool- need for LCA experts • Similar results if performed at a product level • Not so suitable to address local effects and hazardous substances • SLCA are not so reliable for this product

DISCUSSION

Interest of the studied companies on the available tools has increased and different tools have been tried or developed through the years. Today, only a few of those tools are applied in a systematic way and managed to be integrated into product development processes. These are product and sector specific tools that capture regulation requirements e.g. substance and material control lists. Environmental design guidelines seem to be less helpful due their quite generic nature. The use of impact assessment tools e.g. LCA varies significantly among the companies. LCAs are performed by an expert, which limits the interaction with product development groups. Quantitative tools are generally preferred as well as tools that provide outcome which can be connected to specific design requirements. Product developers expressed a need for education and for tools that can be integrated into engineering design tools. The majority of limitations concerned information collection, due to the fact that many stakeholders are involved, but also lack of competence, commitment and motivation. These limitations are more related to internal processes within the company and not so much to the tools per se. Even in companies with a long experience in the use and development of tools such obstacles have not been overcome yet.

CONCLUSIONS

The experience of four vehicle manufacturing companies when it comes to tools for sustainable product development was presented in this paper. Use and interest on such tools has increased compared to previous research although sufficient integration of tools within product development units is not achieved. The obstacles for a more systematic use of tools were related both to the tools but also the users. It can be concluded that a combination of tools can be of more help if designed properly to meet the needs of the user and suit the design processes and existing tools in place. Moreover users need to also adapt to the requirements of the tools and modify the processes and information management that would increase their efficient use.

REFERENCES

Baumann, H., Boons, F., & Bragd, A. (2002). Mapping the green product development field: engineering, policy and business perspectives. *Journal of Cleaner Production, 10*(5), 409-425. doi: Pii S0959-6526(02)00015-X

Birch, A., Hon, K. K. B., & Short, T. (2012). Structure and output mechanisms in Design for Environment (DfE) tools. *Journal of Cleaner Production, 35*, 50-58. doi: DOI 10.1016/j.jclepro.2012.05.029

Byggeth, S., & Hochschorner, E. (2006). Handling trade-offs in ecodesign tools for sustainable product development and procurement. *Journal of Cleaner Production, 14*(15-16), 1420-1430. doi: DOI 10.1016/j.jclepro.2005.03.024

Kvale, S. (2009). *Interviews: An introduction to qualitative research interviewing*: SAGE Publications.

Lindahl, M. (2005). *Engineering Designers' Requirements on Design for Environment Methods and Tools.* Doctoral Royal Institute of Technology.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative Data Analysis. An expanded sourcebook*: SAGE Publications Inc.

Poulikidou, S. (2012). *A literature review on methods and tools for environmentally friendly product design and development. Identification of relevance to the vehicle design context*. KTH Royal Institute of Technology.

UNDERSTANDING THE IMPLICATION OF AN ENVIRONMENTAL STRATEGY ADOPTION

Miriam Kozemjakin da Silva[1], Romain Allais[1,2], Tatiana Reyes[1], Sébastien Remy[1], Lionel Roucoules[2].*
[1]Université de technologie de Troyes. 12 Rue Marie Curie, CS 42060, 10004 Troyes, France
[2]Art et Metiers ParisTech, CNRS, LSIS, 2 cours des Arts et Métiers, 13617 Aix en Provence, France
**kozemjam@utt.fr*

Keywords: Ecodesign; Sustainable strategy; Cause-effect network

ABSTRACT

The objective of this paper is to follow the consequences on the product environmental impact of the industrial strategy through the product development process. Students were observed while designing a bicycle luggage carrier for tracing a cause-effect network that would link the strategy to the designed product and its environmental impact. The results show the strategy's influence through the design process at a macro-level.

INTRODUCTION

Companies are particularly concerned by environmental issues due to legislations, cost benefits and new markets (Dewulf, 2003). To increase the performance of this integration, some authors point out that sustainable aspects (i.e. environmental, social and economic) should be embedded at all corporate hierarchical levels: strategic, tactic and operational (Hallstedt, Thompson, & Lindahl, 2013). This paper deals only with environmental aspects.

In a common top-down approach, environmental path is initiated and spread from strategy over the other levels. A shortcoming of traditional management systems is that companies are unable to link long-term strategies and short-term actions with appropriate measurement tools (Kaplan, 1996). There is clearly a need to improve that feedback for improving the development of an adapted and effective environmental strategy.

This paper aims to demonstrate the implications of the strategy’s choice through the product development process (PDP) and consequently towards the environmental impact of a product; concluding about the feedback that could nurture the sustainable strategy definition.

PROPOSITION

The main objective of the proposal is to indicate the impact of the industrial strategies during the design process. For that, the designers are asked to justify their choices during a PDP. The arguments for a choice could be a constraint, a previous decision in the process or any external influence (e.g. personal experience, background).

The analysis of this designer’s input should allow building a cause-effect network; ideally to link the strategy to the specifications, the specifications to the functions and so on, finishing by the environmental impact of the product. This connection of each phase of the process associates the strategy to the environmental impact. Finally, the analysis of this network points to conclusions about the relevance of the environmental strategy adopted.

CASE STUDY

For demonstrating the proposition above, five students of the University of Technology of Troyes (UTT) were recruited to design a bicycle luggage carrier in a given context. They had 2 sessions of 3 hours to design the product, starting from the interpretation of the context (i.e. available tangible and intangible resources) and definition of the specifications. During the design, they were asked to fill out tables with information about the product development process (e.g. specifications, functions), justifying each input. Besides, the sessions were fully recorded.

Context of the experiment

La roue verte is an organization located at the university that promotes the use of bicycles by, mainly, renting it to students. Interviews were conducted to understand the organization's policy and strategies and, to draw a map of internal and external tangibles and intangibles resources (e.g. partnerships, economic fluxes, workforce, knowledge).

Summarizing, *la roue verte*'s long-term strategy can be declined into three points: to increase the offer of new products and services (e.g. on-line services, new products renting); to measure and communicate on socio-environmental benefits of their activity; and to maintain existing partnerships. These three strategic axes were declined into a tactic roadmap (i.e. the steps to be followed to reach these strategic goals) for the project presented here.

A survey was made to understand the needs and preferences of their customers (i.e. students) for a new product/service proposition. The results pointed in the direction of a product for the biker to carry groceries from the supermarket to home once a week. Following the tactical module for environmental tool choice of the project *Convergence* (Zhang, Rio & Allais, 2013), the free online tool Ecodesign pilot[1] was chosen to support this activity. *La roue verte*, in accordance with their partnership strategy, chose to manufacture the product using student's workforce in a class of UTT where they learn how to handmade wood and metal based products.

Once established the strategy and the tactics, the students were asked to design an artifact that meet both the customers' needs and integrates constraints from the different partners. To identify the specifications, it was given to the students the strategic and tactic information as customers' willingness to pay, needs and preferences about the product (e.g. robustness, size) and constraints from the partners.

[1] http://www.ecodesign.at/pilot/

Results

There were difficulties regarding the cause-effect network set up, i.e. to give a justification for each decision. That is because, the student's justifications, written in the tables, were too fuzzy (e.g. "decision taken after a group discussion").

To overcome that difficulty, there was an attempt to point the reasons for the decisions by looking at the observations, notes and recordings. A transcription of each discussion and the arguments expressed was made.

Information about the influence at a macro-level of strategic and tactic constraints has been observed during the experiment. The students were able to integrate a large amount of resources and constraints to propose a detailed design. Notably, it was possible to identify the arguments that came from the strategy constraints in the discussions. From the transcription, each one of the 88 arguments were classified as issued from a constraint that came from a strategic decision, from the biker's needs or from the designer background (see table 1).

	Source	Example of argument
54%	Background of the designers	The compartment for frozen food was not considered because Troyes is a small city; it takes less than 20mn to go to the supermarket by bicycle.
35%	Strategy and tactic	There are limited manufacturing resources from the TN04 class.
11%	Customers' needs and preferences	The customer does not find important to cover the groceries.

Table 1 – Arguments' classification

It is possible to say that the strategy has an impact on the input data (passive resources) and on the goals (e.g. maintain existing partnerships), with consequences over the design. Even if we did not succeed to trace it in the micro-level of the decision making through the product development process (PDP), a macro-level view of strategy influence on PDP is proposed (see figure1). Figure 1 is a map of stakeholders' contribution (solid arrows) and feedback (dashed arrows).

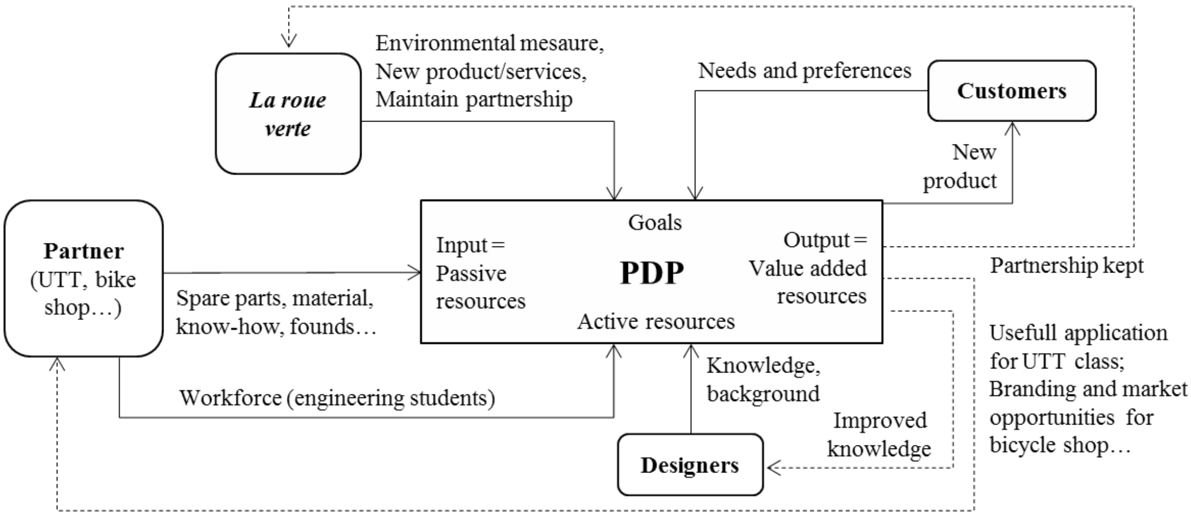


Figure 1 – Strategy influence on the PDP, stakeholders' contribution and feedback.

DISCUSSION AND PERSPECTIVES

Even if the arguments could be allocated to a constraint, the results are only representative of the observations. This means that table 1 is about the constraints that were spoken out loud during conversation, but it does not mean that it had a more important role in shaping the product. It could be that a constraint was so clear in the briefing (e.g. 100€ limit of cost) that all members of the team knew about it and there was no need for recalling it.

To validate and complete the experiment, the product created by the students should be validated by the partners to verify its feasibility and to judge the pertinence of the strategy.

In summary, two problems were found when modeling the cause-effect network: the fuzzy justifications and the random and unclear discussions. The former could be explained by the lack of awareness of the students about the importance of storing more precise justifications. It is believed that if the students were confronted to the reuse of information, they would notice the usefulness of writing more precisely the why of their decisions. The later could be explained by the lack of organization, a moderator who holds the discussions and summarizes the decisions, like in a project meeting.

For a next case-study, it is intended: to improve the interface (instead of the tables) for being more appealing for use; to nominate a moderator or to develop case studies with only one designer, in a protocol of think-aloud; to reduce the complexity generated by communication issues between the designers; to make a series of designs making available the past designs, in a case-reuse approach.

ACKNOWLEDGEMENTS

We acknowledge the volunteer students who participated in the experiment. We would also like to acknowledge the National Research Agency for funding the Convergence project; and the Fonds Unique Interministériel (Single Interministerial Fund) and the Champagne-Ardenne Region of France for funding the Finather3 project.

REFERENCES

Dewulf, W. (2003). *A pro-active approach to ecodesign: framework and tools*. *status: published*. Katholieke Universiteit Leuven.

Hallstedt, S. I., Thompson, A. W., & Lindahl, P. (2013). Key Elements for Implementing a Strategic Sustainability Perspective in the Product Innovation Process. *Journal of Cleaner Production*. doi:10.1016/j.jclepro.2013.01.043

Kaplan, R. S., Norton, D. P., (1996), Using balanced scorecard as a strategic management system. *Harvard business review.76- Jan-Feb. 1996*

Zhang, F., Rio, M., Allais, R. et Al. (*to be published*). *Toward a systemic navigation development into the company. Journal of Cleaner Production*, 1–25.

TRADE ASSOCIATIONS - DRIVERS FOR LCM?

Tuesday, Aug 27: 3:30 pm - 5:00 pm

Session chairs: Pierre Conrath, EDANA, Belgium
Ellen Riise, SCA Hygiene Products AB, Sweden

PLASTICSEUROPE ECO-PROFILES: PROGRESS WITH AN AMBITIOUS PROGRAMME

Dr. Ivo Mersiowsky[1], Guy Castelan[2]*

[1] DEKRA Consulting GmbH, Sustainable Leadership & Culture, Stuttgart, Germany

[2] PlasticsEurope aisbl, Technical & Regulatory Affairs, Puteaux, France

** Handwerkstrasse 15, D-70565 Stuttgart, Germany, ivo.mersiowsky@dekra.com*

Keywords: Eco-profiles; life cycle inventory; plastics.

ABSTRACT

The PlasticsEurope methodology for Life Cycle Inventory in the chemical and plastics sector continues to be developed with a view towards compatibility and globally harmonised procedures. On-going updates concern all relevant precursors and polymers. Challenges include data requirements, emerging methodologies, and decision support. An outlook is given to emerging trends and best practices in industrial LCA and footprinting.

INTRODUCTION

PlasticsEurope, the pan-European association of plastics producers, has been compiling environmental data for polymers since the 1990s. In association with *The Parliament Magazine*, PlasticsEurope organised a meeting at the European Parliament on 10 October 2012 entitled "Life Cycle Assessment (LCA): the future for improved sustainability in Europe?" hosted by the MEP Bas Eickhout of the Dutch Greens Party. Three key challenges were identified:

- Keeping data requirements practical to ensure wide participation;
- Providing high-quality data to support emerging footprint methodologies;
- Developing reliable and scientifically sound footprint approaches to enable informed decisions by policy-makers, industry, and consumers.

Having recently stepped up the ambition of the Eco-profile programme, PlasticsEurope can now report on progress with regards to these challenges.

CHALLENGES FOR ECO-PROFILES

Data Requirements

As a life cycle inventory (LCI) database with global relevance, Eco-profiles critically depend on being up-to-date, internally consistent, and quality assured. In 2011, the PlasticsEurope Management Team decided to have all Eco-profiles fully updated. With more than 70 single datasets and in view of the substantial effort going into the preparation of each dataset, this presents a serious challenge. The adopted strategy is two-fold:

- Update projects involving primary data collection for foreground processes were launched for all relevant polymer families, such as styrenics and polyolefins. It is recognised, however, that key contributions result from upstream precursors, such as benzene and ethylene, which are often outside the operational control of member companies.
- Drawing on the collaboration with several service providers, secondary data for background processes are sourced from pre-validated databases or validated on a case-by-case basis and then used as defaults for future projects. While some basic chemicals and utilities may be entirely generic, petrochemical precursors need to reflect the actual supply situation of polymer manufacturers.

This is exemplified by the update of polystyrenes which showed a strong influence by the choice from two production routes for styrene and, even more so, for benzene. As a result, information about the currently representative market mixes for benzene and styrene production was found to be a key factor in the environmental performance of polystyrenes.

Consequently, obtaining high-quality data cannot be limited to primary data collection, but also entails secondary data, such as petrochemical hydrocarbon feedstocks. Access to quality-assured and validated databases thus becomes critically important, even more so when considering feedstock alternatives, such as renewables with the same rigorous LCI methodology. Critical review of Eco-profiles and the verification of third-party databases are hence part of the quality assurance provided by DEKRA (Schulz & Mersiowsky, 2013).

The collection of activity data from the participating member companies continues to be the single most relevant driver of effort and cost. With new methodologies necessitating an even greater scope and detail (e.g. water balance, statistical variations, data quality assessment), primary data requirements need to be balanced with practicality. By aligning LCI standards with various other initiatives and programmes, such as greenhouse gas inventories, carbon disclosure, and pollution registers, feasibility for industry can be improved. Conversely, new methodologies need to take the effort of collecting appropriate data into careful consideration (Baitz *et al.* 2012).

Emerging Methodologies

Decision makers in industry and policy expect life cycle results to be consistent, irrespective of where they are generated. However, experts are keenly aware that due to methodological differences in life cycle practices this cannot be taken for granted. In fact, industry LCI programmes and even acknowledged databases may sometimes differ substantially in their modelling philosophy of complex operations.

For instance, different value judgments in allocation of the petrochemical cracker and aromatics separation may render downstream results incomparable. The definition of product ranges and appropriate allocation, recognising internal loops and integrated plants, requires careful consideration and justification. As a case in point, the cracker is often shown to provide high-value chemicals (HVC), such as ethylene and other olefins, as main output. In addition, however, the output stream pyrolysis gas is a source of aromatics (BTX), such as benzene, which is mostly counted among the HVC. And finally, there is so-called fuel gas with a high calorific value which may be fed back to the refinery or otherwise used for thermal energy generation. Obviously, the burdens assigned to downstream products, such as polyolefins, are very sensitive to the respective allocation choices.

Likewise, the assumptions about environmental burdens of feedstocks, such as renewable materials and secondary raw materials, may introduce a bias to calculations. In view of the sometimes very disparate production technologies even within one polymer family, it is essential that despite different supply chains and with complex integrated sites, the results be even-handed and consistent.

And finally, the broad variety of impact assessment methods and, in some cases, normalisation and weighting schemes, corresponding with requirements for life cycle inventory detail and nomenclature, exacerbate the issue. Hence, PlasticsEurope supports and contributes to the development of Product Category Rules and a consistent international database.

- As a sector-specific methodology for the chemicals and plastics industry, the Eco-profile Methodology (PlasticsEurope, 2011) builds on the basis of state-of-the-art life cycle assessment practice, specifically the ISO 14040/44 standards as a baseline and striving for alignment with the ILCD Handbook. The methodology is aimed at compatibility and robustness. To ensure compatibility, only scientifically agreed and established methods are adopted, while sector-specific adaptations are kept to a minimum.
- Through engagement with the UNEP/SETAC life cycle initiative, PlasticsEurope fosters the industrial practice of LCA and the world-wide applicability of life cycle databases (UNEP/SETAC 2011). The Eco-profile programme management provided by DEKRA ensures that the database is continuously improved and managed for consistency.

Decision Support
PlasticsEurope provides information consistently across three different levels:

- Life Cycle Inventory (LCI) data to support LCA studies by experts using different software systems;
- Environmental Product Declaration (EPD) as building blocks (information modules) in business-to-business communication, in particular in the building and construction sector;
- Environmental Footprints are currently under development and pilot-tested from a methodological point of view, especially through collaboration with the European Commission’s DG Environment and JRC.

PlasticsEurope believes that the aggregation of multiple criteria to a simplified, single score can be beneficial to support decisions. However, this will require the involvement of the whole supply chain and stakeholders as well as full transparency and accessibility to upstream data. A careful balance needs to be struck between, the complexity reduction through single-score indicators and the transparency and reproducibility of a full-fledged LCA with its necessarily exploratory approach to understanding complex industrial systems. Multi-layered scientific communication, allowing for drill-down from high-level scores to underpinning data, is the guidance here.

CONCLUSIONS

The wide-spread need for readily available high-quality inventory data which support relevant and consensual environmental footprint methodologies is obviously the challenge which the Eco-profiles programme will address in its third decade. The programme aims at being recommended as the most preferable database for the chemical and plastics industry in Europe and with global compatibility. An even better integration, validation, and seamless availability of intermittent updates will be the focus of dataset development in the years to come.

Besides fostering continuous improvement within the plastics industry, Eco-profiles are used in technology assessment, for instance, when considering the pros and cons of alternative feedstock resources or materials from a whole life cycle view. Downstream industries, such as plastics converters and brand companies, rely on Eco-profiles for assessing the environmental footprint of their products.

In preparation of emerging water footprint methods, a more complete water balance has recently been implemented. More generally, alignment with the European Commission's Product Environmental Footprint (PEF) Methodology (EC, 2013) is being sought.

Future development will be geared towards smarter procedures which improve data robustness while at the same time reducing the efforts: this ambitious goal can be achieved through further streamlining of primary data collection combined with an even stronger integration with accredited databases. Quality assurance through review and validation procedures will remain critically important.

REFERENCES

Baitz, Martin, *et al*. (2012) LCA's theory and practice: like ebony and ivory living in perfect harmony? *Int J Life Cycle Assess.* DOI:10.1007/s11367-012-0476-x.

European Commission (EC) (2013). Product Environmental Footprint (PEF) Guide to the Commission Recommendation on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations. Consolidated Version. Web source: http://ec.europa.eu/environment/eussd/smgp/product_footprint.htm

PlasticsEurope (2011). Eco-profiles and Environmental Declarations. Version 2.0. Web source: http://www.plasticseurope.org/plastics-sustainability/eco-profiles.aspx

Schulz, Matthias, and Mersiowsky, Ivo (2013) Critical Review of LCA – Essential for Quality and Understanding. Proceedings of the 6th International Conference on Life Cycle Management in Gothenburg 2013.

UNEP-SETAC Life Cycle Initiative (2011). Global Guidance Principles for Life Cycle Assessment Databases: A Basis for Greener Processes and Products. ISBN: 978-92-807-3174-3.

SUSTAINABILITY ACTIVITIES OF CEFIC

Véronique Garny – Director Product Stewardship at Cefic, avenue E. van Nieuwenhuyse 4 – 1160 Brussels – Email: vga@cefic.be

Keywords: chemical industry; trade association; sustainability; Responsible Care®; performance

ABSTRACT

Sustainable development has been identified as a strategic priority of Cefic, the European Chemical Industry Council. Recognising that the chemical industry's products and services can play a key role in enabling a sustainable society, the industry association has initiated a range of activities to communicate about the sector's sustainability commitment and contributions.

In 2012, Cefic presented the 2050 sustainability vision of the European chemical industry and published the sector's first collective sustainability report. As next steps, the vision is being translated into three objectives: sustainable operations, sustainable products for society and attracting and maintaining investments in Europe. These in turn are declined into action through further development of methods and tools, such as sectoral sustainability metrics and practical guidance on sustainability topics, and through industry flagship initiatives, i.e. major projects that bring together several companies and organisations to address sustainability challenges.

INTRODUCTION

The chemical industry is well placed to tackle the challenges of sustainability, given the industry's proven track record in innovation, its deep integration in the supply and value chains, and its global presence. In fact there is virtually no product, service or human activity that does not in some way rely on the contribution of chemistry. Chemicals can also help solve major societal challenges such as water, energy, climate change, health, food.

The European chemical industry operates under a robust legislative framework, with the European Union's REACH chemicals regulation as a centerpiece for product safety. In addition, the sector has put in place voluntary initiatives such as the global chemical industry's Responsible Care® initiative, which has for more than twenty years provided an overarching framework for continuously improving safety, health and environmental performance of products and operations.

Today, emerging regulatory and social trends around sustainability create both pressure and opportunities for chemical companies. Legislative requirements, stakeholder expectations and companies' own business and Responsible Care® strategies are all driving the development of further industry efforts on sustainability.

In this context, trade associations have an important role to play. Drawing from the expertise of their members and stakeholders, they can contribute to experience sharing and develop common activities based on best practices. In the chemicals sector these types of activities are being developed both at the national level by chemical associations in different countries and at the European level by Cefic, which represents in total 29,000 companies producing about 20 per cent of the world's chemicals.

METHOD

This paper presents the approach taken by Cefic in developing its sustainability activities, by describing selected initiatives undertaken in 2011-2013 and discussing the process from the perspective of a European industry association.

RESULTS

Sustainability vision

"The European chemical industry is determined to play a key role in ensuring that by 2050 over 9 billion people live well, within the resources of the planet.

- It will gear all of its activities towards enabling a future where people have access to the necessities of a healthy life, to economic prosperity and to societal progress.
- It will drive a quantum leap in innovation enabled by investments and partnerships.
- It will join forces with all its stakeholders, including governments and civil society.
- It will strive to be sustainable in terms of its operations and a key enabler of a sustainable society through the excellence of its employees and the benefits of its products.
- It will keep attracting investments by way of its strong economic performance."

Sustainability report

Cefic's first sustainability report, published in 2012, is one step towards achieving the aspirational sustainability vision. The report reviews the sector's performance against standard Key Performance Indicators (KPIs) and offers examples of how the products of chemistry are meeting the needs of society and contributing to sustainable development.

The KPIs selected for the report fall under the three traditional pillars of economic development, social development and environmental protection (3P for Planet, People, Profit). They cover topics such as energy use, emissions, waste, water use, workplace safety, employment, labour productivity, profitability, and investment in research and development.

The selection of KPIs was based on the identification of indicators that are supported by official EU & national statistics such as the European Pollutant Release and Transfer Register, E-PRTR. The KPIs demonstrate how the European chemical industry is performing over time, and are also an important tool to help identify opportunities for improvement. Progress will be measured and publicised every two years, with the next report scheduled for 2014.

In addition to KPIs, the report provides examples of industry initiatives and case studies on how the products of the chemical industry contribute to three areas of major importance to European society: energy and climate change, food and water, and mobility and housing.

Guide on sustainability of products

Building upon the sustainability report, Cefic has published practical guides addressing specific issues. The guide entitled “Sustainability of products – What it’s all about”, published in June 2012, presents approaches that companies can use to assess and develop their product portfolios to help turn sustainability challenges into business opportunities, e.g. through increased resource efficiency.

Aimed particularly at smaller companies, the guide is written in a way that helps demystify many of the concepts and technical terms used by sustainability experts. Topics covered range from general considerations around product stewardship and life cycle thinking to specific tools and methods, such as LCA and environmental footprint methodologies. A “to do” list gives suggestions for first actions to be taken.

The guide is actively used by Cefic’s national chemical industry federations in several European countries, some of which are also translating it into their national language, to help SMEs especially.

Guide on biodiversity and ecosystem services

The guide “Biodiversity and ecosystem services – What are they all about?” published in January 2013 looks at biodiversity and ecosystem services from the perspective of the chemical industry. The guide is based on a study conducted by Cefic in cooperation with environmental consultancy ARCADIS.

Like all sectors, the chemical industry both has an impact on biodiversity and depends on healthy ecosystems. In most cases, the direct impact of chemicals manufacturing on biodiversity is fairly limited, but can be more important in other phases of the value chain.

The guide encourages companies to assess how their operations impact and depend on biodiversity and ecosystem services. Understanding these links helps manage risks and tackle potential opportunities, for example to improve resource efficiency or develop new products.

On the occasion of the launch of the guide, Cefic also organised a workshop focusing on the latest EU policy developments and business initiatives aimed at protecting and restoring biodiversity.

Flagship initiatives

Cefic has also identified “flagship initiatives”, major industry projects that address societal challenges through cooperation between several companies and organisations.

Current initiatives include:

- Zero Plastics to Landfill by 2020: saving plastics from being buried through recycling and energy recovery;
- VinylPlus: tackling sustainability challenges in the PVC value chain;

- Sustainable Process Industry through Resource and Energy Efficiency (SPIRE): boosting innovation in resource and energy efficiency in the process industries in the EU;
- Water management: promoting sustainable use of water in the chemical industry.

These initiatives are intended to be concrete translations of the sector's sustainability vision. Each project has defined its objectives, Key Performance Indicators (KPIs), key milestones, existing and potential partners and important external stakeholders. Cefic's role is to provide support for implementation, communication and cooperation with other actors, such as authorities, Trade Unions, NGOs …. Progress will be reported regularly, and new initiatives are encouraged.

DISCUSSION

Trade associations have a role to play in forging common industry initiatives leading to sustainability. Cefic, representing the European chemical industry, has embarked on this process led by its vision to play a key role in the sustainable future of our planet. Driven by a high level commitment, the sector's performance will be monitored through key indicators. Raising commonly agreed perspectives on the sector's major impact is a challenge that Cefic is continuously facing. Cultural, national and individual companies' differences have to be taken into account. On the other hand, working together and agreeing on common guidance brings a lot of experience to a large number of members. Shared good practice and advice have led to the preparation of "to do" lists or tips - short reminders to keep at hand.

Challenges by external partners are also of importance to ensure the industry is operating as an integral part of society. Raising public awareness of the benefits chemicals bring to society is another focus of ours. The consultation process that ran in parallel to the development of the above-mentioned reports and guides stimulated further thinking.

The next sustainability report to be published in 2014 will highlight accomplishments in the area of sustainable operations, sustainable products and how to maintain and attract investments in EU.

CONCLUSIONS

Sustainability is key for the chemical industry and Cefic has a part to play in enabling efforts. Its sustainability vision "to play a key role in ensuring that by 2050 over 9 billion people live well, within the resources of the planet" is a key driver for several joint initiatives, either guiding its membership or promoting sectoral performance goals. Cefic is committed to continue reporting on progress on a regular basis.

REFERENCES

Cefic sustainability: http://www.cefic.org/sustainability/

SUSTAINABILITY AT CEPE: PRE-COMPETITIVE COOPERATION RESULTING IN AN INDUSTRY STANDARD COATINGS LCI DATABASE

Johanne (H.) van Maurik, Maurits van Kolck, Max (J.) Sonnen, Ecomatters.*

**Museumlaan 2, 3581 HK Utrecht, The Netherlands, max.sonnen@ecomatters.nl*

Keywords: eco footprint tool; LCI database; pre-competitive cooperation; coatings industry.

ABSTRACT

An increasing environmental awareness within the global construction industry has led to a demand for LCI data. In response, a number of European coating companies, gathered within CEPE (the European coatings trade association), have initiated a pre-competitive LCI project. The results - a coatings industry standard LCI database containing almost 300 raw materials and an Eco footprint tool - are accessible to CEPE members for use in the preparation of LCAs, EPDs and eco footprints. Since the deliverables of the CEPE LCI project provide LCI data common for the entire industry, they allow for the fair comparison of the environmental impact of different products and product groups over the life cycle.

INTRODUCTION

Product stewardship and regulatory compliance have been key interests of the European coatings industry for decades. The European Council for the Paint, Printing Ink and Artists' Colours Industry (CEPE) has stimulated and supported its members' compliance with legal frameworks such as the VOC Regulation (European Commission, 1999) and REACH (European Commission, 2006). Further, for over twenty years, it has actively implemented global environmental programs such as Coatings Care® (IPPIC, 2013).

To date, most of the environmental regulations and initiatives have focused on environmental impacts that are specifically associated with the production and the use of paints and printing inks. However, an increasing environmental awareness within the global construction industry challenges the coatings industry to get involved in the developments regarding sustainability. This is particularly true in Europe, where sustainability is high on the agenda. Increasingly more architects work according to green building schemes that contain requirements on material efficiency and indoor air quality. To acquire green building certifications, information is required regarding the environmental impacts of the used materials. Additionally, in France, Environmental Product Declarations (EPDs) are part of the Grenelle II (Gouvernement français, 2010) legislation. Both developments have led to an increased demand for Life Cycle Inventory (LCI) data. As a sector involved in the construction industry, the coatings industry has been confronted with the call for LCI data. In response, CEPE has established a Sustainability Taskforce. To enable member companies to identify, analyze and evaluate the broader environmental effects of their products over the product's full life cycle, the CEPE Sustainability Taskforce has initiated a pre-competitive LCI project to resolve the lack of standard LCI data for raw materials.

PROCESS

Goal and scope

The CEPE Sustainability Taskforce consists of member company representatives responsible for sustainability, as well as the directors of national coatings associations. In 2010, the Sustainability Taskforce made the decision to set up a Sustainability Working Party responsible for the content of the LCI project. The Working Party comprises of a selection of Taskforce members and Life Cycle Assessment (LCA) experts of the CEPE member companies (which include both coatings manufacturers and associated companies such as raw material suppliers).

As a starting point, the Working Party focused on reviewing different software packages and LCI data available in Europe for the computation of singular environmental indicators such as carbon footprint and the water utilization. However, as the discussion of the goal and scope progressed, a consensus was reached that in order to support wider sustainability initiatives like the Green Public Procurement (European Commission, 2008) and Green Building (USGBC, 2013; BREEAM, 2013), a shift should be stimulated towards Life Cycle Thinking. To this end, CEPE set the goal to establish a fully transparent methodology for collecting consistent LCI data, and to subsequently develop a fully open LCI database covering both raw material and coating manufacturing. The scope of this project was agreed to be cradle-to-gate. The types of process within this scope are common for all sector groups in the coating industry; the LCI data for raw materials include the extraction of feedstock and production and transport of the coating raw materials (cradle-to-gate), whereas the LCI models for coating production are restricted by the boundaries of the production plant (gate-to-gate). The Swedish Environmental Research Institute (IVL) was selected as a consultant to create the LCI database and models.

Coatings life cycle inventory

In the first phase of the LCI data collection, each CEPE sector group was asked to list the main raw materials in their industry sector, and indicate the relative importance of each of the selected compounds. The lists were then aggregated and common items were replaced. Ultimately, the final list contains ~ 300 raw materials. Due to time and budget constraints, data were collected using a pragmatic approach. High priority was given to substances that are either used in large volumes or that are of environmental concern, whereas compounds constituting merely a small fraction of the final product mass and posing no risk to the environment were given low priority. The obtained data quality was chosen to be proportional to the status of the raw material, where data of high quality were substance-specific, while low quality data were obtained by modelling an 'average mixture' of representative substances.

The data were acquired in several ways. First, the European raw material associations have been contacted. This yielded some information, but mostly demonstrated that the majority of supplier organizations currently do not have this data readily available. The inquiry however, induced a great interest, suggesting that the LCI project not only fulfils a need at the level of the manufacturer, but at the level of the supplier as well. Further, pre-existing databases where reviewed. As the use of public data was preferred for its transparency as well as from a cost perspective, data sets were mainly extracted from Ecoinvent. As a result, an Ecoinvent licence is required to access the full database. Finally, in cases where a high data quality was required and no specific data were available elsewhere, raw material experts and suppliers where consulted and a raw material LCI model was created.

Further, three LCI models for the manufacturing of coating products were produced; one for water-borne, one for solvent-borne and one for powder coatings. Since many coatings producers where involved in the data acquisition process and for each coating manufacturing process data were included of at least three production sites, the resulting models are highly representative.

Finally, a methodology report and reference manual have been written, in which all assumptions, hypotheses, rationale for the selection of datasets, and source of selected datasets are justified. All background information required for a full LCA study can be retrieved from these documents. The intention is to make the LCI models for coating production available to the larger LCA community at a later stage.

Deliverables

To communicate the industry's position relative to sustainability, CEPE launched the Charter for Sustainable Development in the Paint and Printing Ink Industry (CEPE, 2012). In this charter it sets forth the intention to encourage and support the company members to gain insight into the environmental impact of their products throughout their life cycle. Herewith, CEPE intends to enable its members to identify opportunities for innovation. A significant contribution to this support is formed by the first deliverable of the LCI project: the industry standard LCI database, in accordance to the latest LCA standards and freely usable by LCA experts from members companies.

However, during the project an additional need was identified. The LCI data obtained in this project is of high complexity and will typically be used in combination with of LCA software.

Due to often limited (financial) resources, small and medium-sized enterprises (SMEs) might be prevented from enjoying the benefits of these results. To also enable SMEs to utilize the data and have their first experience with LCA, CEPE decided to provide them with an Eco footprint tool. By means of this web-based tool CEPE members can calculate their products' eco footprints, comprising an overview of environmental indicators such as energy and resource consumption, and emissions to air and water. This information may subsequently be used as the main source of impact information when compiling Environmental Product Declarations (EPDs).

The Eco footprint tool, developed by Ecomatters, is based on the coating manufacturing models and the raw material LCI database. It provides a quick and easy method to adjust the main model inputs and extract an overview of the most important environmental impacts of a product in a document in MS Word or MS Excel format. After initial testing, the convenience provided by the Eco footprint tool does not only seem to fulfil the need of SMEs, but also seems to generate great interest from the larger member companies.

Further development

The deliverables of the CEPE LCI project, that is, the industry standard LCI database and the Eco footprint tool, will be available for further use by sector groups, national organizations and individual companies. Next to this direct use, a number of follow up projects aimed "after the gate" are currently being investigated at CEPE level.

CONCLUSION

Due to its proactive attitude and initiation of the LCI project on a European level, CEPE has taken the position of frontrunner. As a result, rather than several dissimilar and mutually unmatchable systems originating from individual national initiatives, one standard database has been developed that provides LCI data common for the entire industry. This is expected to be great value to the European community of coating and paint manufactures, for it allows for a fair comparison of the environmental impact of different products and product groups over the life cycle.

REFERENCES

BREEAM, Building Research Establishment Environmental Assessment Method, (2013). Public website.

Available at: www.breeam.org (Accessed: 31 May 2013).

CEPE, European Council of the Paint, Printing Ink and Artists' Colours, (2012). Charter for Sustainable Development in the Paint and Printing Ink Industry.

Available at: http://www.cepe.org/EPUB/easnet.dll/ExecReq/Page?eas:template_im=100087&eas:dat_im=105FEF

European Commission (1999). Directive 1999/13/EC.

Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999L0013:EN:NOT (Accessed: 31 May 2013).

European Commission (2006). Regulation (EC) No 1907/2006.

Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32006R1907:en:NOT (Accessed: 31 May 2013).

European Commission (2008). COM(2008) 400, Brussels, July 16, 2008.

Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0400:FIN:EN:PDF (Accessed: 31 May 2013)

Gouvernement français (2010). Law No. 2010-788.

Available at: http://legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000022470434 (Accessed: 31 May 2013).

IPPIC, International Paint and Printing Ink Council, (2013). Public website.

Available at: www.ippic.org/coatings_care (Accessed: 31 May 2013).

USGBC, U.S. Green Building Council, (2013). Public website.

Available at: www.usgbc.org/leed (Accessed: 31 May 2013).

ROLES AND RESPONSIBILITIES IN THE MOBILITY SECTOR

Tuesday, Aug 27:	3:30 pm - 5:00 pm
Session chairs:	Stephan Krinke, Volkswagen AG, Germany
	Christoph Herrmann, TU Braunschweig, Germany

A COMPREHENSIVE APPROACH OF SUSTAINABILITY ASSESSMENT OF PRODUCT IN THE AUTOMOBILE SECTOR: CHALLENGES AND BENEFITS

Marzia Traverso, Volkmar Wagner, Ben Trouvay, Juliane Kluge, Ferdinand Geckeler, Stefan Brattig, BMW Group, Knorrstraße 147, 80788 Munich, Germany,*
marzia.traverso@bmw.de

Keywords: first; life cycle assessment; sustainability; conventional vehicle; electrical vehicle.

ABSTRACT

Environmental and social sustainability along the entire value chain, product responsibility in all areas as well as a clear commitment to resource efficiency are an integral part of the BMW Group's strategy. Already in the strategic & planning stage, sustainability performance of BMW Group´s vehicles is assessed by life cycle assessment approach (ISO14040/44). The results are used to support decision-making process and to define improvements in the life cycle of each designed vehicle. However, there is a rising requirement to also consider social and economic criteria in addition the environmental ones within the framework of sustainability assessment. The sustainability assessment approach for vehicles produced by the BMW Group is presented here with strengths and challenges of the theoretical and practical approach.

INTRODUCTION

The importance of sustainability is frequently underlined by scientist, governments and enterprises. A key issue of the European plan on Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan (European Commission, 2008), is the challenge to improve the overall environmental performance of products throughout their life-cycle. BMW Group's sustainability strategy, adopted in 2009, aligns BMW Group's sustainable operations along the entire value chain and in all fundamental processes, thus creating added value for the company, the environment and society (BMW 2012). Our commitment to sustainability is widely recognized. In 2012, the BMW Group was named industry leader in the Dow Jones Sustainability Index for the eighth consecutive year in succession. The sustainability strategy of BMW Group is also implemented on product stewardship level. The aim of this paper is to outline the current approach used by the BMW Group to develop sustainable products. Furthermore, the challenge of creating transparency along the entire supply chain is addressed.

MATERIALS AND/OR METHODS (WHICHEVER APPLICABLE)

UNEP/SETAC (2011) sees a rising requirement to also consider social and economic criteria in addition to the environmental ones within the framework of product sustainability assessment. Life cycle assessment (LCA) is recognized as a valid supporting tool for assessing environmental performances of vehicles, as it is shown by the various publications (Koffler and Rohde-Bradenburger 2010) and environmental certificates developed in the automotive sector. According to this life cycle thinking approach, new concepts and new models have been developed in BMW Group by addressing environmental and social performances.

Environmental LCA

The environmental LCA has been implemented to support the development and design process of several vehicles of BMW Groups, according to the ISO 14040/44 (2006). The environmental impacts which can be generated by a vehicle life cycle are already assessed at the concept design phase by considering the material compositions and the production processes of components and entire vehicle. The software used to measure them is GaBi© software from PE International. The results obtained are used for defining improvements on the environmental performances of the entire vehicle. The vehicle is consequently designed according to the targets and, in the entire development phase until the production, the relative indicators are monitored and checked (ISO 14062, 2002) towards environmental enhancements.

As reported from several studies the necessity to use light materials for conventional vehicle has been led to the necessity to improve the fuel consumption and environmental performances of the use phase (e.g. efficient dynamics), which produces for example about 80% of the greenhouse gas emissions, measured in global warming potential (GWP), of the entire life cycle of conventional car. The impact measured by GWP is definitively transferred to production phase if we move from a conventional engine vehicle to hybrid and electrical ones. It moves the focus of BMW Group on the environmental performances of supply chain and manufacturing of materials and components, for further improvements of its products.

Social Assessment

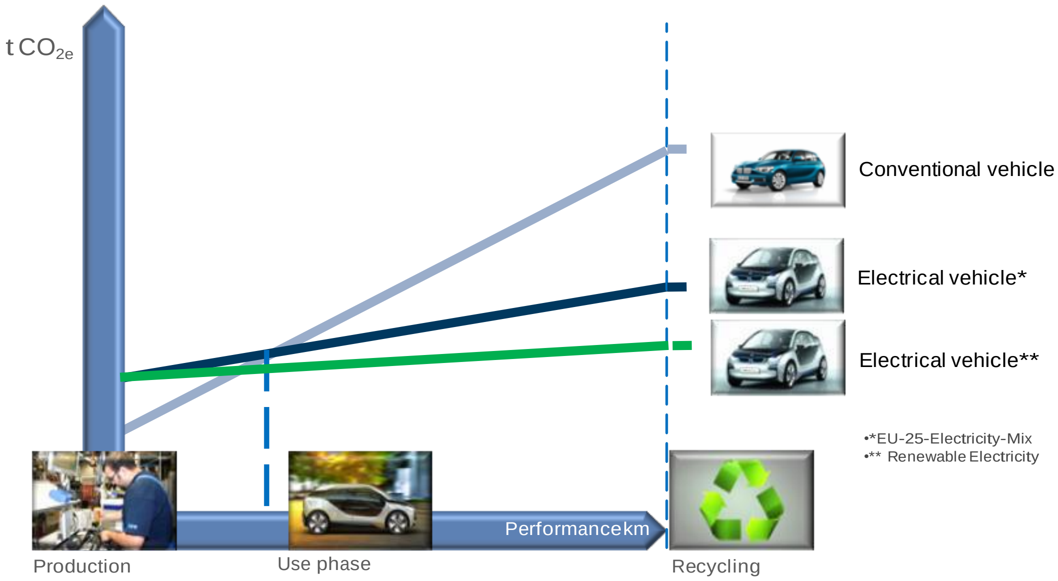
The BMW Group manages its business in accordance with principles of responsible corporate governance. As example, since 2001 it has confirmed its commitment to these principles in its own Corporate Governance code (BMW Group, 2010; OECD, 2004). The social strategy of the company has been implemented by considering several stakeholder groups, such as workers, customers and local communities, in accordance with the social life cycle assessment guidelines (UNEP SETAC, 2009). Until now, the social factors have been mainly considered at corporate level by including suppliers, but it is clear that to implement social assessment at product level, the impact generated along the entire life cycle should be considered. The difference would not be so much if when we assess the social aspects at corporate level we include the entire supply chain and assess it by considering all sites which are involved in the product life cycle.

On one hand, the main difficulty in the implementation of social assessment to the entire supply chain, lays on the lack of primary social data. A company has often not bilateral agreement with all suppliers until n-tier; consequently it has not rights into asking detailed information to the n-tier. On the other hand, to reach a more sustainable production, it is definitively important identifying at least the social hotspots (ILO conventions on human and labour rights) along the entire supply chain. The social hotpot aspects are mainly related to the workers stakeholder group (UNEP SETAC, 2009). BMW Group and all plants of its, are definitively compliant to ILO standards (human and labour rights). Further social aspects, such as working hours, pair opportunities and healthy and safety, social security are assessed and monitored among BMW Group´s employees that leads to move the attention for the social assessment to our supply chain where a further attention is probably necessary. To identify sustainability risks and to mitigate the risk of suppliers not meeting BMW Group's sustainability standards, a BMW Group specific risk filter was developed. The sustainability risk filter evaluates our suppliers and sub-suppliers according to their commodity and the country where the sites are located against environmental, social and governance criteria. The risk filter is the first step to identify which are the sustainability risks in BMW Group´s supplier network and carry on with a further auditing process with questionnaire and /or on-site audits. The social and governance topics used in the risk filter are the same identified by human and labour rights; relative social risk data has been collected at country level by using several databases such as: World Bank, Maplecroft, and Unicef.

RESULTS

In 2011 we presented the BMWi sub-brand embodying our belief that premium cars are increasingly defined by their sustainability. Our design approach by life cycle assessment was already implemented in the respective concept electrical car, BMW i3 Concept, unveiled in 2011. Due to respective targets set from the earliest strategic and planning stages on, it was achieved that the GWP of BMW i3, assuming a European electricity mix (EU 25), is at least a third lower than for a highly efficient conventional combustion engine vehicle in the same segment. If the vehicle is powered by renewable electricity, the improvement increases to well over 50 per cent. In addition to GWP, other environmental impact categories have been taken into account as well. This is reflected in a large number of innovative measures relating to the development, production and recycling stage.

Figure 1. GWP of BMW electrical vehicle compare to the conventional one



For the social assessment, the risk filter is normally used as first step of the assessment. The social risk filter is necessary to identify the main risks at commodity and country level, and to move on with a further assessment of the supplier by questionnaire and site audits. The countries and commodities are ranked according to their potential risk by ranking score and colour scale. Because the non compliance with topics related to ILO standard (e.g. child labour, forced labour) are considered high social risk also according to BMW social strategy, several knot out criteria have been inserted. The further assessment has to be conducted at site level and at the usual social questionnaire some specific questions according to the risk filter results have been added.

DISCUSSION AND CONCLUSIONS

The BMW Group assumes responsibility for all of its products and processes. This is reflected in our long-standing Life Cycle Assessment (ISO 14040/14044), enabling us to ensure from the architecture phase onwards that our products and processes conform to our environmental sustainability standards.

A complementary social assessment is carried to assess new materials, components and technologies more environmental friendly are produced by improving the social conditions of workers, customers and local communities involved in the product life cycle. In the implementation of social assessment a lot of difficulties have been faced up in the definition of the indicators and in the data collection. The gap of a database sector specific and the use of a hotspots analyses often leads to an evident results where the developing and emerging countries resulted having higher social impact compared to developed ones. These results are mainly due to a lack of database related to company and/or commodity that could trace social benefits as well as impacts. A first step in this direction has been made from BMW Group with the implementation of risk filter that even if no so many data at commodity level are still available creates the framework for future systematic implementations of social assessment with quantitative indicators.

REFERENCES

BMW Group, 2010. Sustainable value report. Published by Bayerische Motoren Werke Aktiengesellschaft, 80788 Munich, Germany, http://www.bmwgroup.com/sustainability/,

European Commission, 2008. the European plan on Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan, http://ec.europa.eu/environment/eussd/escp_en.htm

ISO 14040/44, 2006. Environmental management — Life Cycle Assessment — Principles and framework and Requirements and Guidelines. 2006. International Organisation for Standardization

ISO 14062, (2002). Environmental management -- Integrating environmental aspects into product design and development

Koffler C., Rohde-Bradenburger K., 2010. N the calculation of fuel saving through lightweight design in automotive life cycle assessments. Int. J Life Cycle Assess 15:128-135, DOI 10.1007/s11367-009-0127-z

OECD (2004). Principles of Corporate Governance. Published on line at www.oecd.org

UNEP / SETAC (2011) Towards Life Cycle Sustainability Assessment. 65p. Paris SETAC Life Cycle Initiative United Nations Environment

UNEP/SETAC (2009), Guidelines for social life cycle assessment of products, United Nations Environment Program, Paris SETAC Life Cycle Initiative, UNEP ISBN: 978-92-807-3021-0

ADVANCED PROCESS MATERIALS FOR THE AUTOMOTIVE INDUSTRY ENABLE LIGHT-WEIGHT SOLUTIONS

Clara Fiúza [1]*, Mark Schneider[1], Pascal Obringer[2], Matthias Hofmann-Kamensky[1]

[1]Sika Services AG. [2]Sika Schweiz AG.

* Tüffenwies 16, 8048 Zurich, Switzerland, fiuza.clara@ch.sika.com.

Keywords: Sika; light-weight; automotive; LCA; fuel efficiency.

ABSTRACT

Sika provides the Automotive Industry with solutions for increased structural performance, added acoustic comfort and improved production processes, supporting it to manage increasing challenges of safety, CO_2 emissions and fuel efficiency. Two representative product solutions, SikaReinforcer® and SikaPower®, are analyzed, as well as the gains from their enabling light-weight design of vehicles. Aside from other benefits (e.g. increasing passenger safety, simplifying the manufacturing process), it is shown that Sika's solutions higher carbon footprint is largely compensated by gains during the use phase, namely in terms of fuel consumption and carbon emissions, just by allowing light-weight solutions.

INTRODUCTION

Sika is a global supplier of processing materials for sealing, bonding, damping, reinforcing and protecting load-bearing structures. Sika is also a development partner and supplier of the Automotive Industry, with solutions for increased structural performance, added acoustic comfort and improved production processes. This industry is facing challenges in terms of safety, CO_2 emissions and fuel efficiency. The balance between weight reduction, needed to reach new CO_2 legislation, and improved safety and acoustic comfort performance is a complex equilibrium for both Original Equipment Manufacturers (OEM) and Automotive suppliers, which Sika processing materials support.

Moreover Sika aims to assess its portfolio and compare all "costs", financial as well as non-financial (from raw materials, production, application and disposal) with potential "gains" for the customers (from product application and use) on both environmental and economic dimensions, using the Life Cycle Assessment (LCA) methodology. LCA provides a method to quantify and evaluate potential environmental impacts throughout a product's life cycle - from raw material purchase through production, use, end-of-life treatment, to final disposal.

Two representative product solutions for the Automotive Industry are SikaReinforcer® (components of epoxy and polyamide for structural reinforcement of cavities and crash reinforcing) and SikaPower® (structure adhesives based on epoxy, polyurethane and rubber, for crash and structural bonding, hem-flange, sealing and anti-flutter applications). Both solutions also enable light-weight design. They are analyzed here using data from real customer projects and LCA.

METHODS

A cradle to gate LCA was performed on a SikaReinforcer® (SR) component and SikaPower® (SP) adhesives, which covers raw material acquisition, processing and manufacturing of the product, including packaging. Using real customer projects, the "costs" are set against the use phase "gains" these solutions may bring when compared to alternative technologies, mainly by enabling light-weight design of vehicles, lowering fuel consumption in the vehicle's use phase. The Global Warming Potential (GWP 100a) impact category was analyzed, as the sector is facing stronger regulation and customer demands on carbon emissions along the value chain. The LCA Software GaBi 6.0 and databases were used and the impact assessment method was CML 2001-Nov. 2010.

SikaReinforcer® Case Study

An example case study to assess the "costs" and "gains" of replacing a 5 kg high strength steel[1] component with a 2 kg SikaReinforcer® component (including polyamide PA 6.6 GF35[2]) is calculated. The SR's epoxy formulation, production (compounder, in Switzerland) and storage was modeled, as well as the components processing (injection molding, in Switzerland) and packaging (carton box). The steel component needs additionally 51 welding points to be installed. The energy input per welding point is included (based on Stephan, 2007)[3].

SikaPower® Case Study

To illustrate how Sika's adhesives contribute to weight reduction in the use phase, as well as reducing the number of welding points needed in the vehicle production, two different setups were calculated for a high class car model. The first setup represents the serial production car and the second an optimized body with less welding points and thinner metal sheets. Both achieved the required stiffness and crash resistance. By using SikaPower® adhesive it was possible to eliminate 1000 welding points (thus allowing cost and welding energy savings) and to reduce 30 kg weight. The SP's formulation, production (in Italy) and packaging (23 L hobbock) were modeled. The energy inputs for welding and for bonding are included (based on Stephan, 2007).

Use phase gains

For the use phase gains, the standard mileage used for service life is 150'000 km. According to Gies (2009), weight reduction brings gains in terms of carbon emissions from less fuel consumption. In Koffler and Rohde-Brandenburger (2010), fuel reduction values are calculated for the weight-induced fuel consumption and then adapted to the power train (to achieve equal driving performance). According to the authors, the adapted values should be

---

[1] Reinforcing steel dataset from ecoinvent was taken as proxy for high strength steel, since no data was available (also no processing is included).
[2] PA 6.6 GF30 dataset from ELCD/PlasticsEurope.
[3] EU-27 electricity mix dataset from PE International.

used, though it is difficult to quantify how large the weight reduction for a single component needs to be to allow for a power train adaptation if other lightweight measures are likely to appear in the vehicle but not known comprehensively. The life-time energy savings are also influenced by performance, efficiency of the transmission, engine and energy supply (IFEU, 2003). Based on Gies (2009) and Koffler and Rohde-Brandenburger (2010), and assuming a linear relation between weight reduction and carbon emissions and fuel consumption, those gains can be estimated through the following equation (with 1 L Diesel corresponding to 2.63 kg CO_2):

$$Fuel\_reduction/100km = -\frac{\Delta mass(kg) * 0.3l(Diesel)/100km}{100kg}$$

RESULTS

For the SikaReinforcer® case study, Δmass = -3 kg, so the total gains during the use phase coming from weight reduction and consequent fuel reduction amount to 34 kg CO_2., which is 2.5 times greater than the costs. For the SikaPower® case study, where Δmass = 30 kg, the total gains in the use phase amount to 355 kg CO_2, i.e. 15 times the costs. The cradle to installation costs vs. use phase benefits are shown in Figure 1 and Figure 2, respectively.

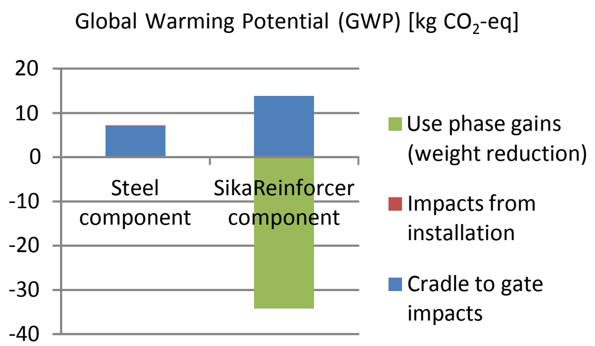


Figure 1. SikaReinforcer® vs. Steel: GWP for the materials in and emission reduction during use phase of the vehicle.

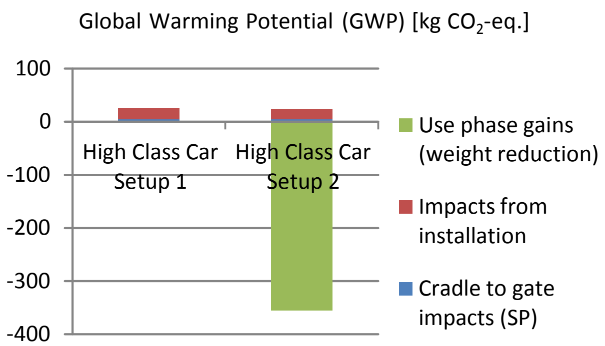


Figure 2. SikaPower® application: GWP costs and emission reduction during use phase of the vehicle.

DISCUSSION

SikaReinforcer® is used for structural reinforcement of cavities for stiffness and for enhancing crash properties through absorption of the impact energy or redistribution in the car structure. It improves the crash performance by adding a structural component that creates a rigid assembly with panels or eventual support. By this, sheet metal thickness can be reduced and steel reinforcement plates removed. SR contributes to reduce the weight of vehicle and may also avoid creation of vibrations (and thus noise and fatigue cracks in the structure).

SikaPower® adhesives are heat-curing adhesives combining properties such as toughness, flexibility, elongation, mechanical strength and an excellent adhesion spectrum on various substrates. SP can be used for crash and structural bonding, hem-flange, sealing and anti-flutter applications. These Crash Resistant Structural Adhesives increase passenger safety, improve car stiffness, and save costs due to decreasing of spot welding points and to simplification of the manufacturing process. They also enable bonding of composite material mix (metal/alu/plastic) and improve long term car durability.

Both case studies demonstrate that these solutions also allow savings in the automobile's production process (by substituting welding and allowing the use of thinner steel sheets) and during its use phase, namely in terms of fuel consumption and carbon emissions (by making a weight reduction possible). It is important to note that specific energy savings for a weight reduction also allow for a higher payload, and that they depend on the vehicle's use and the general physical specifics, with higher energy savings taking place for vehicles which are used with frequent stops and accelerations (IFEU, 2003).

CONCLUSIONS

There is increasing demand for a transparent picture of the environmental performance of products. Particularly in the Automotive sector, the search for lighter, eco-friendlier vehicles, fuel efficiency or "greener" energy sources, are industry drivers. More and more, the fuel efficiency and carbon emissions of the car weigh on consumer decisions. Meanwhile, the quality, safety and security standards must be ensured or even surpassed.

Apart from other benefits, like increasing passenger safety, it is demonstrated that, using high performance adhesives and components for structural reinforcement, the higher cradle to gate carbon footprint is over-compensated by gains during the use phase, namely in terms of fuel consumption and carbon emissions, by allowing light-weight construction. The results and lessons from the assessments can be adapted for similar studies and projects with OEMs as well as for further R&D activities.

REFERENCES

Institute for Energy and Environmental Research (IFEU). (2003). Energy savings by light-weighting, Final Report. 2003. Retrieved from http://www.world-aluminium.org/cache/fl0000125.pdf

Gies, S. (27 May 2009). Research Needs & Future Trends in Lightweight Design. Presented at Innovative Developments for Lightweight Vehicle Structures Conference, Wolfsburg, Germany.

Koffler, C.; Rohde-Brandenburger, K. (2010). On the calculation of fuel savings through lightweight design in automotive life cycle assessments. International Journal of Life Cycle Assessment, 15, 128–135. Doi:10.1007/s11367-009-0127-z

Stephan, H. (2007). Bewertungsmethodik für Fertigungsverfahren im Karosseriebau aus Sicht des betrieblichen Umweltschutzes. Hrsg. Verein zur Förderung des Instituts WAR -Wasserversorgung und Grundwasserschutz, Abwassertechnik, Abfalltechnik, Industrielle Stoffkreisläufe, Umwelt- und Raumplanung- der Technische Universität Darmstadt e.V. (PhD Thesis, only in German).

DEFINITION AND INFLUENCE OF FUNCTIONAL UNIT IN LCA OF ELECTRIC AND PLUG-IN HYBRID VEHICLES APPLIED TO IMPLANTATION SCENARIOS

Florent Querini, Enrico Benetto*

Public Research Centre Henri Tudor (CRPHT) / Resource Centre for Environmental Technologies (CRTE) - 6A, avenue des Hauts-Fourneaux, L-4362, Esch-sur-Alzette, Luxembourg.

**Corresponding author: florent.querini@tudor.lu*

Keywords: mobility; electric vehicles; hybrid vehicles; consequential LCA; agent based; modelling.

ABSTRACT

Life Cycle Assessment (LCA) studies of electric mobility are often limited to the comparison of few electric vehicles (EVs) with their internal combustion engine (ICE) counterparts, suffering from an unclear definition of the functional unit. This bias has potentially significant repercussion on the assessment of the environmental consequences of mobility policies and objectives fixed by European states. This paper aims at proposing a multi-agent model in order to assess the vehicle market of Luxembourg and how the ICE vehicles are going to be replaced by EVs. This model can thus help us to define the functional unit associated with electric mobility, whether it is applied to individual, company or shared cars and feed consequential LCA of policy and implementation strategies.

INTRODUCTION

Context

Electric (EVs) and plug-in hybrid (PHEVs) vehicles are often presented as a way to limit the impact of individual mobility on climate change, air pollution and oil depletion as well as an opportunity for carmakers in a mature European market. Accordingly, member states have started defining mobility policies involving ambitious targets, such as for example the Luxembourgish government which has set an objective of 40,000 electric vehicles in 2020, representing grossly 10% of the circulating fleet.

State of the art

Most of the literature LCA studies have been conducted to assess specific vehicle types and for comparative purposes at technological level, without addressing the overall environmental impacts of these mobility policies. For instance, Notter et al. (2010) have studied the environmental impact of a segment C (VW Golf, Renault Mégane, etc.) electric vehicle with its comparable internal combustion engine vehicle (ICEV). Hawkins et al. (2013) have compared a Nissan Leaf to a Mercedes A-Class. While providing interesting insights as well as proposing inventories for electric vehicles, none of these studies can directly answer the question of deployment policies. Indeed, Hawkins et al. (2012) have conducted a review of the available studies and showed that, depending on the hypotheses retained, the results could greatly vary. The role of the functional unit appears to be crucial (for instance compared cars, lifetime of the battery or lifetime of the car).

Objectives
The goal of this work is to assess the environmental consequences of EV deployment policies in Luxembourg and the Greater Region. For this purpose, a model has been developed to forecast EVs and PHEVs deployment in the circulating fleet, for individual vehicles as well as for company fleet cars and car-sharing. Since Luxembourg is strongly dependent on neighbouring regions (Belgium, France and Germany), Lorraine, a bordering French region, is also included here.

MATERIALS AND METHODS

NetLogo
To calculate the environmental impact of various EV deployment scenarios, a multi-agent (M-A) model has been designed. The model is based on NetLogo, a software tool enabling M-A programming of complex phenomena (Tisue & Wilensky, 2004). M-A modelling allows to simulate complex systems by giving a set of attributes and rules to individual agents that will react to external conditions and toward each other. Here, we use M-A modelling to represent the behaviour of Luxembourg and Lorraine inhabitants towards cars. The purpose of M-A modeling is twofold: it allows simultaneously assessing if an individual would change for an EV or a PHEV and it calculates the characteristics and mileage for every vehicles running.

Synthetic population
The first step to assess the effect of EV policies on the fleet is to build a synthetic population of agents owing a car. This is done by using macro statistics, mainly from STATEC[1], INSEE[2] and Eurostat[3]. The main data used are number of inhabitants, active population, retired population, household composition and car ownership. Considering the detailed composition of the fleet and car types sold in 2012, vehicles are distributed amongst the agents, distinguishing between main or secondary vehicles for households owing at least two cars. Each agent has a set of characters, defining, for instance: the distance between home and work, parking possibilities, attitude towards EV and PHEV or mobility needs. Once the synthetic population is defined, simulations are run, for a time step of one hour and over a given timeline (for instance 5 or 10 years). The agents can then react, considering external conditions and their own set of rules.

Activity chains
For each simulation day, each agent has its chain of activities describing, for each hour, if he will use its car and what distance he will drive for various activities such as commuting, shopping, picking children at school, etc. The activity modeling approach is based on daily-

---

[1] http://www.statistiques.public.lu/fr/acteurs/statec/index.html
[2] http://www.insee.fr/fr/
[3] http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

based activity agendas for mobility, such as defined by Arentze & Timermans (2009) and Becks et al. (2009). This daily agenda will thus determine, for each agent, how many kilometers will be driven during the day and, if applicable, when the EV or PHEV will be charged. Thus, the use of the car for one day is unique for each agent, considering its agenda and which type of car he uses (own, fleet or car-sharing).

Car changing process

For every month of the simulation, a car-changing process occurs when a car is old enough to be dismantled or when an agent wants to change its car. Different decision trees have been designed, for EV and PHEV buying and depending on the type of car which is bought (personal or company fleet). For instance, before buying an EV, an agent will ask himself, considering its own characteristics and external factors (such as the price of fuels and electricity, incentives, prices and technical characteristics of EVs...): can I park and charge an EV? Is the range sufficient for my mobility needs? Am I ready to change for a new technology? Is a car model available in the fleet of vehicles sold by the targeted car manufacturer, having the necessary performances (size, acceleration, type of body, etc.)? Is the cost of EV competitive enough? If all the answers are positive, the agent will then buy an EV and start to use it. If not, he will buy a new ICEV.

The combination of synthetic population, activity chains and monthly car-changing process can thus model the deployment of EVs and PHEVs for a given territory, with given policies (e.g. incentives or deployment of public charging infrastructures). It also defines the functional unit of EVs for different types of uses, since it allows knowing how the EVs and PHEVs are used and which car they actually replace.

RESULTS

EV and PHEV deployment

In figure 1 are presented the results of the deployment of EVs and PHEVs for Luxembourg and Lorraine residents (only private vehicles, i.e. company fleet cars are not included). The main differences between these two regions are: the incentive value (5,000€ in Luxembourg, 7,000€ in Lorraine), the distance travelled, the prchasing power and the car market. As a consequence, the penetration of EV and PHEV are not the same for the two regions. The deployment of EVs and PHEVs is higher in France and Lorraine, because of the value of the incentive, though at the beginning the deployment is faster in Luxembourg because of its higher renewing speed.

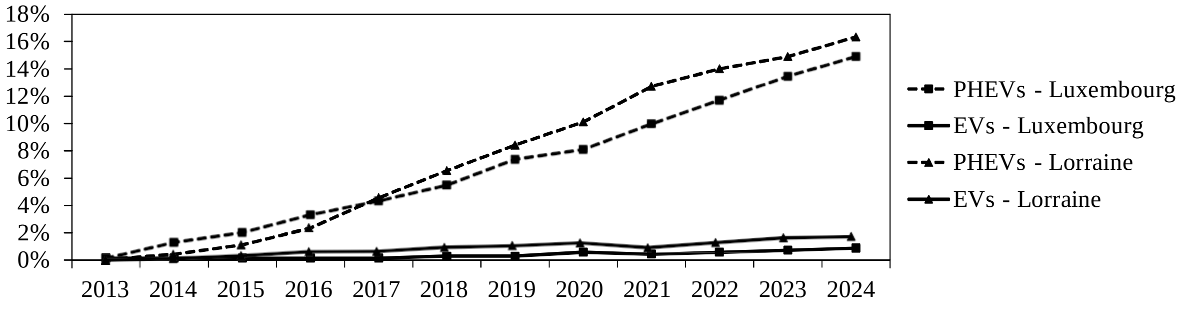


Figure 1. Share of EVs and PHEVs in the circulating fleet in Lorraine and Luxembourg

Functional unit

The functional unit for EVs and PHEVs is defined by the mileage per day, the total mileage and the replaced vehicles. For instance, Table 1 shows the average commuting distance per day for different types of vehicles at the end of the simulation (year 2024).

Region	ICEVs	PHEVs	EVs
Luxembourg	14 km / day	14 km / day	17 km / day
Lorraine	15 km / day	19 km / day	19 km / day

Table 1. Commuting distance for ICEVs, PHEVs and EVs in Luxembourg and Lorraine.

Though EVs are frequently seen as “urban” cars, it is shown here that they tend to replace the vehicles with longer commuting distances, since the main benefit of EVs is their cost / km. PHEVs can also be used for longer distance. However, the mileage of EVs per year is significantly higher for EVs than for ICEVs because 92% are used for commuting, while this share falls to 46% for ICEVs at the end of the simulation.

DISCUSSION AND FURTHER RESEARCH

The model developed is still in its preliminary stage and is now being validated for the Luxembourgish context. Many parameters can vary, thus leading to very different results. It is now necessary to study the influence of these parameters and, since many of them are linked, define some cornerstone scenarios as defined by Pesonen et al. (2000).

The agent based model will be coupled with LCA data to assess the environmental impact of the various scenarios. These data will have to cover the different types of cars included in the model (ICEVs, PHEVs, EVs of different sizes) and be updated during the simulation (for instance, if the simulation duration is 10 year, the electricity mix shall be updated).

REFERENCES

Arentze TA, Timmermans HJ (2009). A need-based model of multi-day, multi-person activity generation. *Transportation Research Part B: Methodological, 43(2), 251–265.*

Beckx C, Int Panis L, Van De Vel K et al. (2009). The contribution of activity-based transport models to air quality modelling: a validation of the ALBATROSS–AURORA model chain. *Science of the Total Environment, 407(12), 3814–3822.*

Hawkins, T. R., Gausen, O. M., Strømman, A. H. (2012). Environmental impacts of hybrid and electric vehicles—a review. *The International Journal of Life Cycle Assessment, 17(8), 997–1014.*

Hawkins TR, Singh B, Majeau-BettezG, Strømman AH (2013). Comparative environmental life cycle assessment of conventional and electric vehicles. *Journal of Industrial Ecology 17(1) 53–64.*

Notter DA, Gauch M, Widmer R et al. (2010). Contribution of Li-ion batteries to the environmental impact of electric vehicles. *Environmental science & technology 44(17) 6550–6556.*

Pesonen HL, Ekvall T, Fleischer G et al. (2000). Framework for scenario development in LCA. *The International Journal of Life Cycle Assessment, 5(1), 21–30.*

Tisue S, Wilensky U (2004). NetLogo: A simple environment for modeling complexity. *International Conference on Complex Systems, pp. 16–21.*

IMPLEMENTING THE LIFE CYCLE APPROACH AT VOLKSWAGEN

Jens Warsen, Stephan Krinke, Günter Damme.*

**Volkswagen AG Group Research Environmental Affairs Product 38436 Wolfsburg Germany. jens.warsen@volkswagen.de*

Keywords: Design for environment; automotive; LCA; Think Blue. Engineering

ABSTRACT

With its environmental strategy, Volkswagen is not only working on developing the most environmentally-friendly vehicles, but also on building them with the greatest possible sustainability. In order to manage the implementation of this strategy in a targeted manner, an approach is needed that considers environmental impacts of a product from a life cycle perspective. Thus, with Think Blue. Engineering Volkswagen introduces a concept that aims to identify aspects which are relevant for environmental compatibility at an early stage and to consider them throughout the organization and at all stages of the product life-cycle.

INTRODUCTION

The car industry is facing new challenges. It must not only make its cars ever more comfortable, faster and safer, but must at the same time improve their environmental performance. In the past, this was usually achieved by reductions in fuel consumption (and, correspondingly, emissions) during the service life of the vehicle. Today, the development of sustainable mobility requires a more comprehensive approach. Efforts to minimize the environmental impacts of the vehicle must focus on the entire product life cycle. This means that the potential environmental impacts of new vehicles, components and materials must be assessed before they have even left the drawing board, looking at all aspects from the initial concept and design sketches to the production process, subsequent vehicle operation and recycling. A life cycle perspective is therefore key to environmentally sustainable vehicle development. It allows the company to identify those areas in which improvements will have maximum effect, and to prioritise its innovations accordingly. However, to be applicable such an approach must be based on a binding strategy and practical targets.

FUNDAMENTALS

Volkswagen has set itself the strategic goal of becoming the world's leading automaker in environmental terms by 2018. This strategy implies a fundamental ecological restructuring of the Volkswagen Group coming along with investments directly or indirectly in ever more efficient vehicles, new powertrains and technologies as well as environmentally compatible production at its plants all over the world. In this context, Volkswagen is committing to reducing the CO_2 output of the European new car fleet to emissions below the threshold of

120 grams CO_2/km by 2015 and furthermore to 95 grams per kilometer by 2020. Another target is to make the production in the Volkswagen Group 25 percent more environmentally compatible by 2018. Furthermore, the Group aims for a 40 percent reduction in greenhouse gas emissions associated with production-related energy supplies by 2020.

A prerequisite for a successful implementation of this strategy is the translation and integration of the overarching targets into specific company policy and processes. Due to this, in its environmental policy Volkswagen considers climate change, health/air quality and sustainable resource use the biggest environmental challenges. This applies for all activities within our production sites worldwide as well as for the process of product development. Consequently, the three areas of environmental protection also have been incorporated into the environmental goals for product development at the Volkswagen brand [Volkswagen, 2003].

IMPLEMENTATION

Concept of Think Blue. Engineering.

The ongoing improvement of our vehicle fleet in terms of environmental impacts and resource conservation forms an integral part of Volkswagen's corporate policy. Thus, the Technical Development department has set itself the goal to continuously improve the environmental compatibility of its facilities and the products it develops. All activities and processes within the life cycle of our products are laid out to be environmentally friendly. We identify aspects which are relevant for environmental compatibility at an early stage and consider them throughout the organization and at all stages of the product life-cycle. This is what we call Think Blue. Engineering (Figure 1). Facing the three environmental challenges mentioned before, with Think Blue. Engineering we set ourselves the following objectives:

1. Climate protection

- Reducing CO_2 emissions of the 2015 new vehicle fleet to below 120 g/km for EU27 countries
- Increasing efficiency by 10–15% for every new generation of cars compared to its predecessor
- Developing the most fuel-efficient model in every segment and every vehicle class
- Developing and providing technical solutions for reducing fuel consumption over the vehicle's service life with the customer
- Reducing greenhouse gas emissions over the entire product life-cycle

2. Resource conservation

- Increasing resource efficiency
- Continuously increasing the use of renewable and secondary raw materials
- Engineering new models that have ideal recycling and recovery characteristics, employing innovative recovery technologies
- Develop and make available alternative powertrain technologies
- Enabling the use of alternative fuels

3. Health protection

- Reducing regulated and non-regulated emissions
- Avoiding the use of hazardous and harmful substances within the framework of the strictest materials legislation of the world
- Minimizing passenger compartment emissions, including odours
- Attaining best possible exterior and interior noise levels

Furthermore, for the activities and processes at the Technical Development department in Wolfsburg five key performance indices (KPI) have been defined. Setting 2010 as a reference, we will have achieved a 25% reduction in energy consumption, waste accumulation, emissions, water consumption, and CO_2 emissions by 2018.

Figure 1. Think Blue. Engineering Logo

From Life Cycle Assessment to Think Blue. Engineering

In accordance with Think Blue. Engineering we develop each model in such a way that, over its entire life-cycle, it presents better environmental properties than its predecessor. The tool chosen by Volkswagen to implement this approach is the life cycle assessment (LCA) in line with ISO standards 14040 and 14044 [2,3]. The purpose of a LCA study – not just at Volkswagen – is to analyse and assess in detail all the data on energy consumption, emissions and the other environmental impacts generated during the production of vehicles or technologies and/or during related processes. Making LCAs at Volkswagen means to collect all the important facts over the entire life cycle of a vehicle, component or technology and back them up with figures. For each step in the process we determine the volume of raw materials and energy that goes into its production and the production of the fuel it requires. This process is carried over into the vehicle's service life. The fuel consumption and the resultant emissions during this phase are worked out based on the legally prescribed New European Driving Cycle (NEDC). In addition, the amount of energy consumed during the dismantling and/or recycling of the vehicle parts is calculated. The data collection process is based on the vehicle parts lists, material and weight information stored in the company's own Material Information System (MISS), technical datasheets and drawings, as well as the threshold values for regulated emissions in line with the current EU regulations [Koffler et al., 2007]. These are joined by processing-related data taken from the GaBi database or drawn up in conjunction with the production plants, suppliers or industrial partners.

However, the process of performing reliable and scientific sound LCAs is just one aspect for the implementation of the Life Cycle Approach into Think Blue. Engineering. Another challenge is the need to integrate two different perspectives: that of the LCA modeling expert, who profiles the environmental performance of the product, and that of the engineer who develops the products and technical solutions that actually impact the environment. In order to integrate the LCA methodology and its results into the product development process, it is necessary to translate the results into technical goals. These goals must be expressed in a form that is sufficiently specific and concrete to allow an engineer or planner to apply them to a particular concrete project, even if he/she has no specific knowledge of life cycle assessments and their underlying methodology. Typical examples of LCA-derived goals include a maximum weight for a given component made from a given combination of materials, or the use of particularly efficient production and processing methods for given materials.

Communication of target achievement

When a LCA confirms that the vehicle, technology or process analyzed has met the goals of Think Blue. Engineering, then they qualify for an Environmental Commendation (see www.environmental-commendations.com). Through the Environmental Commendation, Volkswagen documents ecological progress in a vehicle or technology compared to its predecessor. Environmental Commendations provide our customers, shareholders and other stakeholders inside and outside the company with detailed information about how we are making our vehicles, components and processes more environmentally compatible and what we have achieved in this respect.

CONCLUSIONS

A life cycle perspective is a key requirement for targeted and effective environmentally sustainable vehicle development. Life Cycle Assessments based on ISO 14040/44 provide an appropriate environmental management tool for quantifying and evaluating the product development process with regard to environmental impacts across the full life cycle of the vehicle. With the concept of Think Blue. Engineering, Life Cycle Thinking becomes embedded to relevant business processes at Volkswagen that allow environmentally compatible product development to be implemented throughout the different sectors of the company and along the entire value chain. Being based on Volkswagens overarching environmental strategy and referring to the environmental goals for product development at the Volkswagen brand, Think Blue. Engineering facilitates the translation of LCA findings into quantifiable targets and into practical actions that produce genuine environmental benefits.

REFERENCES

ISO.(2006).ISO 14040: Environmental Management – Life Cycle Assessment – Principles and Framework. ISO, Geneva

ISO.(2006).ISO 14044: Environmental Management – Life Cycle Assessment – Requirements and Guidelines. ISO, Geneva

Koffler, C.; Krinke, S.; Schebek, L.; Buchgeister, J.(2007).Volkswagen slimLCI – a Procedure for Streamlined Inventory Modelling within Life Cycle Assessment (LCA) of Vehicles. In: International Journal of Vehicle Design (Special Issue on Sustainable Mobility, Vehicle Design and Development). Olney: Inderscience Publishers

Volkswagen.(2013). Environmental Goals of the Technical Development Department. http://en.volkswagen.com/en/company/responsibility.html

KEY METHODOLOGICAL ASPECTS FOR THE ASSESSMENT OF SURFACE FREIGHT TRANSPORT ACTIVITIES IN A LCA ANALYSIS

Jorge Leon, Antonio Dobon and Mercedes Hortal. ITENE- *Packaging, Transport and Logistics Research Center. Parque Tecnológico, C/ Albert Einsten 1, 46980, Valencia, Spain. e-mail: jleon@itene.com*

Keywords: Life cycle assessment; freight transport; infrastructure processes; land use; impact categories; carbon footprint

ABSTRACT

This paper reviews the most common methodological issues found in Life Cycle Assessment (LCA) studies associated with freight transport activities. Main conclusion drawn is that LCA is a suitable tool to assess the environmental impacts of freight transport activities, since other pollutants rather than CO_2 and other GHGs are produced, although carbon footprint can be applied in certain situations. A deep study on the pollutants produced in these activities revealed that a comprehensive analysis should be accompanied by a full set of impact categories. Infrastructure processes and land use should be included although it makes difficult the analysis. Furthermore empty backhaul trips and pre and post-positioning trips should be considered and attributed to the product transported in the fronthaul trips.

INTRODUCTION

Transport is of fundamental importance as it supports increasing mobility demands for passengers and freight (Rodrigue et al., 2009). Freight transport is essential to continued economic growth (BTS, 2010), but it is also one of the main sources of energy consumption and greenhouse gases emissions giving rise to significant air pollution, which can seriously damage man's health and ecosystems (EEA, 2003). Many studies have been carried out to evaluate the impacts that transport systems have on the environment (Eriksson et al., 1996; Johnsen and Fet, 1998; Stripple and Uppenberg, 2010).

Life cycle assessment (LCA) is one of the most widespread methods for assessing the environmental impacts of transport systems (Johnsen, 2000; Stripple and Uppenberg, 2010, Chester and Horvarth, 2010). However, difficulties are likely to occur in their evaluation. The aim of this paper is to provide some general guidelines to be applied when freight transport activities are evaluated using LCA perspective and to overcome methodological problems such as the selection of relevant impact categories for transport activities, the inclusion of infrastructure processes and backhaul trips and the integration of land use in a transport LCA. This study is focused on surface freight transport, excluding air freight since it represents only about 0.1% of freight transport and hardly competes with other modes as Den Boer et al. (2011) reviewed.

METHODS

A systematic literature review of environmental assessment studies about transport systems has been performed. Both ancient and recent studies have been considered in order to show how the evolution of the approaches with the development of powerful and comprehensive tools and databases. Four main methodological issues related to transport activities have been identified amongst more than twenty articles and standards. Each methodological aspect is discussed with regard to differences between studies and current LCA literature, followed by recommendations for each one.

RESULTS

As a result of the review of selected literature, several results were achieved with regard to methodological issues in the LCA of freight transport. A set of main impact categories have been suggested based both in the literature and the analysis of main pollutants in freight transport: climate change, photochemical oxidation, acidification, eutrophication, inorganic respiratory, human toxicity (carcinogens) and cumulative energy demand (CED). The review also confirms the relevance of infrastructure processes since may affect all impact categories. Furthermore a close relationship between infrastructures and land use impact category was observed. It was found out that empty backhaul trips, and specifically pre and post-positioning trips, had also effects on the environment and therefore they have to be accounted.

DISCUSSION

This section outlines four methodological aspects to support LCA practitioners to assess the environmental impacts due to freight transport activities.

Selection of impact categories for life cycle impact assessment

The main pollutants related to transport activities are CO_2, NO_x, SO_x, PM, CH_4, NMVOC and CO. LCA allows the selection and definition of the impact categories and the assignment of the each substance to the impact categories. Some of them contribute to only one impact category, so the assignment is straightforward. Other pollutants contribute to two or more different impact categories and the assignment depends on the interaction between them. Consequently, transport sector is an important source of pollutants, rather than only CO_2 emissions. Therefore, LCA methodology seems to be as the most suitable tool to address the environmental performance of freight transport instead of using only one indicator such as carbon footprint. In that sense, the use of LCA avoids disregard other relevant potential impacts of transport activities on the environment. However carbon footprint could be suitable in certain cases (ILCD Handbook, 2010).

Infrastructure processes

The different LCA studies reviewed show that capital goods are of fundamental importance when assessing environmental impacts of freight transport. The actual databases have already comprised data about infrastructure processes. Therefore, including infrastructure processes in LCA analysis seems an appropriate and unified approach for transport sector. Although including infrastructure processes is recommended, sometimes they may be omitted. For instance, when assessing carbon footprint of transport services since, as Frischknecht et al.

(2007) reported, capital goods contribute to climate change with only 18.1%. In these cases infrastructure processes may be neglected simplifying the calculations.

Backhaul trips

Life cycle in transport activities is subject, when multiple national and transnational production sites are involved, to a variety backhaul trips (Cooper et al., 2008) and other empty trips such as pre-positioning and post-positioning before and after loading the cargo (BSI Group, 2011). Little consistency has been found in backhaul assumptions used in LCA studies investigating specific transport systems (Cooper et al., 2008). When return trips are considered, a backhaul factor may be assumed referred to fronthaul or a specific load factor for the return trip may be applied. Moreover, empty trips depend on the type of goods transported. In general, it can be assumed that the transport of bulk goods, such as coal or oil, requires more empty trips than that of volume goods like for instance industrial parts or consumer goods (EcoTransit, 2011). The European Standard EN 16258 (2012) sets a general approach based on considering the empty trips, but also the pre-positioning and post-repositioning operations to load the vehicle. Both, pre-positioning and post-repositioning, according to this standard should be included within the vehicle operation. Consequently, following the approach set by the standards, it seems appropriate to attribute backhaul trips and pre-positioning and post-repositioning operations to the commodity transported when transport system are being studied with a LCA perspective.

Land use considerations

The review of previous studies reveals land use is an important intervention that has potential effects on the environment, especially the fragmentation of habitats. On the other hand, the closely relationship between land use impact category and capital goods has been demonstrated by some authors.

CONCLUSIONS

This paper suggests some guidelines to overcome with some common methodological issues that are usually facing LCA experts and practitioners: selection of impact categories, inclusion of infrastructure processes, procedures to deal with backhaul trips or land use implementation. In accordance with the findings of this review, it is clear that a comprehensive LCA analysis of freight transport should be accompanied by a full set of impact categories like: climate change, photochemical oxidation, acidification, eutrophication, inorganic respiratory, human toxicity (carcinogens), Cumulative Energy Demand (CED). Regarding infrastructure processes, the review reveals that they should be included when a LCA is being carried out since their construction involves a large amount of particulate matter emitted. Moreover, the studies point out that they have an important contribution to all impact categories, especially to land use and mineral resources consumption.

In accordance with the findings of this review article, backhaul trips and more specifically pre-positioning and post-repositioning operations have to be attributed to the product transported in the fronthaul trip.

On the other hand, the implementation of land use impact categories is still unclear. However, several authors recognize that it is closely related to infrastructure processes. The construction, maintenance or pre-combustion infrastructures can account for about 95% of the total land use in freight transport.

REFERENCES

British Standards Institution (2011) PAS 2050, 2011. Specification for the assessment of life cycle greenhouse emissions of goods and services. BSI. *ISBN: 978- 05-8071-382- 8*

Bureau of Transportation Statistics (BTS) (2010) Freight Transportation: Global Hightlights. *U.S. Department of Transportation.* http://www.bts.gov/publications/freight_transportation/pdf/entire.pdf. Accessed 29 November 2011

Chester, MV, Horvarth, A (2010) Life-cycle assessment of high-speed rail: the case of California. *Environ.Res.Lett. 5: 1-8*

Cooper, JS, Woods, L, Lee, SJ (2008) Distance and backhaul in commodity transport modelling. *Int.J. LCA 13: 389-400*

Den Boer, E. Otten, M, van Essen, H (2011) Comparison of various transport modes on a EU scale with the STREAM database. *STREAM International Freight 2011*

EcoTransit World (2011) Ecological Transport Information Tool for Worldwide Transports. Environmental Methodology and Data. Update. *IFEU Heidelberg*

Eriksson, E, Blinge, M, Lövgren, G (1996) Life cycle assessment of the road transport sector. *Sci. Total Environ. 189-190: 69-76*

European Committee for Standardization prEN16258 (2011) Methodology for calculation and declaration on energy consumptions and GHG emissions in transport services (good and passengers transport): CEN

European Environment Agency (EEA) (2003) Freight transport demand by mode and group of goods. Indicator Fact Sheet. *TERM 2003 13a AC+CC.* http://www.eea.europa.eu/data-and-maps/indicators/freight-transport-demand-by-mode/term2003_13a_accc_freight_transport_demand_by_mode_and_group_of_goodsfinal.pdf. Accessed 15 December 2011

Frischknecht, R, Althaus, HJ, Bauer, C, Doka, G, Heck, T, Jungbluth, N, Kellenberger, D, Nemeeek, T (2007) The Environmental Relevance of Capital Goods in Life Cycle Assessments of Products and Services. *Int.J.LCA. doi: 10.1065/lca2007.02.308*

ILCD (2010) International Reference Life Cycle Data System. General Guide for Life Cycle Assessment-Detailed guidance. *JRC European Commission*

Johnsen, T (2000) Environmental Comparison of Transport Chains for paper. A case study. *Technical Report No. 2000-3295. Revision No.1 Det Norske Veritas*

Johnsen, T, Fet, AM (1998) Life Cycle Evaluation of Ship Transportation. Screening Life Cycle Assessment of M/V Color Festival. *Research report HiÅ 10/B101/R-98/009/00*

Rodrigue, JP, Comtois, C, Slack, B (2009) The Geography of Transport Systems. *Routledege,* New York

Stripple, H, Uppenberg, S (2010) Life Cycle Assessment of railways and rail transports- Application in environmental product declarations (EPDs) for the Bothnia Line. *Swedish Environmental Research Institute*

LIFE CYCLE MANAGEMENT OF Z-BEE – AN ELECTRIC 3-WHEELER MADE OF POLYMER COMPOSITES

Magdalena Szpieg[1] and Sandra Roos[2,3]*

[1] Swerea SICOMP AB, P O Box 104, SE-431 22 Mölndal

[2] Swerea IVF AB, P O Box 104, SE-431 22 Mölndal

[3] Chalmers University of Technology, Sweden

**magdalena.szpieg@swerea.se*

Keywords: Life Cycle Assessment (LCA), Polymer Composites, Electric Vehicle

ABSTRACT

Z-Bee is a new type of electrified vehicle concept that has been developed by the Swedish company, Clean Motion AB, using life cycle thinking. Z-Bee has a remarkably low emission factor of 0.014 kg CO_2 equivalents per km, including production and waste management. This is nearly ten times lower than the EU target of 0.120 kg CO_2 equivalents per km for all new passenger cars in 2012. The extremely low curb weight of approximately 160 kg has been achieved through employing solely composite materials into Z-Bee's body in white. The life cycle thinking also includes development of an efficient supply chain and development of recycling strategy for the end-of-life vehicle. This approach has shown to be successful in achieving the environmental efficiency.

INTRODUCTION

Environmental protection is a growing concern for many industries today, with emphasis on the reduction of carbon dioxide (CO_2) emissions in order to soften climate change. This is of particular importance for the transportation sector, which is currently one of the greatest contributors of anthropogenic greenhouse gas emissions within the European Union (EU). A contributing factor to the large emissions is that there are too many and too big vehicles for transportation. As a result, to transport a liter of milk home from the store we use a tool weighing 1500 times the weight of the transported goods.

Z-Bee (see Figure 1), an electric 3-wheeler with a curb weight of approximately 10% of a normal car, with electric drive and no tailpipe emissions has been developed by Clean Motion AB. For the minimal energy consumption, the body in white of the Z-Bee is made of fibre reinforced plastic (FRP) sandwich.


Figure 1. Z-Bee - an electric 3-wheeler.

The objective of the LCA study is to understand the environmental impacts of the Z-Bee vehicle in a life cycle perspective, to give recommendations for the further product development. The study is focused on the composite parts of the vehicle, while the other non-composite components are considered more general due to the product development strategy at Clean Motion.

METHOD

For the current LCA study, input data has mainly been drawn from the commonly used LCA database Ecoinvent 2.2 (Swiss Centre for Life Cycle Inventories (ecoinvent Centre), 2010) and from Swerea IVF's own database. The LCA software SimaPro 7.3.3.2 has been used for the calculations. The Life Cycle Impact Assessment is performed using the guidelines from the International EPD Consortium (IEC, 2008) for values describing primary energy consumption, climate change and photochemical smog (emissions of solvents).

Functional unit

The functional unit is defined as the use of the Z-Bee for transport of one person 8000 kilometres, i.e. an approximate yearly use of the Z-Bee. The results are also expressed as the whole life cycle impact of Z-Bee, where the life length is set to 18 years.

System boundaries

System boundaries for the study are shown in Figure 2.

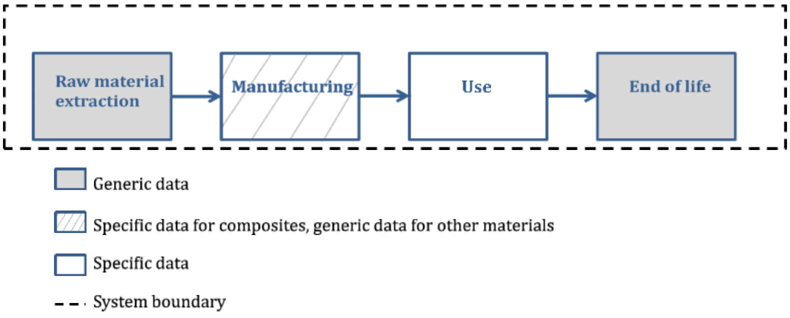


Figure 2. System boundaries for the Z-Bee study.

Life cycle inventory

The composite constituents have been modelled in detail using specific data from the suppliers to Clean Motion AB. All composites components are manufactured using vacuum infusion (Åström, 1997) at HJ Kompositmontering AB. The modelling of the non-composites components has been made by dividing the components into separate materials from which they have been manufactured. For electricity used in the use phase, Swedish average low voltage electricity has been used. For composites end-of-life, three different scenarios, namely mechanical recycling, incineration and landfill, are assumed based on literature as there are no facilities in commercial use in Sweden at the moment.

RESULTS

Impact assessment for Z-Bee's life cycle

The total global warming potential (GWP) for the cradle to grave life cycle of Z-Bee is 1 980 kg CO_2 equivalents. The manufacturing phase is the largest contributor, where the composite components and the battery are the dominant aspects. The use phase stands for 31% of the total life cycle impact on climate change. The negative result (-100 kg CO_2 equivalents) in Figure 3 a) for the end-of-life phase is due to avoidance of greenhouse gas emissions when virgin material is replaced by recycled material. The battery shows to have large impact on the whole life cycle result (27 % of the global warming potential) and should thus be modelled more detailed in future studies. For the primary energy consumption, it can be seen that the energy used in the use phase is 67% of the total primary energy use in the life cycle.

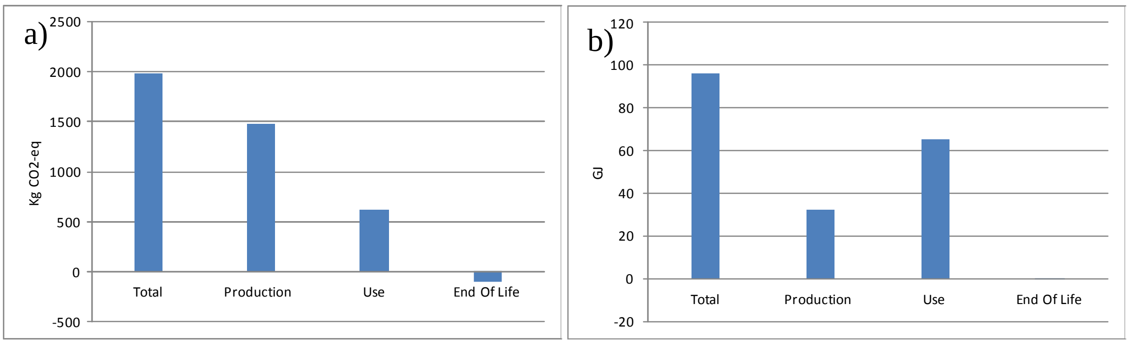


Figure 3. a) The global warming potential (kg CO_2-eq), b) primary energy consumption (GJ) in the life cycle phases of Z-Bee.

End-of-Life

The climate change potential for the 3 different waste scenarios used in the study is shown in Figure 4. The climate change impact category does not take into consideration all aspects of waste generation and management, such as land use and toxic emissions. However, in this particular work, the figure below shows that the best solution, incineration, renders a saved climate impact (due to energy recovery) of 15 kg CO_2 equivalents. This is not a large number compared to the climate impact of 2 tonnes CO_2 equivalents from the life cycle as a whole.

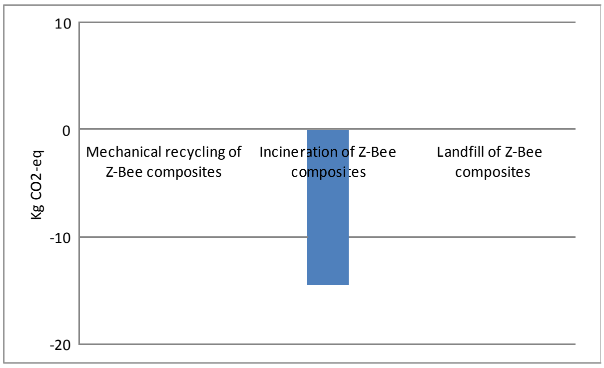


Figure 4. Climate change potential for the different waste scenarios considered in the study.

DISCUSSION

A life cycle assessment (LCA) from cradle to grave has been performed on Z-Bee vehicle, an electrified three-wheeler made of polymer composites. The results show that Z-Bee has a remarkably low emission factor of 0.014 kg CO_2 equivalents per km, including production and waste management. This is nearly ten times lower than the EU target of 0.120 kg CO_2 equivalents per km for all new passenger cars in 2012. Concerning the waste treatment, the global warming potential, which is the main focus in this study, is not the key environmental aspect. Instead, it is the use of land area for landfill, leakage of acidifying, corrosive and toxic substances. Also, the inability to recycle materials will lead to increased extraction of virgin material from the earth's crust, which is a concern commonly shared in discussions of end of life scenarios of products. For the comparison between the different components, it should be noted that some of the figures are built on data from the material supplier and some on data from generic databases, which have direct influence on the accuracy of the results.

CONCLUSIONS

The results from the calculation of global warming potential on the Z-Bee vehicle give a total cradle to grave impact of 1 980 kg CO_2 equivalents. The use phase is no longer the dominant phase for the climate change potential as in the case of the conventional vehicles. Instead the manufacturing phase is the largest contributor, where the composite components and the battery are the dominant aspects.

REFERENCES

IEC. (2008). *EPD – Environmental Product Declaration: General Programme instructions for an international EPD® system for environmental product declarations, and Supporting annexes. Version 1.0.*

Swiss Centre for Life Cycle Inventories (Ecoinvent Centre). (2010). *Ecoinvent data v2.2, Final reports ecoinvent 2010*. Dübendorf.

Åström, B. T. (1997). *Manufacturing of Polymer Composites* (pp. 229–231). Chapman & Hall.

MAKING PUBLIC TRANSPORTATION MORE SUSTAINABLE – A SOPHISTICATED LCA & LCC MODEL FOR ASSESSING BUS BASED PUBLIC TRANSPORT

Michael Faltenbacher, PE INTERNATIONAL AG;*
Markus Wiedemann, Stuttgarter Straßenbahnen AG.
** Hauptstr. 111-113, 70771 Leinfelden-Echterdingen, Germany;*
m.faltenbacher@pe-international.com.

Keywords: decision support, LCA, LCC, bus, public transport.

ABSTRACT

As integral part of its sustainability strategy Stuttgarter Strassenbahnen AG (SSB AG) has decided to implement a holistic life cycle based evaluation approach for its bus fleet back in 2006 which was developed by PE International. Since then a combined modular LCA & LCC model is used and constantly refined. Covering a 15 year time horizon the environmental and economic life cycle profiles of different fleet scenarios are quantified via a transparent comparison of resources consumed, emissions released and costs incurred for different combinations of fuels and propulsion technologies. The developed model proves to be an effective tool to support the strategic decision making of a bus operator to enhance the competitiveness and attractiveness of the public transport service offered.

INTRODUCTION

The provision of an attractive, sustainable public transport system is a key goal of SSB AG. Public transport is seen as one of the key solution options for addressing mobility demands as well as air pollution in growing urban areas. As such public transport operators are under constant pressure for innovation with regard to resource efficiency and the limitation of harmful emissions. For the bus based public transport recent developments show a variety of options for fuels & propulsion technologies. As decisions made on fuel & propulsion technologies not only define direct emissions and costs for the regular operational lifetime of a bus which is 10 to 14 years but also have an influence on the up- and downstream processes, it is essential to transparently quantify and evaluate all life cycle stages of the bus system including the production and End-of-Life of the considered vehicle technology as well as the production of the consumed fuel and the operation of the bus.

METHODS

The goal is to determine the most beneficial fuel/ propulsion technology for the community and the bus operator from a sustainability perspective. In this context it is of key importance to consider the specific local boundary conditions such as availability of fuel resources, major pollution issues which need to be addressed, operational conditions (topography & speed profiles etc.), energy supply vector (e.g. fuel) etc. As integral part of its sustainability strategy SSB AG has decided to implement such a holistic life cycle based evaluation approach for its bus fleet in 2006 which was developed by PE (Faltenbacher, 2006). Since then a combined modular LCA & LCC model is used and constantly extended (Wiedemann, 2007).

Scope of the model:
Covering a 15 year time horizon the environmental and economic life cycle profiles of the current bus fleet as well as different fleet development scenarios are quantified via a transparent comparison of resources consumed, emissions released and costs incurred for different combinations of fuels and propulsion technologies. With a worldwide market share of >90 %, diesel ICE is the current reference drivetrain technology in public transport buses. By now a range of different fuels incl. fossil diesel, 1st & 2nd gen. biofuels (blends & pure), gas-to-liquid, natural gas, hydrogen (from various sources) and a equal number of propulsions systems incl. diesel combustion (with various exhaust gas treatment systems) combined with parallel & serial hybrid drive trains, natural gas and fuel cell technology have been analysed using the developed model (Faltenbacher, 2010). The scope of this publication is given below.

Table 1. Considered fuels and drivetrain technologies

Propulsion	Diesel	Diesel-Hybrid	Fuel Cell-Hybrid	Battery
Type of fuel	Diesel conventional (B7)		Hydrogen from electrolysis of wind power	Wind power
	(Bio)Diesel B30			
Exhaust gas treatment	Depending on Euro-class: DeNOx (from Euro IV; AGR/SCR) Particle filter (optional until Euro V)		N/A	N/A
Energy storage	N/A	26 kWh Li-Ion battery	26 kWh Li-Ion battery	200 kWh Li-Ion 2-3x recharg. during daytime + recharg. during nighttime

RESULTS

Analysis of fuel/drivetrain combinations
The model allows the comparison of individual fuel/drivetrain combinations on specific routes, i.e. for the bus operation the topography and speed profile of a given route is considered incl. the route specific fuel consumption and emission values (Hausberger, 2009). Figure 2 gives an example for the break even analysis of 18m conv. Diesel and a Dieselhybrid bus with a parallel hybrid drivetrain, both Euro V, on Stuttgart's Line 44 (Rau, 2011).

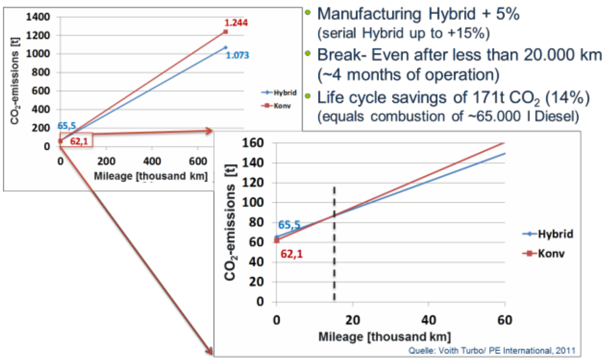


Figure 2. Break-even analysis 18 m Diesel vs. Diesel-Hybrid (parallel) bus

While the vehicle manufacturing of the Hybridbus is associated with ~5% higher CO_2 emissions compared to the conventional Diesel bus the 15% reduction of fuel consumption for the hybrid bus leads to a break even already after 4 months of operation and to a total life cycle saving of 14% or 171 t of CO_2 emissions.

Complete fleet analysis
Based on the analysis of individual fuel & drivetrain combinations the environmental as well as the cost profile of the bus operator's fleet can be compiled. Baseline is the fleet composition for a given year. In the case of SSB this is the fleet composition as of Dec. 31

2012 featuring 89 12 m & 177 18m buses. Starting from this baseline fleet composition ‘what-if scenarios’ for the future structure of the bus fleet can be developed. Usually any new drivetrain technology is gradually introduced i.e. it is important to consider the operator specific vehicle renewal cycles for the development of the scenarios. For this publication three scenarios considered by SSB are investigated. The 1st scenario is the business-as-usual scenario, i.e. any decommissioned bus will be replaced by a new conventional Diesel bus which, as of beginning of 2014, has to comply with the Euro VI emission standard. Scenario 2 assumes that from 2017 onwards all decommissioned Diesel 18 m buses are replaced by Euro VI Diesel hybrid 18m buses and that all 12 m Diesel buses are replaced with Fuel Cell hybrid 12 m buses. Scenario 3 follows scenario 2 for the 18 m buses (replacement with 18 m Euro VI Dieselhybrid buses from 2017). The 12 m buses are replaced by 50% Euro VI Dieselhybrid and 50% Battery buses. Fig. 3 depicts the development of SSB’s bus fleet from 2013 to 2025 for scenarios 1 & 3. SCR & CRT stand for DeNO$_x$ and particle exhaust gas cleaning systems.

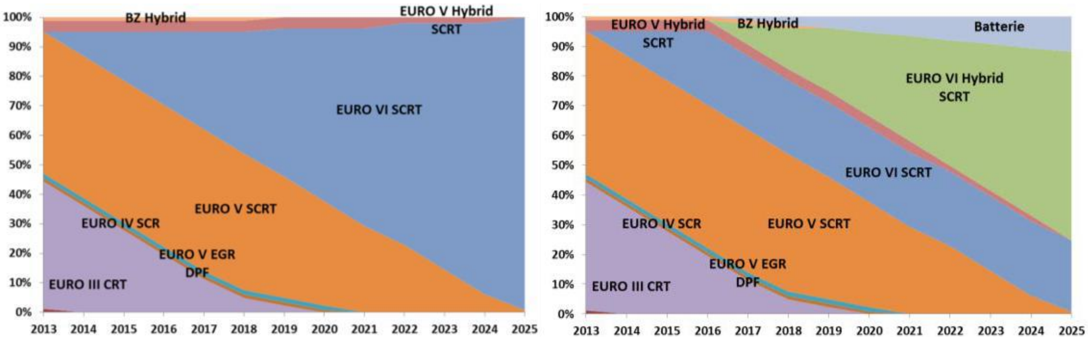


Figure 3. SSB’s bus fleet composition Scenario 1 (BAU) and 3 (Diesel Hybrid/ Battery)

Considered results from the environmental (LCA) part of the model include CO_2, NOx, PM_{10}, HC, CO as well as the impact categories Primary energy demand, Global warming potential (GWP100), “Summer smog“ potential (POCP) and human toxicity potential. The economic (LCC) part of the model considers the following cost categories: investment cost for buses and filling station, maintenance, fuels and operating materials (e.g. Ad Blue, oils etc.) costs as well as external costs for the above mentioned emissions to air. Bus driver costs are not included. Figure 4 gives the expected as an example the yearly GWP emissions of the SSB fleet for the three scenarios and the cumulated LCC costs from 2013 to 2025.

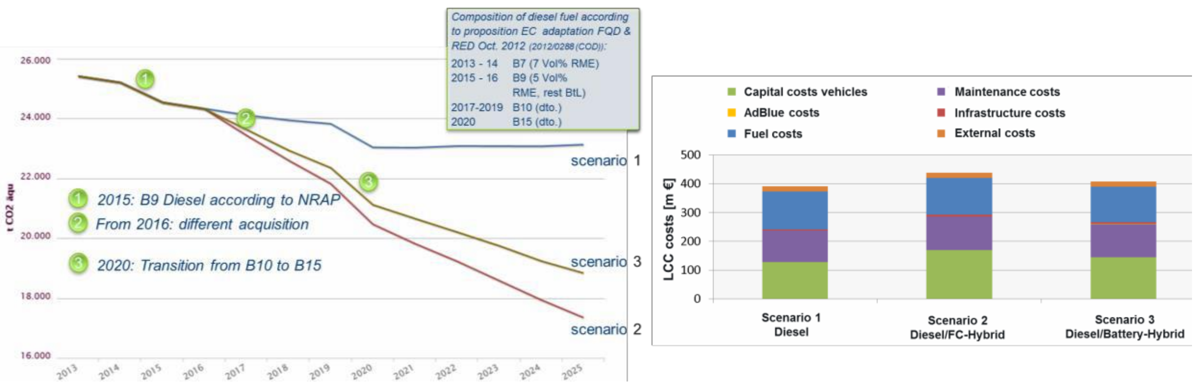


Figure 4. Yearly GWP emissions and aggregated life cycle costs for the 3 scenarios

GWP emissions of the SSB bus fleet are dependent on different factors. One factor changing over time is the share of the biodiesel according to European/national regulations European Parliament (2012). E.g. for Germany an increase from today 7% to 9% Biodiesel in 2015 and to 15% in 2020 is planned leading to GWP reductions accordingly Fed. Republic of Germany (2010).

From 2017 on the different drive train technologies are gradually (8% of all vehicle p.a.) introduced in each scenario leading to the depicted differences in GWP. While Scenario 1 features a 9% reduction in 2025 vs. 2013, scenario 2 leads over time to a 32% reduction in yearly GWP. In 2025 Scenario 2 leads to 5.800t lower emissions compared to the Business-as-usual scenario. If a Diesel with a share of 30 % biodiesel (B30) is used the analysis showed that roughly additional 10 % GWP can be saved in all three scenarios. However it needs to be noted that most bus manufacturers currently do not allow a Biodiesel share beyond 7% (B7).

Looking at the LCC of the scenarios it becomes clear that improved environm. performance of a bus fleet comes with a price tag, both scenarios 2 and 3 feature higher costs. Scenario 2 has 12% higher cost, i.e. a markup of ~47 Mio € over 13 years. This results in CO_2 abatement costs of ~1,600 €/t CO_2e. The distribution between the cost categories is relatively homogeneous. The external cost account for ~ 5% of the total LCC, i.e. are not a big enough factor to offset by themselves the increased costs for altern. fuels & drivetrain technologies.

CONCLUSIONS

The developed analysis model based on LCA and LCC allows a transparent evaluation with regard to GWP and other environm. impact categories (e.g. smog, human toxicity), energy efficiency and resource consumption as well as costs including emission abatement costs. It enables the quantification of the current and potential environmental as well as cost profile of the entire fleet including upstream processes and external effects. This holistic life cycle based approach allows the identification of potential tradeoffs between environmental impact categories and/or costs as well as life cycle phases (e.g. bus operation vs. fuel supply). The results from the model serve as a comprehensive, updateable quantitative information basis for questions regarding the environm. performance & relevance of bus based public transport (e.g. clean air action plans). Last but not least its results are well suited for communication with stakeholders (e.g. employees, customers, local administration and politics).

In summary the developed model proves to be an effective tool to support the strategic decision making of a bus operator to enhance the competitiveness and attractiveness of the public transport service offered.

REFERENCES

European Parliament (2012). Proposal for a directive of the European parliament and of the council amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources. COM(2012) 595 final, Brussels, 17.10.2012.

Faltenbacher, M. (2006). Modell zur ökologisch-technischen Lebenszyklusanalyse von Nahverkehrsbussystemen. Dissertation, University of Stuttgart, 2006.

Faltenbacher, M. (2010). Propulsion Scenarios for strategically and environmentally optimized bus fleet development (diesel, EEV, CNG, BTL, hybrid, electric). UITP, 6th Intern. Bus Conference, Lyon, June 2010.

Federal Republic of Germany (2010). National Renewable Energy Action Plan in accordance with Directive 2009/28/EC on the promotion of the use of energy from renewable sources. BMU, Berlin,2010.

Hausberger, S. et al (2009). Emission Factors from the Model PHEM for the HBEFA Version 3. Report Nr. I-20/2009 Haus-Em 33/08/679, Universtiy of Graz, 07.12.2009.

Rau, W. (2011). DIWAhybrid – Entwicklung eines Parallelhybrid-Antriebssystems für Stadtbusse. BMVBS, Final Conference "Elektromobilität in Modellregionen", Berlin, November 2011.

Wiedemann, M.; Faltenbacher, M. (2007). Quo vadis Omnibus?. Der Nahverkehr 7-8/2007. Alba Verlag, 2007.

PROMOTING SUSTAINABLE MOBILITY THROUGH THE ECODESIGN OF MULTIFUNCTIONAL URBAN INFRASTRUCTURES IN THE CONTEXT OF SMART CITIES

Mendoza JM[1,], Sanyé-Mengual E[1], Angrill S[1], Gonzalez-Garcia S[2], Garcia-Lozano R[3], Feijoo G[4], Moreira MT[4], Josa A[5], Gabarrell X[1,3,6], Rieradevall J[1,3,6]*

[1] *Sostenipra (UAB-IRTA-Inèdit), Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona (UAB), 08193 Bellaterra (Cerdanyola del Vallès), Barcelona, Spain. *Corresponding author: joanmanuel.fernandez@uab.cat*

[2] *CESAM, Department of Environment and Planning – University of Aveiro, 3810-193 Aveiro, Portugal*

[3] *Inèdit Innovació, S.L,. Parc de Recerca de la UAB, 08193 Bellaterra (Cerdanyola del Vallès), Barcelona, Spain*

[4] *Department of Chemical Engineering, University of Santiago de Compostela (USC), 15782 Santiago de Compostela, Spain*

[5] *Department of Geotechnical Engineering and Geosciences, Technical University of Catalonia-Barcelona Tech (UPC), Campus Nord, Building D2, 08034 Barcelona, Spain*

[6] *Department of Chemical Engineering,Universitat Autònoma de Barcelona (UAB), 08193 Bellaterra (Cerdanyola del Vallès), Barcelona, Spain*

Keywords: Pedestrian mobility; Electric mobility; Pergola; Bikes; Green electricity.

ABSTRACT

Sustainable mobility is a focus of major concern for promoting environmental friendly cities. Life cycle thinking arises as an interesting alternative in the design of mobility infrastructures to effectively mitigating overall environmental impacts from transport. This paper analyzes the CO_2 savings of an eco-designed solar pergola (SP) that supports pedestrian and electric bike mobility during 10 years. Results indicate that SP can save 20,135 kg of CO_2 eq. due to its optimized design, energy self-sufficiency, and generation of surplus electricity. Surplus electricity can be used for charging e-bikes, which contributes to an extra saving of 112 kg of CO_2 eq. The design of smart mobility infrastructures plays a key role in promoting sustainable mobility at a minimum environmental cost.

INTRODUCTION

Cities are confronted with a common core set of environmental problems associated with urban mobility. In Europe, half of all road transport fuel is combusted in cities where urban traffic accounts for 40 % of greenhouse gas emissions and more than 70% of local noxious emissions (European Commission, 2007). City planning is being performed in a way that aims to rethink urban mobility towards the optimization of the use of public transportation and the consolidation of walking and cycling activities. However, greening the urban motorized vehicle fleet is a key strategic issue towards the achievement of the European 20-20-20 Climate and Energy targets (European Commission, 2010). The use of electric vehicles (EVs) is foreseen as one of the most promising technology pathways for restricting fuel consumption and CO_2 emissions on a per-kilometer basis (IEA, 2012). Within the last years, an extensive network of urban infrastructures has been implemented in cities to facilitate the shift towards sustainable mobility. However, recent literature (Mendoza et al., 2012; Oliver-Solà et al., 2011) has highlighted the relevance of incorporating life cycle environmental criteria in the planning, design and management of supporting infrastructures for sustainable mobility to reduce to effectively mitigate overall environmental impacts from urban transportation which results into an important issue in the development of smart cities. This paper addresses the environmental assessment of a multifunctional eco-designed solar pergola (SP) for promoting pedestrian and electric mobility at a minimum environmental cost.

MATERIALS AND METHODS

By applying the methodological framework presented in Gonzalez-García et al. (2011), based on the application of Design for the Environment principles, a conventional pergola (CP) that provides diurnal shadow and nocturnal light for pedestrian mobility has been environmentally characterized. Results were used as reference to rethink the CP towards an environmentally optimal design. The specifications of the product systems and case scenarios analyzed are defined in Figure 1.

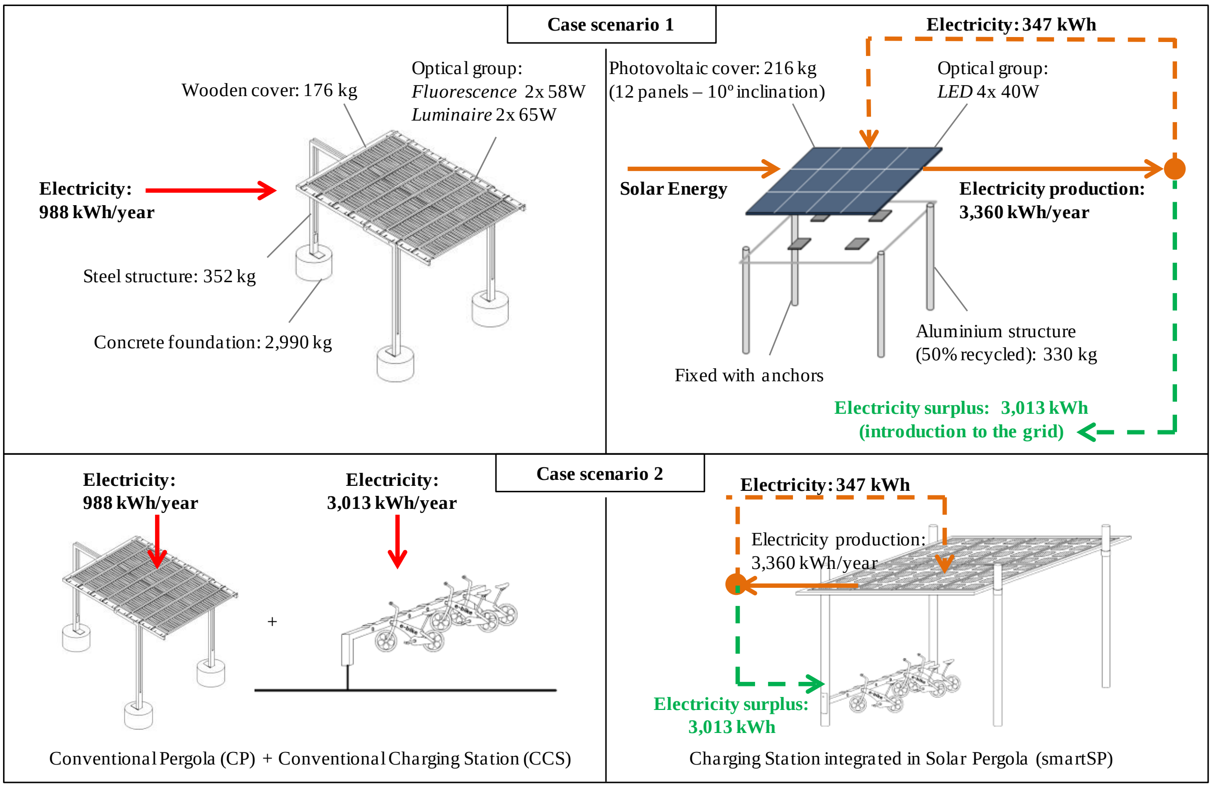


Figure 1. Basic features of the product systems compared under different case scenarios

The functional unit (FU) used was defined as the prospect of supplying shadow (45,000 h) and nocturnal light (42,600 h) over a surface of 20 m^2 for pedestrian mobility during a timeframe of 10 years in the geographical context of the city of Barcelona (Spain). The SP was eco-designed based on two strategies: optimization of the use of materials and implementation of photovoltaic panels on the cover. The photovoltaic production is 3,360 kWh per year. It has been determined by the application of PV Estimation Utility considering 10% of inclination. With only 11.5% of the photovoltaic production, the annual energy demand of the SP is satisfied and, therefore, an important electricity surplus is available. Two different case scenarios were assessed to determine the environmental benefits associated with the use of the surplus electricity generated by the SP: introduction of the surplus electricity into the grid, and use of the surplus electricity for charging electric bikes (e-bikes). In the first case, the environmental gains related to the substitution of conventional electricity from the grid is accounted and allocated to the SP. In the second case, the FU was expanded to analyze the substitution of a functionally equivalent slow-charging station implemented at the public space of the city of Barcelona for charging e-bikes.. The CML-GWP indicator expressed in terms of kg of CO_2-eq. emissions is calculated.

RESULTS AND DISCUSSION

Figure 2 shows the life cycle GWP of each of the product systems analyzed. In scenario 1, the implementation of the CP at the urban public space accounts for a total contribution to GWP higher than 8,700 kg CO_2 eq. after 10 years of operation, while the implementation of the SP will have no contribution to GWP. The SP infrastructure has 74% higher environmental burden than the CP infrastructure, which mainly comes from the photovoltaic panels and the aluminium structure. However, after the first year of operation the GWP of the SP will be lower than the related to the CP. After the third year of operation, the GWP balance of the SP will become “zero” due to the carbon credit related to the introduction of the surplus electricity into the grid. During the following seven years of operation, the SP will generate net environmental benefits. For every photovoltaic kWh introduced into the grid the emission of 0.59 kg of CO_2 eq. related to the production of a conventional kWh will be avoided, which finally provides a total saving of over 11,400 kg CO_2 eq. during the time period analyzed. The overall contribution to GWP by the SP is 231% lower than the CP. In scenario 2, a major GWP saving can be achieved by promoting the implementation of a smartSP design instead of the set CP+CCP. The integration of a charging station for e-bikes in the SP contributes to save an extra amount of 112 kg of CO_2 eq. due to the substitution of the functionally equivalent charging infrastructure. The materials requirements to implement a charging station in the SP are assumed to be around 3 times lower than the required for implementing a charging infrastructure at the public space. It makes almost negligible the increase on the life cycle GWP of the smartSP infrastructure. The GWP of the use phase of the smartSP is “zero” due to all the solar electricity produced is used for providing nocturnal lighting and e-bikes charging. The total GWP savings correspond to the substitution of the CP+CCP product system. Nowadays, e-bikes have batteries of 0.20 kWh to 0.35 kWh of capacity that can be fully recharged after 4 h. By assuming a daily electricity surplus of 8.3 kWh, from 5 to 10 e-bikes could be completed recharged under ideal conditions.

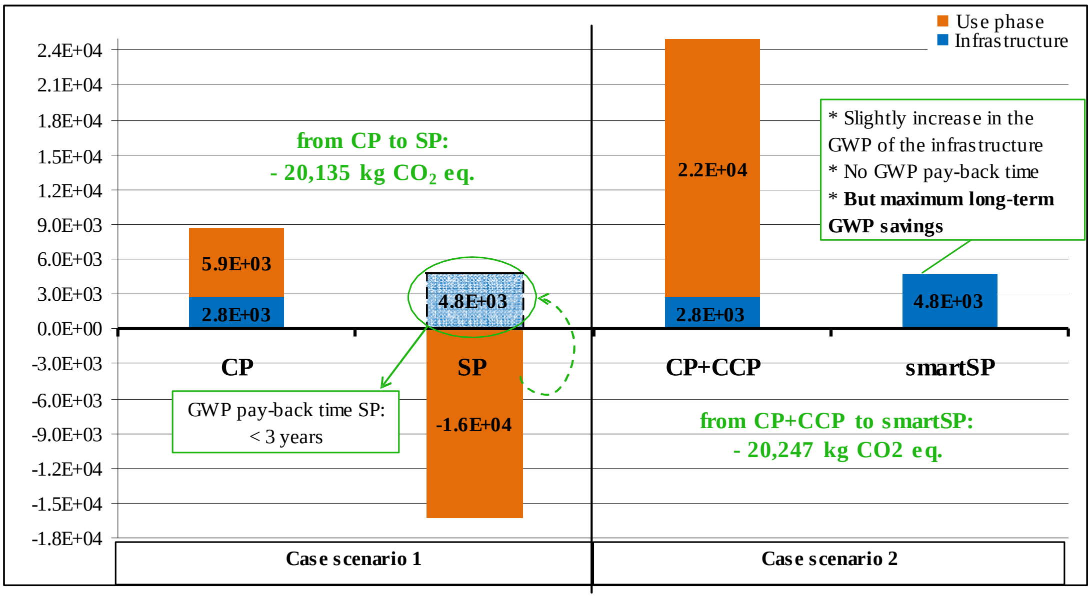


Figure 2. Life cycle GWP of the product systems analyzed

CONCLUSIONS

The promotion of eco-designed urban infrastructures has been demonstrated to play a key role in the development of sustainable mobility at a minimum environmental cost in cities. Smart pergolas can represent an active contribution to sustainability since they support pedestrian mobility and promote the use of "zero emission" e-bikes that represent an attractive alternative mode of transportation from kids to elderly people. The use of e-bikes can be also an attractive mode of transportation demanded by tourists. Smart pergolas represent therefore multi-modal urban elements that can provide different functions depending on the end-user of the green surplus electricity.

REFERENCES

European Commission (2007). Green Paper: Towards a new culture for urban mobility. *Communication from the Commission of the European Communities, COM(2007) 551 final.*

European Commission (2010). Europe 2020: A strategy for smart, sustainable and inclusive growth. *Communication from the Commission, COM(2010) 2020.*

González-García, S., Silva, F. J., Moreira, M.T., Castilla, R., García-Lozano, R., Gabarrell, X., Rieradevall, J., & Feijoo, G. (2011). Combined application of LCA and eco-design for the sustainable production of wood boxes for wine bottles storage. *International Journal of Life Cycle Assessessment, 16, 224–237.*

IEA (2012). EV city casebook: a look at the global electric vehicle movement. *International Energy Agency, Paris.*

Mendoza, J.M., Oliver-Solà, J., Gabarrell, X., Rieradevall, J., & Josa, A. (2012). Planning strategies for promoting environmentally suitable pedestrian pavements in cities. *Transportation Research, 17, 442-450.*

Oliver-Solà, J., Josa, A., Arena, A.P., Gabarrell, X., & Rieradevall, J. (2011). The GWP-Chart: An environmental tool for guiding urban planning processes. *Application to concrete sidewalks. Cities, 28, 245–250.*

TOOLS FOR ENVIRONMENTAL PLANNING IN INFRASTRUCTURE CONSTRUCTION

Håvard Bergsdal, MiSA AS, Johan Berg Pettersen, MiSA AS*

Address: Innherredsveien 7B, 7014 Trondheim, Norway

**E-mail: havard@misa.no*

Keywords: transport infrastructure, planning tools, LCA, planning phases

ABSTRACT

LCA-based studies for transport infrastructure are gaining momentum, and this paper presents a brief overview of recent and ongoing work in Norway and Sweden with regard to status of framework, guidelines and tools. Both countries are still in an early phase of implementing this work into decision making processes, but the approaches in both countries are similar and recommend generic data for early screening of concepts and alternatives, while the more detailed planning stages call for common guidelines rather than common data.

INTRODUCTION

Studies of environmental impacts from transport have traditionally focused mainly on the direct emissions from the combustion processes. In recent years, national transport authorities have given increased attention to environmental effects of the transport infrastructure itself, and the way it is being constructed, operated, maintained, and also planned.

This short paper will present some of the current and recent work on LCA-based evaluation of rail and road infrastructure in Norway and Sweden, and how different tools and databases are applied to inform decision makers at different stages of the planning and building process. The main focus will be on the Norwegian case and on rail infrastructure.

LCA FOR INFRASTRUCTURE ASSESSMENT

A central element in the recent studies of infrastructure related emissions is the use of life cycle assessment (LCA) methodology. Examples include the Swedish Bothnia line (Stripple and Uppenberg 2010), the first Norwegian LCA-based environmental budget for a planned railway infrastructure (Korsmo and Bergsdal 2010), the Norwegian national high-speed railway assessment (Svånå (Ed.) 2011; Bergsdal, Pettersen et al. 2012), and a methodological framework for assessment of climate emissions and energy use in road infrastructure projects (Hammervold 2009). These studies have brought new knowledge to transport planners and decision makers by highlighting the role of infrastructure and identifying potential trade-offs.

Infrastructure is important for railways in particular since they are more complex and material intensive, and in particular in Norway with its challenging topography. The Norwegian high speed rail assessment found that infrastructure accounted for two thirds of total emissions for a 60 year operation period (Bergsdal, Pettersen et al. 2012). The figure could be even higher with a less conservative assumption for the electricity production.

Recent studies in Norway were initiated following the government's work with the National Transport Plan (NTP) which calls for development of tools and framework for estimating climate emissions from infrastructure projects in a life cycle perspective, and for development of environmental budgets. Norwegian transport administrations have since established joint guidelines for such assessments, and will continue this work in the coming years (Kjerkol H et al 2010). The Norwegian Public Roads Administration (NPRA) has implemented their own tool (Hammervold 2009), and the Norwegian National Rail Administration (NNRA) has developed detailed guidelines for implementation and organization of environmental assessments for each individual planning phase from early concept evaluation to documentation of final solution after construction (Jernbaneverket 2012).

The Swedish Transport Administration (Trafikverket) has initiated work on establishing routines and guidelines for life cycle assessment of transport infrastructure, and how this can be integrated into planning and construction of infrastructure (Öman, Andersson et al. 2012).

LCA AS DECISION SUPPORT IN INFRASTRUCTURE PLANNING

Figure 1 shows the conceptual planning process for rail projects in Norway. In the early assessment stage, strategic decisions are taken regarding concept choices, alignment options and composition, design speed etc. Decisions at this stage rely on more generic and less specific data than later planning stages in order to provide some key information for decision makers. Later planning stages include more technical planning and is done in several stages with increasing level of data quality and detail. Decision support tools for this stage should be able to assess different technological solutions to optimize the performance of the chosen concept and alignment. In the construction stage, tools need to assist in the choice of materials and suppliers, and provide a basis for specific requirements during the construction.

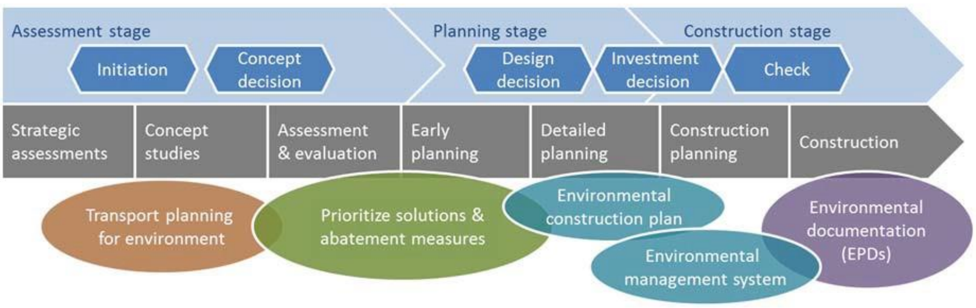


Figure 1. Overview of planning stages and environmental decision milestones and decision support for railway projects in Norway.

Figure 2 give an overview of the tools and structure that have been used in Norway and a proposed structure for the same in Sweden. The Norwegian work was initiated by governmental requirements, but the means and tools were not specified. The transport administrations have therefore started a process to establish joint guidelines, and tool developments have been the result of initiatives and work in single projects that have become pilot projects more by chance than by strategic choice. For rail infrastructure, the new Follo line currently in planning has become the pilot for the NNRA's environmental work, following the LCA-based environmental budget developed for the concept assessment stage of the project (Korsmo and Bergsdal 2010). Relevant tools and guidelines in Norway include:

- National Transport Plan - General guidelines and framework for climate emissions.
- High speed rail climate assessment and interactive calculator – Assessment report and interactive tool for high speed rail concepts in Norway and transition effects.
- SimaPro database – Generic database information based on Norwegian projects.
- SimaPro Follo pilot – Model, structure and organization of data for rail projects. Guidance document for LCA of rail infrastructure has been developed based on this.
- Environmental budget calculator – Interactive tool for result presentation, dissemination, simplified analysis of alternatives/assumptions, and benchmarking.

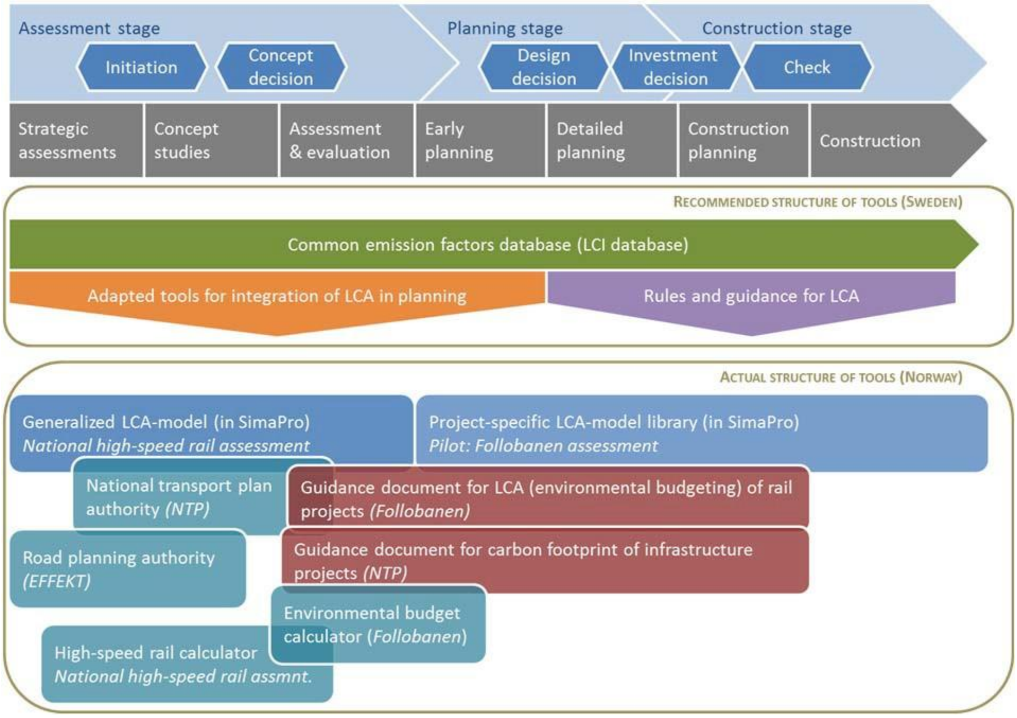


Figure 2. Overview of recommended tool structure (in Sweden) and actual observed structure in Norway of LCA-based environmental tools in planning for railway projects.

The tools developed so far are mainly related to the early assessment stages to evaluate alternative alignments and support concept choices, but are also being adapted to other and more specific questions about of technology, materials, suppliers etc. Further development is expected. A general feature for all the tools is that they rely on a database structure and information compiled and documented in the SimaPro software for LCA, thereby enhancing the flexibility for adapting tools to new planning stages and to compile, structure and transfer knowledge between projects and planning stages.

Comparing with the recommendations for Sweden, we see that the approaches are similar. The Swedish recommendations call for a common emission factors database as a basis for adapted tools for integrated planning in the earlier stages of the assessment and planning process (Öman, Andersson et al. 2012). This corresponds with the NTP guidance documents, the Norwegian NPRA's EFFEKT model for climate assessment, and the NNRA's work with building a database based on completed LCA-projects. Both approaches use generic empirical data for early screening and evaluation. Information from new projects is supposed to be integrated in a common database which is continuously improved and updated. Generic data should describe material use and associated emissions intensities.

In the technical planning stages and final construction, the two approaches are also similar. The Swedish recommendations call for a common framework with rules and guidance, whereas the tool for assessment is free of choice. This is similar to the Norwegian approach where framework and guidance documents are developed and in use. Even if the applied tool has been the same so far, this is not a requirement in the guidelines.

Figure 2 shows no tools for completed projects and environmental accounts for Norway. The reason is simply that no project has yet been completed. The focus has so far been on the assessment and early planning stages, and these projects are not finished. However, guidelines are preparing for this and we can expect to see environmental accounts in the next years for some completed projects. The Swedish Bothnia Line was followed from environmental budget in the assessment and planning stage to an environmental account after completion, even extending to environmental product declarations (Stripple and Uppenberg 2010).

CONCLUSIONS

National transport administrations in both Norway and Sweden have both initiated processes for establishing common and standardized sets of guidelines and framework for reporting and tools. Current developments are based largely on pilot projects and experiences from these are being implemented in the guidelines, and data is compiled and available for future projects and developments. The primary goal for the work is to support decision-making at various stages of the planning process. A challenge for the near future is to avoid the results becoming merely a documentation of a chosen solution, and rather integrate into the decision process at an early stage in order to provide relevant information before concepts and technical solutions are chosen. Both countries are currently working towards this end.

REFERENCES

Bergsdal, H., J. Pettersen, et al. (2012). Environmental analysis - Climate. Norwegian High Speed Railway Project Phase 3, MiSA AS, for Jernbaneverket, Trondheim, Norway.

Hammervold, J. (2009). Metode for beregning av energibruk og klimagassutslipp for vegprosjekter. Oslo, Norge, Statens Vegvesen.

Jernbaneverket (2012). Veileder for utarbeidelse av miljøbudsjett for jernbaneinfrastruktur.

Kjerkol H et al (2010). Felles metode for klimagassbudsjett. Oslo, Norge, Sekretariatet for Nasjonal transportplan.

Korsmo, A.-R. and H. Bergsdal (2010). Miljøbudsjett for Follobanen - Infrastruktur, AsplanViak, ViaNova, MiSA, for Jernbaneverket, Oslo, Norway.

Stripple, H. and S. Uppenberg (2010). Life-cycle assessment of railways and rail transport. Appplication in environmental product declarations (EPDs) for the Bothnia Line. Göteborg, Sweden, IVL, Swedish Environmental Research Institute Ltd.

Svånå (Ed.), R. B. (2011). A methodology for environmental assessment - Norwegian high speed railway project phase 2. Sandvika, Norway, Asplan Viak, MiSA, VWI, Brekke & Strand.

Transportetatene and Avinor (2012). Forslag til Nasjonal Transportplan 2014-2023.

Öman, A., M. Andersson, et al. (2012). Förstudie livscykelanalys i planering och projektering, WSP for Trafikverket.

MANAGEMENT OF NATURAL RESOURCES - ABIOTIC

Tuesday, Aug 27:	3:30 pm - 5:00 pm
Session chairs:	Nydia Suppen, Center for LCA and Sustainable Design, Mexico Anders Hammer Strømman, Norwegian University of Science, Norway

CORE ELEMENTS FOR THE REGIONALISED ASSESSMENT OF ABIOTIC RESOURCE USE - THEORY AND FEASIBILITY FROM A LIFE CYCLE PERSPECTIVE

Stefanie Markwardt, Christoph Lauwigi, Anna Hennecke, Maria Müller-Lindenlauf*

**IFEU-Institute for Energy and Environmental Research*

Wilckensstraße 3, D-69120 Heidelberg, Germany

stefanie.markwardt@ifeu.de

Keywords: abiotic resource depletion; water use; Life cycle assessment; regionalisation

ABSTRACT

Growing demand for reliable information on sustainable abiotic resource use is promoting efforts to develop robust impact assessment methods for LCA purposes. This study assessed current methods to evaluate the reliability of their safeguard objectives and requirements for inventories for impact approaches of water and metals. Water use approaches consistently included freshwater scarcity, whereas the depletion potential of metals focused on varying aspects of their availability. Current inventories of freshwater use allow an appropriate assessment, although information on water released is still lacking. In contrast, due to inconsistent safeguard subjects, crucial aspects of metal inventories cannot be analysed sufficiently. Meaningful safeguard subjects and regionalised inventories are prerequisites for reliable assessment of abiotic depletion as a profound basis for decision makers.

INTRODUCTION

According to Europe´s thematic strategy on the sustainable use of natural resources, "European economies depend on natural resources, including raw materials such as minerals, (...); environmental media such as air, water and soil" (EC 2005). Growing awareness of the impacts of intensive resource use has led to discussions about the efficient use and management of natural resources. Therefore, efforts to develop comprehensive impact assessment methods for abiotic resource use are increasing in the life cycle community. The aim is to provide reliable information for decision makers in politics and industry and meet the demands of the debate regarding sustainable production and consumption.

Life cycle assessment (LCA) is widely used as a reliable tool to provide decision support in sustainable resource consumption such as water use. LCA practitioners rely on comprehensive inventory data sets and applicable methods in order to target relevant safeguard objectives. Water footprint methods focusing on spatial factors and use patterns at the specific location have recently been reviewed in terms of their applicability and methodological challenges (e.g. Kounina et al. 2013). The safeguard objectives and the required level of differentiation at the inventory level for these methods differ significantly. Furthermore, other finite abiotic resources such as metals are being assessed with a number of approaches, yet there is no common consensus on the comparability of results.

In the present study, we analysed and compared selected resource use assessment methods regarding the reliability of their safeguard objectives and the level of regionalisation required for corresponding inventory data for the resources (A) water and (B) metals such as copper and lead. Furthermore, we examined the linkage between inventory data and safeguard subject, thus identifying core elements that allow a comprehensive and uniform assessment of abiotic resource use.

MATERIALS AND METHODS

Eco-profile of Ingeo® polylactide (PLA)

The current Ingeo® polylactide (PLA) production published by Vink et al. (2010) was chosen to evaluate the safeguard objectives of current water use assessment methods. In addition, we analysed the compliance of the PLA eco-profile according to the required level of regionalisation (A). The eco-profile comprises an agricultural part (corn production) and industrial processes from “cradle-to-factory gate”, hence covering all relevant stages of water use during the entire production cycle. Furthermore, we examined three assessment approaches of mineral resource depletion (B) to extract core elements that are crucial for a comprehensive assessment of abiotic natural resources.

A) Comparison of water use assessment methods

The water use assessment method of Ridoutt & Pfister (2013) aims to prevent regional water scarcity. Consumptive water use (CWU) and degradative water use (DWU) are captured in a single-score, stand-alone water footprint. Calculation of the CWU requires the Water Stress Index (WSI) at the specific geographic location and the quantity of water consumed.The DWU assessment requires information regarding emissions into water covered by the ReCiPe (2008) assessment framework, such as toxic chemicals and P- and N-compounds. The approach of Mila i Canals et al. (2009) targets the prevention of regional water scarcity as well, while also considering Ecosystem Water Requirements (EWR). Their method requires the same information as for the calculation of the CWU. In addition, it can assign different impact pathways to each water source, if the type of water source is included in the inventories. The water flow inventory of Boulay et al. (2011) seeks to prevent water scarcity caused by pollution. To allocate the water use to the specific categories developed in this approach, the quantity and quality of water extracted and released as well as water quality requirements of downstream water users are required.

B) Comparison of metal use assessment methods

The assessment methods van Oers et al. (2002), Schneider et al. (2011), and ReCiPe (2008) were applied to extraction of 1 kg copper and 1 kg lead to examine the different safeguard objectives and levels of regionalisation. Van Oers et al.’s (2002) model of “abiotic depletion potential” (ADP) assesses the global geological scarcity of abiotic resources. The model uses annual extraction rates and finite reserve data taken from the United States Geological Survey (USGS). The inventory requirement is the amount of metal used. Schneider et al. (2011) extend this concept by considering the anthropogenic stock to address the economic availability of metals. Their model thus provides an “anthropogenic stock extended abiotic depletion potential” (AADP). The inventory requirement is the amount of metal used. In contrast, ReCiPe (2008) assesses the growing effort required for future extraction on account of ongoing resource extraction activities and based on data from the USGS deposits database. This more regionalised approach accounts for the spatially specific extraction conditions of a given resource. The inventory requirement is the amount of metal used.

RESULTS AND DISCUSSION

A) Water

With the information provided in the eco-profile of biobased PLA produced in the factory in Blair, Nebraska, USA, the WSI was determined to vary between 0.0385 and 0.9996, depending on the level of intensity of corn cultivation. One possible caveat of our analysis is the assumption that the individual WSI values would need to be weighted by the amount of corn cultivated prior to the calculation, since the eco-profile provided coarse-scale information only. However, it is not clearly stated whether the given values mean the actual amount of water consumed according to the definition, or if it was simply the amount of water extracted. Regarding the type of water source used, a differentiation is made between river, sea and groundwater in the eco-profile. However, the main part of the water is taken from public supply, and therefore the respective combinations of water sources needs to be taken from public databases. This requirement concerns neither LCI nor LCA practitioners but public institutions. According to the type of land conversion, no information on the land use prior to corn cultivation provided. The emissions to determine the DWU are listed in the eco-profile in sufficient detail. However, since the amount of water released is not included, a categoriation into quality classes according to Boulay et al. (2011) is not possible.

The three methods to assess water use that we analysed all focussed on regional water scarcity. Ridoutt & Pfister (2013) assess freshwater use and pollution related to the amount of water consumed by the depletion. Yet, the authors recommend further research pertaining the DWU calculation. Mila i Canals et al. (2009) also target freshwater consumption as well as the water demand of the surrounding ecosystem, but recognise the same lack of research concerning the EWR calculation. Boulay et al. (2011) evaluate the freshwater use and freshwater pollution as well as the water requirements of downstream users.

B) Metals

For metal use, all inventory data were accessible, and no requirements were given here.

Van Oers et al. (2002) assessed the geological availability of metals and discussed the use of different reserve range data related with the selected safeguard objective. They emphasised the need for further research to define the problem of abiotic resource depletion in LCA. Schneider et al. (2011) addressed the economic availability of metals and thus contribute to the discussion of abiotic resource depletion. ReCiPe (2008) took a different path to assess the depletion of metals by focusing on the intergenerational sustainability of future costs of metals extraction. The three methods differed substantially in their definition of the safeguard subject, and hence, yield different results.

CONCLUSIONS

Depending on the type of abiotic resource that is addressed, the safeguard subject varies between the assessment methods available. The evaluated methods regarding water use show a consistent development towards the impact assessment of freshwater scarcity as a safeguard subject and therefore enable the calculation of a reliable, concurrent result on a regionalised level. Current inventories provided by the industry already include the majority of data required by the assessment developers and are provided at an appropriate level of regionalisation. Thus, a reliable scarcity impact assessment of fresh water use is already available. For the evaluation of water consumed by pollution, the total amount of water released would further improve the reliability of the impact assessment. The analysed metal use assessment methods focused on varying safeguard objectives, as each of them focused on different aspects of resource availability. As they all aim to measure the "depletion potential" of mineral resources, it is important for decision makers in politics and industry to have reliable and meaningful results from LCA studies, which do not differ significantly when different assessment methods are applied. Regarding inventories, issues of regionalisation cannot be investigated as long as the methodological framework is not clearly defined. In conclusion, the assessment of abiotic resource use requires the definition of a meaningful safeguard objective and corresponding regionalised inventories. These pre-requisite core elements allow an evaluation of the impact of resource depletion and provide reliable decision support in terms of sustainable production and consumption.

REFERENCES

Boulay, A.-M., C. Bouchard, C. Bulle, L. Deschenes, & M. Margni. (2011). Categorizing water for LCA inventory. International Journal of Life Cycle Assessment 16(7): 639–651. DOI 10.1007/s11367-011-0300-z.

Commission of the European Communities. (2005). Thematic Strategy on the sustainable use of natural resources. 21.12.2005. Brussels.
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2005:0670:FIN:EN:PDF.

Kounina, A.; Margani, M.; Bayart, J.-P.; Boulay, A.-M.; Berger, M. Bulle, C.; Frischknecht, R. Koehler, A.; Mila i Canals, L.; Motoshita, M.; Nunez, M.; Peters, G.; Pfister, S.; Ridoutt, B.; van Zelm, R.; Verones, F.; Humbert, S. (2013): Review of methods addressing freshwater use in life cycle inventory and impact assessment; International Journal of Life Cycle Assessment 18, 707-721; DOI: 10.1007/s11367-012-0519-3.

Mila i Canals, L., J. Chenoweth, A. Chapagain, S. Orr, A. Anton, and R. Clift. (2009). Assessing freshwater use in LCA: Part I — Inventory modelling and characterisation factors for the main impact pathways. International Journal of Life Cycle Assessment 14: 28–42. DOI: 10.1007/s11367-008-0030-z.

ReCiPe (2008). A life cycle impact assessment method which comprises harmonized category indicators at the midpoint and the endpoint level, first edition revised July 2012, Den Haag, Goedkoop, M.; Heijungs, R.; Huijbregts, M.; De Schryver, A.; Struijs, J.; van Zelm, R.

Ridoutt, B.G, Pfister,S. (2013). A new water footprint calculation method integrating consumptive and degradative water use into a single stand-alone weighted indicator. Int J. Life Cycle Assess., Volume 18 Issue 1, pages 204-207. DOI: 10.1007/s11367-012-0458-z.

Schneider, L.; Berger, M.; Finkbeiner, M. (2011). The anthropogenic stock extended abiotic depletion potential (AADP) as a new parameterisation to model the depletion of abiotic resources; International Journal of Life Cycle Assessment 16: 929-936. DOI: 10.1007/s11367-011-0313-7.

Van Oers L., de Koning A., Guinee J.B. and Huppes G. (2002). Abiotic Resource Depletion in LCA. Road and Hydraulic Engineering Institute, Ministry of Transport and Water, Amsterdam.

Vink, E.T.H.; Davies, S.; Kolstad, J.J. (2010). The eco-profile for current Ingeo® polylactide production Industrial Biotechnology Vol.6 No.4: 212-224, DOI: 10.1089/ind.2010.6.212.

DEVELOPMENT GLOBAL DAMAGE FACTORS OF RESOURCE CONSUMPTION

Takeshi Matsuda[1], Ryota Ii[1] and Norihiro Itubo[2]*
[1]*Pacific consultants Co.,LTD.*
[2] *Tokyo City University*
**1-7-5, Sekido, Tama-shi, Tokyo, Japan. takeshi.matsuda@ss.pacific.co.jp*

Keywords: Mineral resource; Damage function; Impact assessment; Biodiversity; Fossil fuel

ABSTRACT

Resource consumption causes destruction of nature by mining and economic damage by resource depletion. To evaluate these damage, we need Life Cycle Impact Assessment (LCIA) indicators.

In this study, we developed grovel LCIA damage factor of resource - consumption. We evaluated damage of biodiversity, primary production and human economy. By using some static data, we made damage factor of resources extracted in each country. Then, by using international trade data, we made damage factors of resources consumed in each country. This method will contribute to LCIA of resource consumption around the world.

INTRODUCTION

Resource consumption causes destruction of nature by mining and economic damage by resource depletion. Also integration and comparison these damage with other environmental damage are highly concerned. To evaluate these damage, we need Life cycle Impact assessment (LCIA) indicator. Though some methods are proposed(Watando, 2012, Vieira, 2012), no method contains both environmental and economic damage. In Japan, previous study developed damage factors for Japanese resource consumption. This result was published as part of LIME2 (Itsubo and Inaba, 2010).

In this study, we expanded geographical boundary to the world and recalculated damage factors for many resources extracted in each country. We evaluate three impact category related to resource consumption, "Social assets", "Net Primary production (NPP)" and "Expected Increase in Number of Extinct Species (EINES)". Additonaly, by using international trade data, we made damage factors for resources consumed in each country. However, we introduced only damage factors of each extracting countries because of space limitation.

METHODS

Characterization factor of resource depression

The framework of evaluation was shown in Fig.1. We chose "inverse of reserve (1/R)" as characterization factor(midpoint) which directly refer to the resource depletion. We used the data of mine production and reserve of each mineral from “Mineral Commodity Summaries 2010 (MCS2010)”(USGS, 2011) and other statics (British Petroleum, 2011).

Additionally, we chose characterization factor for fossil fuel was “Lower Heating Value (LHV)”. This is the good factor when we focus on the problem of energy.

Characterization factor of natural destruction

We chose “the area of land transformation” as characterization factor of destruction of nature. We made mining model in Fig.2 and Eq. (1) and estimated the area of land transformation for mining and wasting. This is one of the inventory analysis for mineral consumption.

We set parameters of each resource from some statics such as USGS(2012). We reflect a difference in mining type(surface or underground mining), orebody thickness of each resource in each country. Additionally, some mineral such as rare earth are extracted from same ore. So we allocated the transformed area to each resource on the basis of ore grade.

$$
\begin{aligned}
A &= m_i \times \frac{1}{C_i} \times \frac{1}{G_i} \times \frac{1}{D_i} \\
&+ \left(m_i \times Oo_i \times \frac{1}{go} \times \frac{1}{Ho} + m_i \times Ot_i \times \frac{1}{gt} \times \frac{1}{Ht} \right) \\
&\cong \underbrace{m_i \times \frac{1}{C_i} \times \frac{1}{G_i} \times \frac{1}{D_i}}_{a} + \underbrace{m_i \times O_i \times \frac{1}{g} \times \frac{1}{H}}_{b} \qquad (1)
\end{aligned}
$$

A : Area of land transformation [m2]

mi: Weight of metal content of mineral i [t]

Ci: Ore grade of mineral i

Gi: Specific gravity of mineral i

Di: Orebody thickness of mineral i [m]

Ooi: Weight ratio between metal and overburden [t/tmetal]

Oti: Weight ratio between metal and tailing [t/tmetal]

Oi: Weight ratio between metal and overburden + tailing

=Hidden flow [t/tmetal]

g: Density of overburden and tailing [t/m3]

H: Height of overburden and tailing [m]

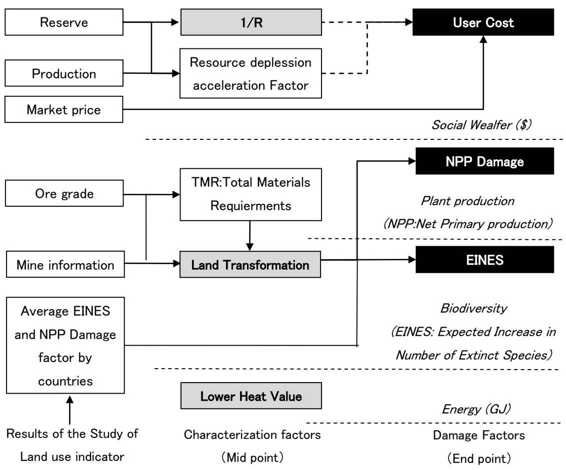


Fig.1 Framework of evaluation of resource consumption

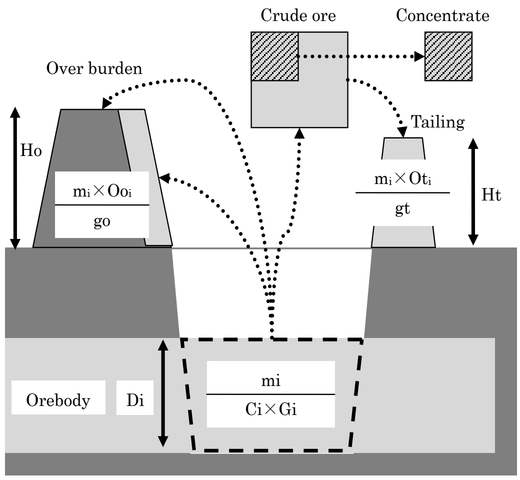


Fig.2 The model of the area of land transformation

Damage factor of social asset

We used “User cost” as the damage factor of social asset. User cost presented by El serafy(1989) was the investment to keep constant income after mining. It is equal to the cost to prepare the resource depletion. User cost was calculated by Eq. (2). The market value of each metal in *MCS 2010* and other statics was used.

Damage factor of primary production

The primary production means the plant growth from photosynthesis. We considered primary production because it is essential for ecosystem as if money in human society. In the resource consumption, the damage of “Net Primary Production (NPP)” was calculated by multiplying the area of land transformation by the average NPP loss of each country. A detailed discussion of the method to calculate average NPP loss will be published by our project soon.

Damage factor of biodiversity

We chose “Expected Increase in Number of Extinct Species (EINES)” as the indicator of biodiversity. In the resource consumption, the EINES was calculated by multiplying the area of land transformation by the average EINES of each country. As well as NPP loss, a detailed discussion of the method to calculate average NPP loss will be published by our project soon.

RESULTS

We calculated all characterization factors and damage factors.

In the impact of social asset, the damage factor of gold is the highest. User cost of consuming 1 metric ton gold is 23 million US-$. This is more than four times larger than that of platinum or palladium. On the other hand, User cost of consuming 1 metric ton iron was only 12 US-$. Lithium has the smallest economic damage because of its huge reserve.

The NPP loss per unit of resource consumption was shown in Fig.3. In this figure, a point means a damage factor of one country. At almost all resources, differences between extracting countries are less than 10 times. Countries with rich nature such as Indonesia and Brazil have bigger damage factors. The result indicates the mining of Gold, platinum, palladium has a million times NPP loss of Iron. The grade of minerals is dominant on the difference between minerals.

The EINES per unit of resource consumption was similar to NPP loss. Because both of them are proportionate to the area of land transformation.

DISCUSSION

The damage factor of social asset, user cost was the cost to compensate future generation for a resource. This method assumed that the human economy can continue after the resource depletion. The user cost consider longer period than that of the surplus cost. Additionally, both of them could not consider the stock and recycling of the mineral. So an user of these factors should be careful this difference.

A few methodologies directly treated the land use by resource consumption. It may be the matter of inventory analysis, but we hope more discussion and information about the association between the resource consumption and land transformation in terms of LCIA.

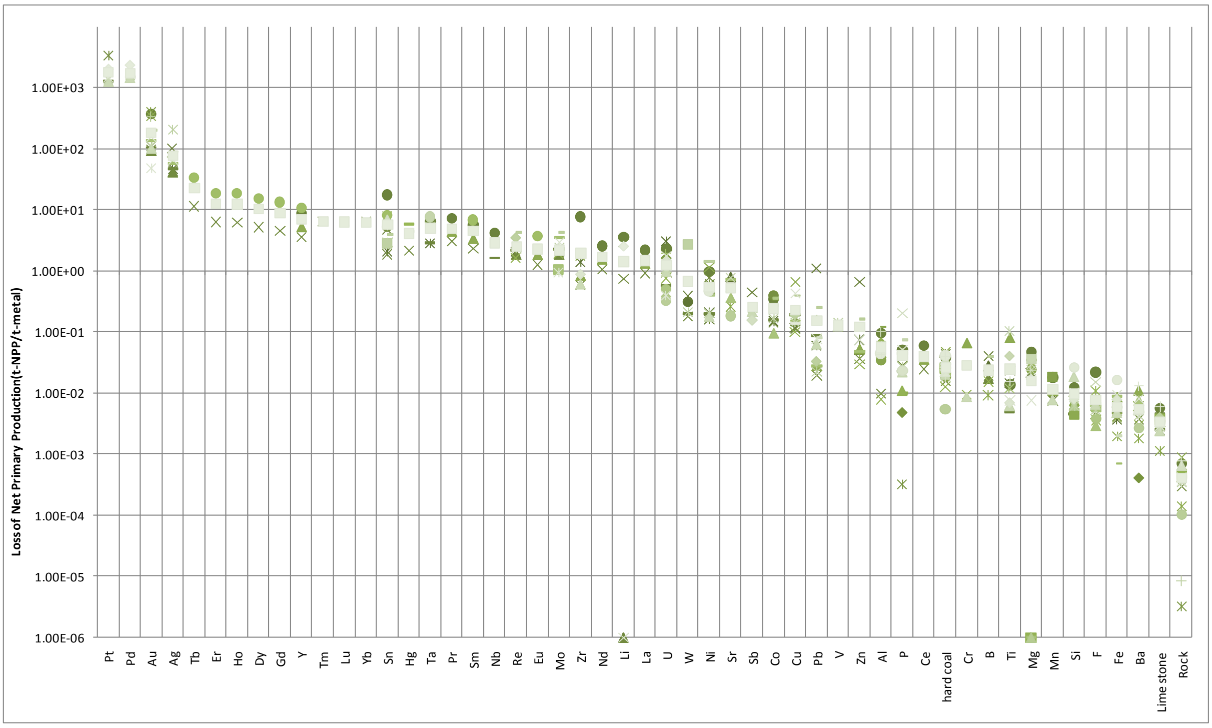


Fig.3 The damage factors of primary production of each extracted country

CONCLUSIONS

We developed grovel LCIA damage factor of resource consumption. We made damage factor of resources extracted in each country and resources consumed in each country. Our damage factors of NPP and biodiversity have differences between extracting countries. The differences between countries are less than 10 times at the damage factor of NPP. We hope this method contribute to LCIA of resource consumption around the world.

REFERENCES

British Petroleum.(2011). Statistical Review of World Energy.

El Serafy. (1989). The proper calculation of income from depletable natural resources, in environmental accounting for sustainable development. *The world bank*.

National Institute for Material Science. (2004). Characterization factor of “Mineral resource consumption”.

Norihiro Itsubo and Atsushi Inaba.(2010).LIME2- Environmental assessment method supporting decision making. *Japan Environmental Management Association for Industry*.

United States Geological Survey (USGS).(2011). Mineral Commodity Summaries (MCS) 2010.

USGS.(2012). Mineral Resource Data System, *http://tin.er.usgs.gov/mrds/, Accessed 1.June.2012*.

Vieira M, Goedkoop M, Storm P and Huijbregts M. (2012). Ore grade decrease as indicator for metal scarcity in Life Cycle Assessment. The 10th International Conference on Ecobalance.

Watando H, Kamimoto M, Kobayashi H. (2012).A new quantitative method of evaluating the impacts of mining on biodiversity. The 10th International Conference on Ecobalance.

DYNAMIC MODELING OF WORLD STEEL CYCLE TOWARD 2050

Niina Fujitsuka[*1], *Ichiro Daigo*[*1], *Yoshikazu Goto*[*1], *Kenichi Nakajima*[*2], *Yasunari Matsuno*[*1]

**1 Department of Materials Engineering, Graduate School of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku Tokyo 113-8656, fujitsuka@mfa.t.u-tokyo.ac.jp*

**2 National Institute for Environmental Studies, 16-2Onogawa, Tsukuba-City, Ibaraki, 305-8506, nakajima.kenichi@nies.go.jp*

Keywords: dynamic material flow; steel stock.

ABSTRACT

In this work, a dynamic material flow analysis (MFA) was conducted to estimate the global flow and in-use stock of steel for 42countries until 2010. The growth of the future in-use stock and demand of steel for three products (civil engineering, building, and vehicles) towards 2050 was also estimated under the concept of “stocks drive flows”, considering the economic and population growth in every country. In addition, we analyzed the steel scrap generation in each product and in every country up to 2050, and investigated the steel use potentials by using waste input-output material flow analysis (WIO-MFA).

INTRODUCTION

For the conservation of natural resources and protection of environment, effective use of material stock in the society as the secondary resources should be enhanced. Therefore, material flow analysis (MFA), which can estimate the flow of materials, has been developed (Graedel et al. 2004a; Graedel et al. 2004b; Wang et al. 2007). MFA can be distinguished into two types, a dynamic MFA and a static MFA. A dynamic MFA can estimate the in-use stock over extended time intervals (Spatari et al. 2005), whereas A static MFA can only estimate the flow of materials in a specific area over short periods,

As steel is the most widely used material in the world, numerous studies have been conducted to investigate the flow of steel on the developed countries. For instance the United States (Müller et al. 2006), the United Kingdom, and Japan (Hatayama et al. 2010). Hatayama et al. (2010) conducted a dynamic MFA for steels to estimate the flow and in-use stock of steel globally until 2005. They classified the steel end-uses into eight groups (civil engineering, building, vehicles, electric appliance, machinery, shipbuilding, containers and packaging, and other) in each country. Moreover, the growth of future in-use stock and demand of steel for three products (civil engineering, building, and vehicles) towards 2050 was estimated. However, they have not evaluated the steel scrap use potentials.

Hsu et al. (2012) investigated the country differences on steel use intensity for building which was one of the largest products of steel. They indicated that the steel use intensities for buildings in Asian countries were about two times larger than those in European countries. These country differences should be considered in estimating the future demand of steel for building.

Therefore, in this paper, we conducted a detailed dynamic MFA for 42 countries during 1950-2050 in which the country differences in steel use intensities for buildings were taken into account, and investigated the recycling potential of the steel scraps.

METHODS

A dynamic material flow analysis of steel
In this paper, based on the method by Hatayama et al. (2010), we conducted a dynamic MFA to estimate the global flow and in-use stock of steel until 2010 and the growth of future in-use stock and demand of steel for three products (civil engineering, building, and vehicles) towards 2050. We focused on 42 countries and regions, which accounted for 87 % of steel consumption of the world in 2010.

Estimation of future in-use steel stock for building considering country differences
We estimated the in-use stock of steel for building of each country with the assumption that in-use stock of steel would grow along the S-shaped logistic curve represented by Eq. 1.

$$S_t = \frac{S_{sat}}{1 + \exp(\alpha - \beta \times GDP_t)} \quad \text{Eq. 1}$$

S_t is the in-use stock of steel per person in year t, S_{sat} is a saturation value of the in-use stock, GDP_t is GDP per capita in year t, α and β are parameters that determine the shape of the logistic curve. We calculated for the curve fitting by the method of least squares.

In the countries whose GDP per capita was 20,000 USD or more in 2010, and average growth rate of in-use steel stock for building per person from 2006 to 2010 was more than 2%, S_{sat} was obtained by the curve fitting method mentioned above. In contrast, in the countries whose average growth rate was below 2%, we considered that the in-use steel stock for building per person would not increase much in the future and it is assumed to be stable with the level of 2010.

For the countries whose GDP per capita in 2010 was 20,000 USD or less, S_{sat} was adopted from the maximum, average and minimum values obtained from the countries mentioned above, and the future in-use stock of steel for building was estimated by Eq. 1.

Waste Input-Output Material Flow Analysis (WIO-MFA)
The WIO-MFA model is a top-down MFA method for estimating the material or substance composition of a product, which can assess the mass balance between inputs and outputs of each industry. We calculated pig iron and obsolete steel scrap component in the finished products from this method and obtained the obsolete scrap use intensity for each product from Eq. 2

$$\text{the obsolete scrap use intensity} = \frac{\text{the obsolete scrap component}}{\text{the pig iron component} + \text{all scrap component}} \quad \text{Eq. 2}$$

Although the obsolete scrap use intensity for each end-use was calculated in the basis of material components in Japan, it was applied globally, because WIO-MFAs in other countries were not available. By multiplying this intensity by steel demand for each product, we calculated the future obstacle steel scrap demand and evaluated the steel use potentials.

RESULTS&DISCUSSION

A dynamic material flow analysis of steel

Figure 1 shows the in-use steel stock in the world up to 2010 by region. The in-use steel stock had doubled during 1980-2010, and reached to 16 billion ton in 2010. It is attributable to the rapid growth in Asia.

Estimation of future in-use steel stock for building considering country differences

It was found that the saturation value of steel for building in Asia was twice as large as that in other areas. It is likely that people in Asia preferred structural material because there were always many damages caused by natural disasters such as an earthquake in this area.

It was also estimated that steel demand for building would be stable from 2020 and would reach about 13 billion ton. This value is about 2.5 times as much as that in 2010, which is attributable to the growth of developing countries.

We estimated the change of steel demand, in-use stock, and obsolete scrap generation for three products (civil engineering, building, and vehicles). Figure 2 shows the estimated in-use steel stock towards 2050. The in-use steel stock for civil engineering and vehicles is 4 times as much as those in 2010, and in-use steel stock for buildings is 5 times as much as that in 2010.

Waste Input-Output Material Flow Analysis (WIO-MFA)

The obsolete scrap use intensity for each product obtained by WIO-MFA was shown in Table 1. With these results, the demand of obsolete steel scrap was estimated. If we will use the obsolete steel scrap in the same use intensities in 2010, the obsolete steel scrap generation will exceed the demand around 2035, and be as twice as its demand.

CONCLUSIONS

In this study, we conducted a dynamic material flow analysis of steel in the world until 2010. In addition, taking into account the countries differences in steel use intensity for buildings, we conducted a dynamic flow analysis of steel for tree products (civil engineering, building, and vehicles) in the world towards 2050.

We calculated the obsolete scrap use intensity by WIO-MFA. By comparing the obsolete steel scrap demand to the generation, we estimated the steel use potentials. The steel use intensities for each product should be enhanced because the obsolete steel scrap generation may expect to exceed the demand in a couple of decades.

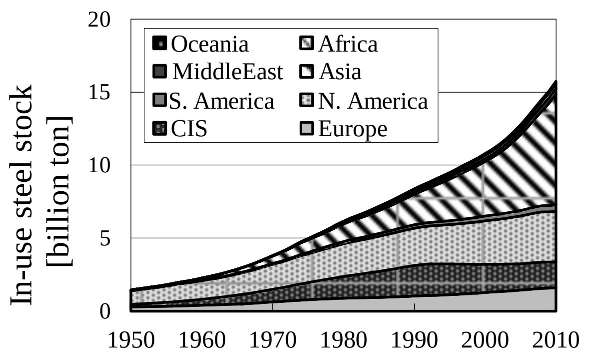


Figure 1. In-use steel stock by region, 1950-2010

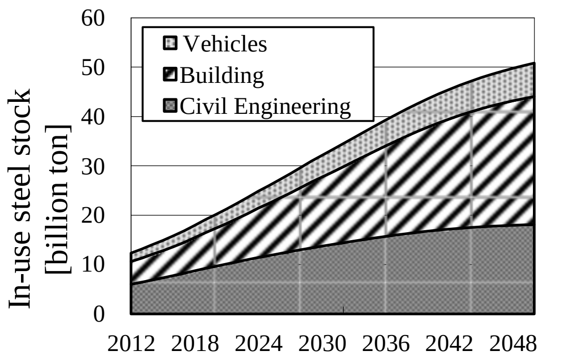


Figure 2. Change of steel in-use stock

Table 1. Obsolete scrap use intensity for each product

Product	**Intensity (%)**
Vehicles	15.7
Building	36.2
Civil engineering	36.9

REFERENCES

Davis, J., Geyer, R., Ley, J., He, J., Clift, R., Kwan, A., Sansom, M., & Jackson, T. (2007). Time-dependent material flow analysis of iron and steel in the UK Part 1: Production and consumption trends 1970–2000, *Resour. Conserv. Recy.*, 51, 118-140. doi:10.1016

Graedel, T. E., Bertram, M., Kapur, A., Reck, B., & Spatari, S. (2004a). Exploratory Data Analysis of the Multilevel Anthropogenic Copper Cycle, *Environ. Sci. Technol.*, 38, 1253-1261. doi:10.1021

Graedel, T. E., Beers, D. van, Bertram, M. Fuse, K. Gordon, R. B., Gritsinin, A., Kapur, A., Klee, R. J., Lifset, R. J., Memon, L., Rechberger, H., Spatari, S., & Vexler, D. (2004b). Multilevel Cycle of Anthropogenic Copper, *Environ. Sci. Technol.*, 38, 1242-1252. doi:10.1021

Hatayama, H., Daigo, I., Matsuno, Y., & Adachi, Y. (2010). Outlook of the World Steel Cycle Based on the Stock and Flow Dynamics. *Environ. Sci. Technol.*, 44, 6457-6463, doi:10.1021

Hsu, Feng-Chi, Fujimoto, S., & Matsuno, Y. (2012). Exploring the International Difference on Building Steel Intensity. *Tetsu-to-Hagane*, 98, 143-150.

Müller, D. B., Wang, T., Duval, B., & Graedel, T. E. (2006). Exploring the engine of anthropogenic iron cycles, *Proc. Nat. Acad. Sci*., 103, 16111-16116.

Spatari, S., Bertram, M., Gordon, R. B., Henderson, K., & Graedel, T. E. (2005). Twentieth century copper stocks and flows in North America:A dynamic analysis, *Ecological Economics*, 54, 37-51, doi:10.1016

Wang, T., Müller, D. B., & Graedel, T. E. (2007). Forging the Anthropogenic Iron Cycle, *Environ. Sci. Technol.*, 41, 5120-5129, doi:10.1021

ESTIMATION OF IN-USE STOCK AND FUTURE DEMAND OF STEEL FOR WORLD RAILWAY

Naoki Togawa, Yasunari Matsuno.*

Department of Material Engineering, Graduated School of Engineering, The University of Tokyo. 7-3-1 Hongo, Bunkyo-ku Tokyo 113-8656, Japan. togawa@gold.t.u-tokyo.ac.jp

Keywords: material flow; steel; railway.

ABSTRACT

In recent years, the construction of a sustainable society has been promoted from the view point of environmental protection and conservation of natural resources. Steel is the most widely used metal in the world, and numerous studies have investigated its flow and stock. However, the flow of steel for world railways has not been investigated. Although railways have been minor products for steel use, but have influence on the use of vehicles, major products for steel. So we estimated in-use stock and future demand of steel for world railways during 1980-2010. As a result, the in-use steel stock for railway vehicles and tracks in the 58 countries was estimated as 47 and 100 million ton in 2010, respectively.

INTRODUCTION

In recent years, the construction of a sustainable society is being promoted from the view point of environmental protection and conservation of natural resources. Therefore, it is necessary to use the in-use stock as secondary resources. Steel is the most widely used metal in the world, so it is important to estimate the flow and the amount of steel in the society.

Material flow analysis (MFA) is a method to calculate the flow and stock of materials in a society, which has been applied to various materials (e.g., Hirato, et al., 2009; Spatari, et al., 2005; Johnson, et al., 2005). The method used for estimating material stocks in a society can be divided into two types: the top-down approach and the bottom-up approach. The top-down approach is a method used to calculate material stocks by using annual time series statistical data for material consumption, trade of materials and lifetime distributions of end-use products in a society. On the other hand, the bottom-up approach is used when the top-down approach cannot be used due to a lack of data. In the bottom-up approach, the number of products within a specified boundary is quantified. Then, the material use intensities of the products are multiplied by the number of products to give an estimate of material stocks (Hirato, et al., 2009).

Hatayama et al. (2010) classified the end uses of steel into 8, i.e. civil engineering, building, electrical appliances, machinery, vehicles, shipbuilding, containers and packaging and other, and estimated in-use stock of steel for each end use. However, in their study, railway vehicles and tracks were included in machinery, and not investigated in detail. In addition, their study was mainly intended in developed countries.

Railway vehicles and tracks have long life, and many countries developed the railway in the early stages of their economic development to distribute commodities. Therefore, the flow and stock of steels for railways were of interest, especially, in developing countries. So, in this study, we estimated in-use stock and future demand of steel for railway in 58 countries of the world

MATERIALS AND METHODS

In this study, we used the bottom-up approach to estimate the in-use steel stock of railways. We obtained chronological data for the use of tracks and railway vehicles, i.e. passenger carriages and freight cars, and the data about the steel use intensity for those products. The former data of 58 countries during 1980-2010 was obtained from International Union of Railways; the latter data of Japan was obtained and applied to the other 57 countries.

Passenger carriages consist of body, bogie, electrical parts, and equipment and others. It was assumed that only body and bogie contain steel. The body is made of common steel, stainless steel, or aluminum, and also the amount of steel used for the body is different. The ratio of common steel, stainless steel, and aluminum body in 2007 in Japan was obtained, and was applied to other 57 countries for the entire study range.

We also assumed freight cars to be entirely made of steel. The weight of a Japanese freight car was obtained, and was applied to other 57 countries.

Tracks consist of rail, crosstie, and pavement. It was assumed that only rail contains steel. In Japan, rails are standardized by the weight per unit length. So we obtained the steel use intensity for tracks in Japan, and applied the data to other 57 countries.

We divided 58 countries into two groups. The first group comprised of countries whose quantity of in-use steel had its maximum value in 2010; whereas, the second group was made up of countries whose quantity of in-use steel stocks did not have its maximum value in 2010. And then, we estimated the future demand of steel under the assumption that the in-use steel stocks of the first group will increase according to logistic curves respectively, and those of the second group will keep at the value of 2010.

RESULTS AND DISCUSSION

Figures 1, 2, and 3 show the in-use steel stock for railways, i.e. passenger carriages, freight cars and tracks. The in-use steel stock for passenger carriages, freight cars, and tracks in the 58 countries was estimated as 8.48, 38.9, and 99.0 million ton in 2010, and 8.58, 39.2, 99.5 million ton in 2050, respectively.

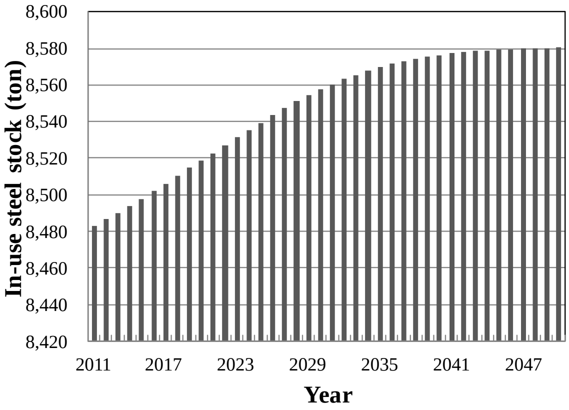


Fig. 1 In-use steel stock for passenger carriages in the world

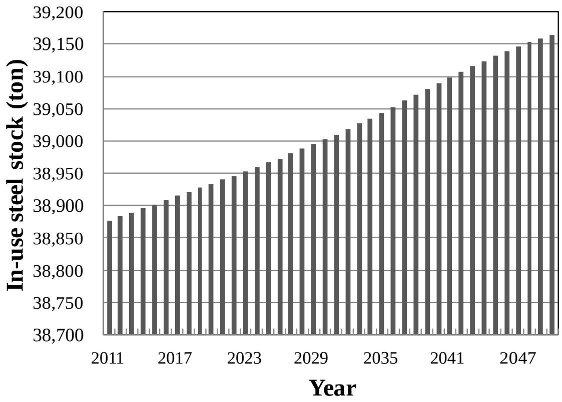


Fig. 2 In-use steel stock for freight cars in the world

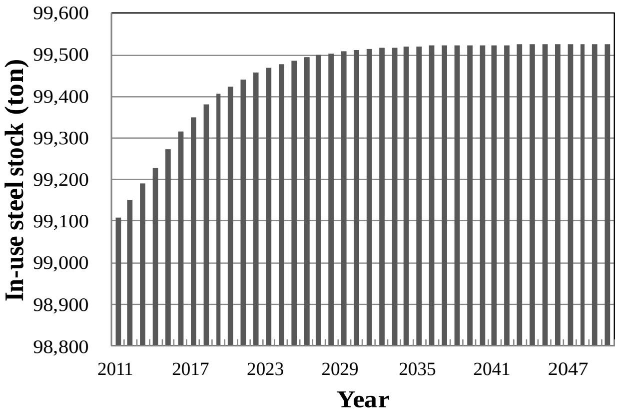


Fig. 3 In-use steel stock for tracks in the world

The future demand of steel for passenger carriages, freight cars, and tracks in the 58 countries was estimated as 2.46, 2.04, and 5.30 million ton in 2050, respectively. The future demand of steel for passenger carriages is expected to reach its maximum in 2033, and then decrease. This is because most of the demand is caused by replacement of old stocks. The future demand of steel for freight cars and tracks will also reach maximum in a specific year, and then decreases for the same reason.

CONCLUSIONS

In this study, we estimated the in-use stock and future demand of steel for world railway in 58 countries during 1980-2050. It was estimated that the in-use stock in 2010 was 146 million ton, and the future demand in 2050 was 7.26 million ton.

ACKNOWLEDGEMENT

This work is partially financially supported by JFE Steel Corporation.

REFERENCES

Hatayama, H., Daigo I., Matsuno, Y., & Adachi, Y. (2010). Outlook of the World Steel Cycle Based on the Stock and Flow Dynamics. *Environmental Science & Technology, 44, 6457-6463.* DOI: 10.1021/es100044n

Hirato, T., Daigo, I., Matsuno, Y., & Adachi, Y. (2009). In-use Stock of Steel Estimated by Top-down Approach and Bottom-up Approach. *ISIJ International, 49, 1967-1971*. DOI: http://dx.doi.org/10.2355/isijinternational.49.1967

Johnson, J., Jirikowic, J., Bertram, M., van Beers, D., Gordon, R.B., Henderson, K., Klee, R.J., Lanzano, T., Lifset, R., Oetjen, L., & Graedel, T. E. (2005). Contemporary Anthropogenic Silver Cycle: A Multilevel Analysis. *Environmental Science & Technology, 39, 4655-4665*. DOI: 10.1021/es048319x

Spatari, S., Bertram, M., Gordon, R. B., Henderson, K., & Gradel, T. E. (2005). Twentieth century copper stocks and flows in North America: A dynamic analysis, *Ecological Economics, 54, 37-51*. DOI: http://dx.doi.org/10.1016/j.ecolecon.2004.11.018

LIFE CYCLE ASSESSMENT OF PHOSPHOROUS RECOVERY FROM SEWAGE SLUDGE

Birgitte Lilholt Sørensen, Ole Dall, University of Southern Denmark,*

Niels Bohrs Alle 1, DK-5230 Odense M, email:bls@kbm.sdu.dk

Keywords: LCA, phosphorous, sludge, resource, gasification

ABSTRACT

The Danish waste treatment plant for hazardous waste "Nordgroup a/s" plans to recover phosphorus from waste water sludge. The presented LCA-study indicates that environmental impacts by phosphorous recovery in an energy efficient process are at the same level or lower than through the re-use of sewage sludge applied directly on farmland.

The recovery method is based on drying and thermal gasification of activated sewage sludge followed by extraction of phosphorous from the ashes. The obtained product can be used as a fertilizer replacing similar products on the marked.

The conclusion is that the general rule according to waste hierarchy, where re-use is preferable to material and energy recovery, is wrong in this case.

INTRODUCTION

Until now sludge waste treatment in Denmark has followed the general waste hierarchy where reuse is preferred instead of incineration. This means that sludge most commonly has been spread on farm land as fertilizer and soil improver. Only when the sludge did not meet the threshold values for hazardous compounds has incineration been approved. The Danish EPA has initiated an LCA-study to verify how different treatment options performs if several environmental and resource parameters are included (Kirkeby et al, 2012). As a contribution to this study, the University of Southern Denmark has assisted Nordgroup a/s to deliver LCA-data for a planned treatment process for sewage sludge with focus on phosphorous recovery by efficient use of energy in all process steps (Sørensen and Dall, 2012).

THE TREATMENT PROCESS AND METHODS FOR THE LCA STUDY

The treatment consist of 4 steps as shown in figure 1, and the data sources are mentioned for each step:

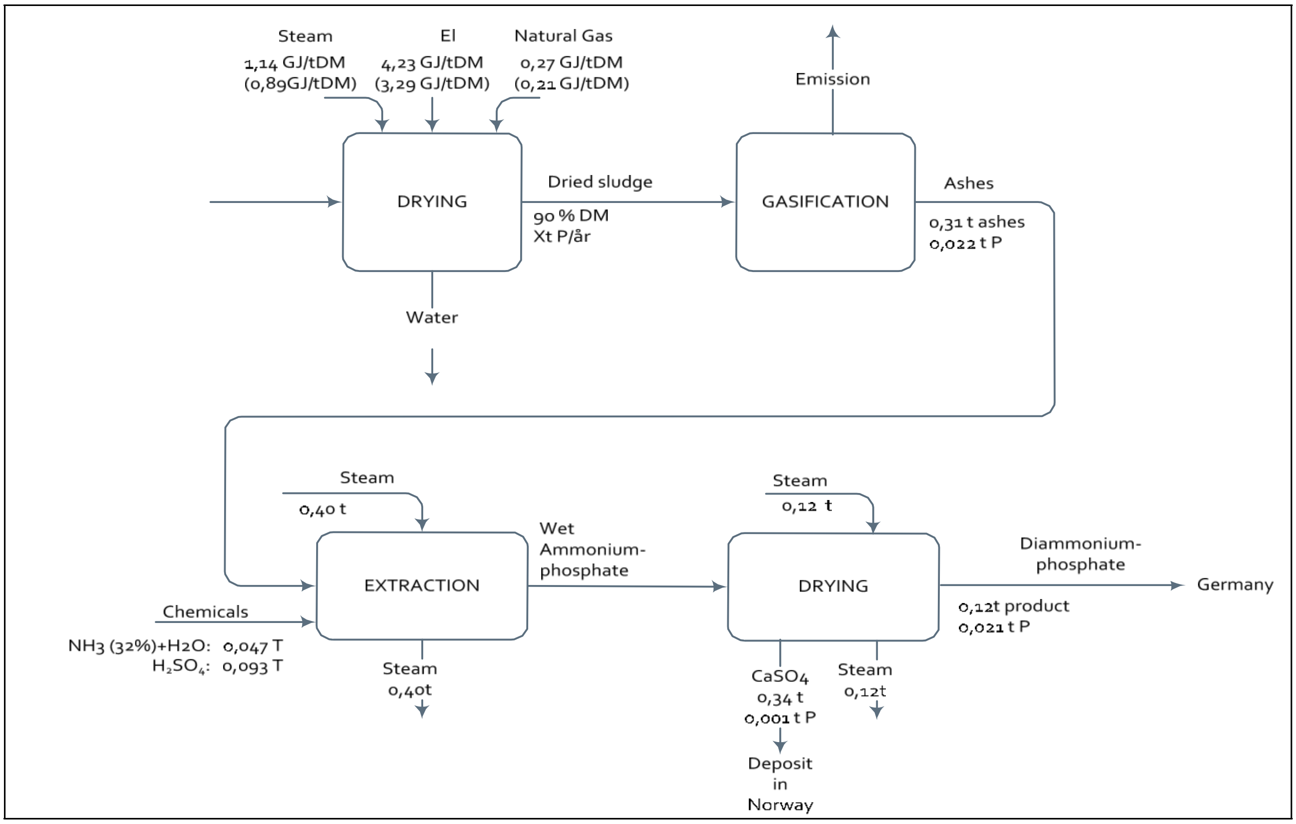
- Drying of sewage sludge by use of heat (Dall, Ole et al. 2009),
- Gasification dried sludge and use of gas (DONG, 2012),
- Chemical Phosphorous extraction (Nordgroup, 2012)
- Drying of final fertilizer product (Dall, Ole et al. 2009),

The LCA study has one ton of dry matter sewage sludge as functional unit. The study is based on consequential LCA, using as far as possible marginal data sets and system expansions.

The LCA study includes all 4 process steps, but also the avoided production of fertilizer (diammoniumphosphate) and all necessary transportation to make the study fully compliant to the studies in the Danish EPA report.

Besides the above mentioned data sources, we have used LCA data for production of chemicals, transportation and energy based on the EcoInvent database, 2012). The LCA-calculations presented in this article are based on the EDIP 2003 methodology (Laurent, A. et al 2011) and updated according to (USGS, 2010) for all resource parameters. The biogenic C emissions are added to complete the picture of all processes.

Figure 1: Treatment steps in the recovery process.



RESULTS

The results for selected LCA-impacts and resources consumption/savings are show in figure 2 and 3 as PE (person equivalents) per ton (dry matter) sewage sludge. There are both reduced impacts (negative values) and increased impacts for each parameter.

For fossil global warming contribution and acidification there is a small (both values are minus 0,015 PE) reduction in the total process which is due to the avoided marginal energy production and replacement of fossil energy with biogenic fuel originating from the sewage sludge. This is also reflected in the increased emission of biogenic C, which in this case should be considered as neutral to global warming, since the biogenic materials in sewage sludge typically are grown in a timespan of a few years before being discarded.

The only impact that has a relatively small increase (0,0016 PE) is photochemical ozone formation.

Resource use and savings are calculated as PE/ton dry matter. The normalization reference is the global use of fossil energy resources and phosphorous in 2010 (USGS, 2010).

The results show a total resource reduction for energy resources and for phosphorous, which means that 1 ton of dried matter in sewage sludge replaces almost (0,9 PE) the use of phosphorous per person globally. On the other hand, the total content of phosphorous in sewage sludge only accounts for a small percentage of the use in Denmark.

Figure 2: LCA-results for all process steps in PE/ton dry matter, negative values are reductions and positive increased – the total is the sum of both.

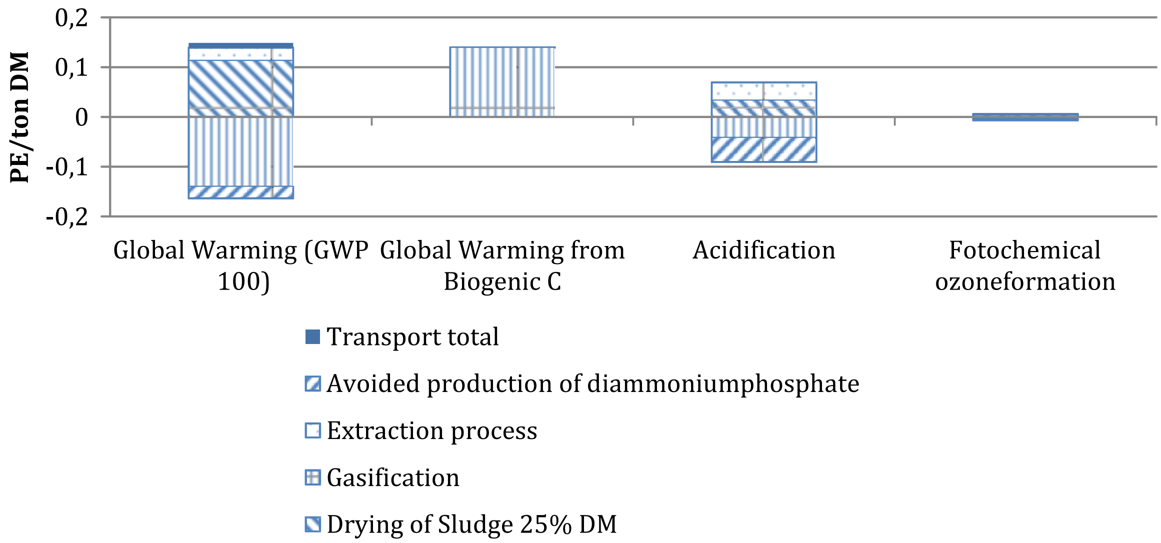
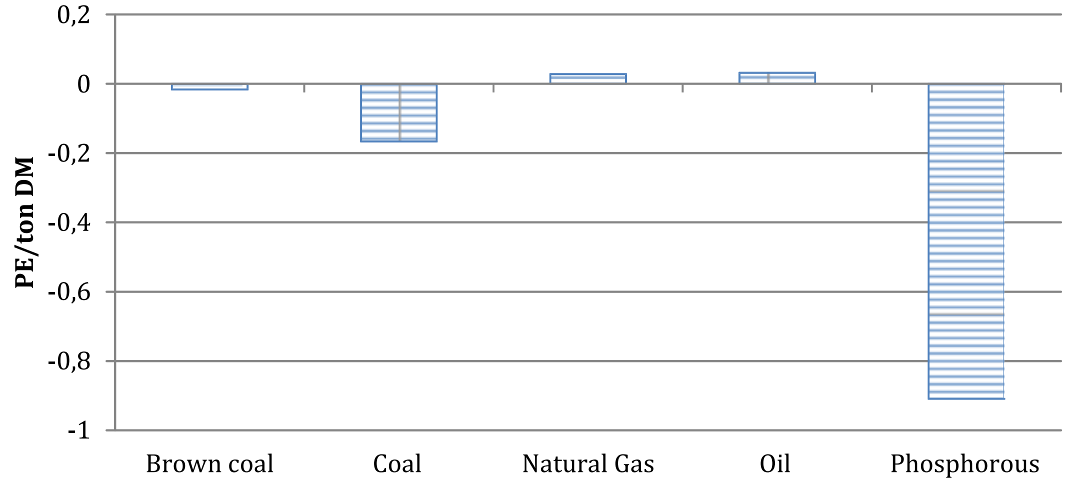


Figure 3: Shows resource and savings in PE/ton dry matter.



DISCUSSION

The impacts of phosphorous recovery from waste activated sludge are investigated on a specific waste treatment plant in Denmark but can be implemented elsewhere with similar conditions

The LCA is included in a study by the Danish EPA where other treatment options for sewage sludge are also analyzed. The comparison to other treatment options shows that the proposed process performs as good as direct use of sludge on farmland. Especially the reduction of fossil CO2 emission is remarkable, due to the efficient drying and incineration processes and the replacement of fossil fuel by biogenic based fuel from sewage sludge.

The recycling of phosphorous resources is crucial due to its life threatening necessity, lack of substitution options and a forecast showing global scarcity. The optional direct use of sludge on farmland can provide similar phosphorous recycling over a long time span, but does not have the potential to avoid use of phosphorous fertilizers due to transportation costs.

CONCLUSIONS

The LCA-study shows that energy efficient processing has a positive environmental impact compared to production of other phosphorous fertilizer. If the process is compared to optional treatment methods it turns out to be just as good – but has an advantage to provide an easy distributable phosphorus fertilizer.

The conclusion is that the aim of the waste hierarchy is fulfilled by incineration with efficient energy use and phosphorous recovery.

REFERENCES

Dall et al. 2009, (Dall, Ole; Gammelby, Line og Wenzel, Henrik 2009). Klimaregnskab og Carbon Footprint beregning for Kommunekemi a/s. Published at www.nordgroup.dk

DONG, 2012. Personal information about the existing gasification plant at Kalundborg.

Eco Invent database, 2012, background reports published at www.ecoinvent.org.

Kirkeby, Janus S. et al., 2012. Livscyklusvurdering og samfundsøkonomisk analyse for anvendelse af spildevandsslam Danish EPA-report only published online at www.mst.dk as Miljøprojekt nr. 1459, 2013 (in Danish language but summary in English)

Laurent, A. et al., 2011. (Laurent, Alexis; Olsen, Stig I. and Hauschild, Michael Z., 2011). Normalization in EDIP97 and EDIP2003: updated European inventory for 2004 and guidance towards a consistent use in practice. International Journal of Life Cycle Assessment, Vol 16, pp. 401-409.

Nordgroup, 2012. Personal information about chemical and energy use for the phosphorus recovery process.

Sørensen, Birgitte and Dall, Ole, 2012. Miljøvurdering af tørring, forgasning og udvinding af fosfor fra spildevandsslam. Unpublished technical report in Danish language.

USGS, 2010. Minerals Yearbook 2010. Published at www.minerals.usgs.gov.

SETTING RECYCLING TARGETS FOR METALS IN A LI BATTERY

Bengt Steen[1], Stefan Allard[1], Christian Ekberg[1], Viktor Ekermo[2], Christer Forsgren[3], Sravya Kosaraju[1]*

[1]Chalmers University of Technology, Sweden; [2]ETC Battery and FuelCells Sweden, Sweden; [3]Stena Metall, Sweden

**Rännvägen 6, 412 96 Göteborg, Sweden, bengt.steen@chalmers.se*

Keywords: Li battery; recycling; target; metals; vehicles.

ABSTRACT

In the EU APPLES project, a new Li ion battery is developed. An LCA model including weighting was developed for this battery and a reference. Simulations were made with different materials and recycling rates.

The results indicate that if all cars are BEVs or HEVs, global mining of Li, Ni and Sn may have to increase several times. There will also a significant increase in the demand of Cu and Mn. If the electricity used for charging the batteries is made by non-fossil methods, such as water power, management of metal resources are a prime sustainability factor. The optimal recycling rate depends highly on the recycling technology, but also on the weighting methods used.

INTRODUCTION

In the EU APPLES project (APPLES 2013), a Li ion battery based on a cathode of $LiNi_{0.5}Mn_{1.5}O_4$ on Al and an anode of Sn-carbon on Cu is developed. The battery has good potential in terms of performance, but a full scale use of the battery for propulsion of cars has a significant impact on the use of metal resources and therefore requires efficient recycling processes. A question arises if this battery is better than other Li ion batteries and how to integrate recycling options and targets in this comparison.

There are several comparative LCA studies of batteries used for propulsion in literature (Hawkins 2012), but to our knowledge, none of them has addressed the question of what is an acceptable recycling rate. To do so, one has to be able to handle trade-offs between different environmental issues and other issues. The picture is complicated by the fact that recycling methods are not well developed yet. In this study, we will add some information that can be used for setting recycling targets by using an analysis of global mass flows and estimate monetary measures for environmental impacts. Monetary measures may be used to assess which cost increase that is acceptable for recycling processes.

METHODS

An LCA model including weighting was developed and simulations made with different materials and recycling rates. The LCA was supported by a MFA (Mass Flow Analysis) of global metal flows needed in Battery Electric Vehicles (BEV) scenarios.

If considering long term economy aspects like in the EPS method, we can deduce an optimal recycling rate dependent on recycling cost from the following calculation, where the present virgin metal price is V and K is a cost increase factor so the acceptable price of the metal is K*V. N is the natural capital value of the metal ore, recycling cost is R, recycling efficiency is E and number of cycles is C.

Then $C = 1/(1-E)$ and $KV = (N+V)/C + R$, or $E = (N+R-V(K-1))/(N+V)$

If we assume that the acceptable price is equal to the present market price V, the K=1 and we get $E = (N+R)/(N+V)$

RESULTS

The results indicate that if all cars are BEVs, Global flows of Li, Ni and Sn may increase several times, and that there also is a significant increase in the use of Cu and Mn. (Table 1) The results also indicate that if the electricity used for charging the batteries is made by non-fossil methods, such as water power, management of metal resources are the prime sustainability factor (figure 1). The optimal recycling rate depends highly on the recycling technology but also on the weighting methods used including their assumptions about the future. The picture is complicated by technology bridging aspects, e.g. the most sustainable solution may not be economically feasible in the short term and thus not contributing to a real improvement. Therefore recycling technology options in terms of costs and efficiencies become important factors in setting recycling targets for metals in Li batteries.

Table 1 Global metal flows if all cars in the future were propelled by APPLES batteries. The figures for natural capital are estimated by using the EPS 2000d method (Steen 1999).

Metal	Present virgin global production	Estimated use if all cars were BEV and driven by APPLES cells	Recycling market value	% of virgin global production used by APPLES cars without recycling	Natural capital in ore	Natural capital used for metal production	Use of natural capital without recycling
	ton/yr	ton/yr	$/yr		$/ton	$/ton	$/yr
Al	2,50E+07	2,46E+06	4,92E+09	9,8	4,39E+02	9,40E+03	2,32E+10
Cu	1,62E+07	3,78E+06	3,01E+10	23	2,08E+05	2,68E+05	1,01E+12
Li	2,53E+04	6,29E+05	2E+10	2490	1,00E+02	1,01E+04	6,36E+09
Mn	1,08E+07	6,22E+06	3,48E+09	58	5,64E+03	7,28E+03	4,53E+10
Ni	1,45E+06	2,28E+06	4,47E+10	158	1,60E+05	2,06E+05	4,71E+11
Sn	2,60E+05	2,59E+06	5,44E+10	997	1,19E+06	1,53E+06	3,98E+12

As shown in table 1, the global production of Li and Sn has to increase several times in order to satisfy the demand for batteries of APPLES types. Li is an abundant element and large amounts are available in sea water, but even with 80% recycling there may be problems of increasing the global production fast enough to satisfy the demand if all cars use Li batteries for propulsion (Kushnir and Sanden 2012**).**

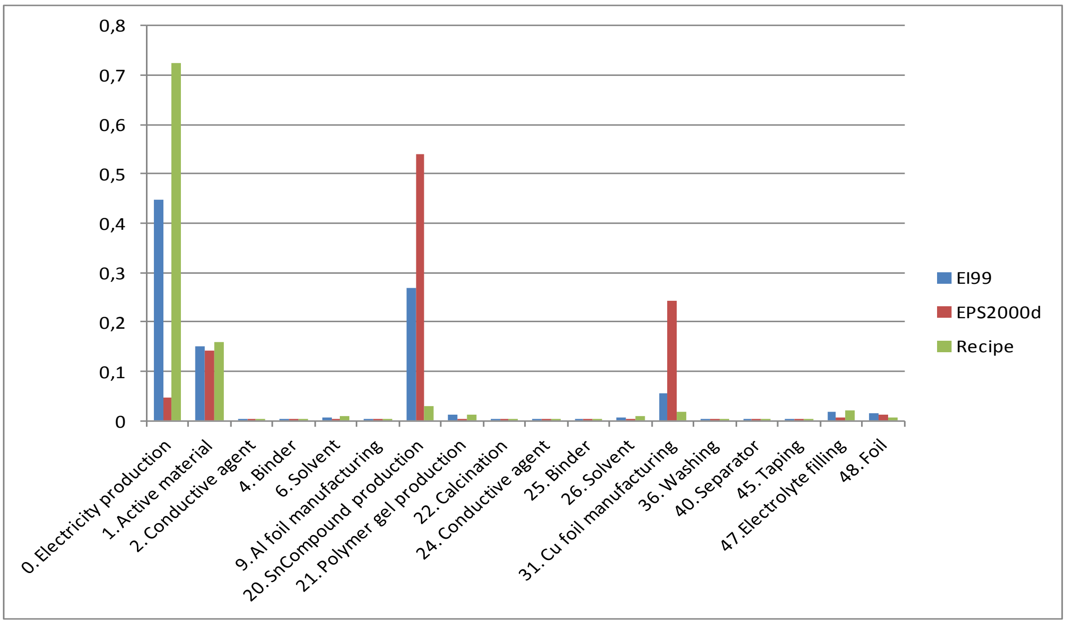


Figure 1 Relative contribution to weighted impacts in APPLES cell according to three methods when electricity comes from water power (Goedkoop 1999, Steen 1999, Goedkoop 2008). Full life cycle, no material recycling.

The results in figure 1 indicate, as expected, that electricity production is an important factor in the battery life cycle, but also that manufacturing of active material, Sn and Cu for the electrodes give significant contributions to the overall impact. It also shows that there are significant variations in priorities between the weighting methods. EPS2000d is more focused on resources due to longer temporal system boundaries than the other methods. Using different LCA weighting methods may therefore significantly influence which recycling rates that will be optimal. Figure 2 shows the optimal recycling rate using N and V values of table 1.

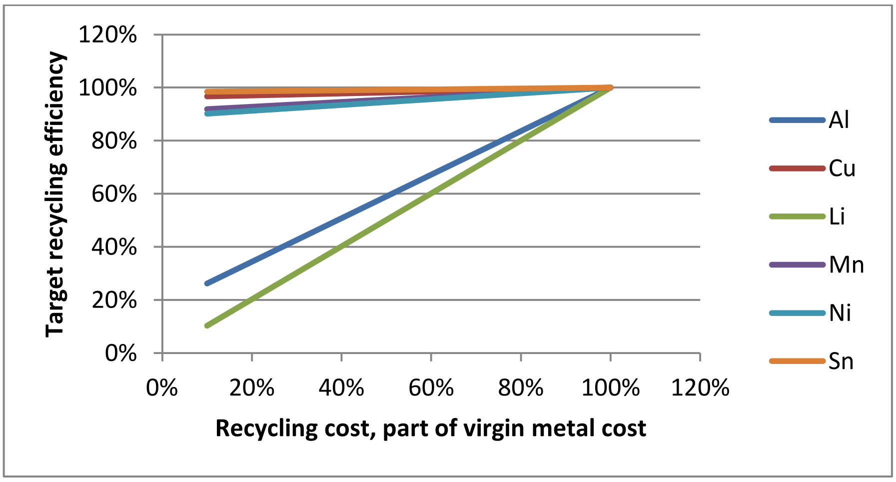


Figure 2 Target recycling efficiency as a function of recycling cost in a scenario with present metal prices.

DISCUSSION

Development of sustainable technology involves several assumptions about the future, assumptions about technical issues as well as assumptions about what will constitute sustainability. Our assumption about the future is not necessarily that all cars will be propelled by APPLES batteries, but we find it meaningful to investigate that scenario. The main advantage with using Sn-C in the anode is a significant increase in storing capacity compared to conventional C anodes. This will in turn lead to lower battery weight and costs, and may help to bridge the technology gap between electric and conventional cars. If so, the exact sustainability performance of the tin-based APPLES battery may not be critical.

CONCLUSIONS

From a sustainability point of view recycling should be focused on Cu, Li, Ni and Sn. Al and Mn may be recycled as motivated by current economics or as required by law. The target for recycling rates seem to be in the >90% region, but the exact optimum depend on weighting methods and how recycling technology evolves. Considering the significance of the resource issue and the need for replacing fossil fuels, weighting methods and recycling technology should be higher up on the agenda.

REFERENCES

APPLES (2013) available at http://www.applesproject.eu

Goedkoop M, Spriensmaa R (1999): The Eco-indicator 99 – A Damage Oriented Method for Life Cycle Impact Assessment. PRé Consultants, Amersfoort, The Netherlands

Hawkins T, Gausen O M and Strømman AH. (2012). Environmental impacts of hybrid and electric vehicles – a review. Int J Life Cycle Assess, Volume 17, Issue 8, pp 997-1014

Mark Goedkoop, Reinout Heijungs, Mark Huijbregts, An De Schryver, Jaap Struijs, Rosalie van Zelm. (2009). ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Ruimte en Milieu, Ministerie van Volkshuisvesting. (Weighting factors, version 0.6 downloaded from ReCiPe homepage http://www.lcia-recipe.net)

Kushnir, D and Sandén,B. (2012). The Time Dimension and Lithium Resource Constraints for Electric Vehicles. Resources Policy, Volume 37, Issue 1, March 2012, Pages 93–103

Steen B (1999): A Systematic Approach to Environmental Priority Strategies in Product Development (EPS). Version 2000 –Models and Data. Chalmers University of Technology, Centre for Environmental Assessment of Products and material Systems (CPM) Report 1999:5, Gothenburg 1999

BROADENING THE SCOPE OF LCA – LCSA

Wednesday, Aug 28: 8:30 am - 10:00 am

Session chairs: Jeroen Guinée, Leiden University, The Netherlands
Martin K. Patel, Utrecht University, The Netherlands

GAPS IN ASSESSING SUSTAINABILITY AND PROPOSAL OF A TIERED APPROACH

Sabrina Neugebauer, Ya-Ju Chang , Matthias Finkbeiner.*

**Technische Universität Berlin, Str. des 17. Juni 135, 10623 Berlin; sabrina.neugebauer@tu-berlin.de.*

Keywords: sustainability assessment; sustainable indicators; tiered approach.

ABSTRACT

Sustainability is one of the important topics in nowadays societies, but the assessment of sustainability is still in its early stage. This is partly substantiated by the lack of a consistent framework. Besides that available indicators are often on different levels within the three dimensions. Another problem occurs with regard to the data availability. Although for the environmental dimension usually sufficient data are available, gaps are identified for the social and economic dimension. The experience shows that dealing with environmental or sustainable impacts is a continuous process. Thus a tiered approach is proposed starting with "basic" indicators for all sustainability dimensions. Different levels are defined including indicators according to the background, available data and trade-off between theory and practice.

INTRODUCTION

Sustainability is one of the important topics in nowadays societies since it was brought up in 1987 from the Brundtland Commission (United Nations, 1987). However the assessment of sustainability is still in its early stage. Most of the already existing methodologies only focus on some aspects but do not cover all three dimensions of sustainability (social, environmental, economic) comprehensively. This is substantiated by three problems mainly: the lack of a consistent framework, the lack of sufficient data and the lack of consistent impact indicators (Finkbeiner, Schau, Lehmann, & Traverso, 2010).

Although for the environmental dimension sufficient data are available at least for the common impact categories, e.g. Climate Change, Acidification, inter alia due to existing databases (e.g. GaBi, ecoinvent (UNEP & SETAC, 2011)). For the social and economic dimension gathering data is harder, which sometimes is more related to a lack of knowledge and common understanding than to a real data gap. Databases so far only exist on country or sector level, e.g. the Social Hotspot Database ("Social Hotspot Database," 2013).

In case of impact assessment the environmental dimension has already well-established indicators (e.g. ReCiPe (Goedkoop et al., 2009)), but within the social dimension inventory and impact indicators are mixed up and for the economic dimension so far only inventory indicators are used.

As a result sustainability assessment studies do not consider the complete life cycle of a product in every detail. Although the environmental dimension on behalf of LCA is reaching a more complete assessment level, the economic and the social dimension neglecting parts, as lacks of data and/or knowledge occur.

METHODS

One of the most common methods for assessing sustainability is the Life Cycle Sustainability Assessment (LCSA), even if the mentioned problems still remain. However it can be seen as the foundation for assessing sustainability and will serve as the basis for this study.

Life Cycle Sustainability Assessment

Life Cycle Sustainability Assessment (LCSA) is covering all three dimensions by integrating Life Cycle Assessment (LCA) (Finkbeiner, Inaba, Tan, Christiansen, & Klüppel, 2006), Life Cycle Costing (LCC) (Hunkeler, Rebitzer, & Lichtenvort, 2008) and social Life Cycle Assessment (sLCA) (Benoit & Mazijn, 2009).

The assessment of the environmental dimension is the most advanced procedure within the LCSA framework, as LCA is a standardized method (ISO 14044, 2006) and widely used to investigate the potential environmental impacts of products (Klöpffer & Grahl, 2009). Environmental Life Cycle Costing (LCC) is proposed for the assessment of the economic dimension. However, it is relatively new within sustainability assessment (Hunkeler et al., 2008) and indicators on the impact level are so far missing. Social Life Cycle Assessment (sLCA) assesses the potential social impacts of products and pays great attention to workers, societies/communities and consumers affected by the products (Benoit & Mazijn, 2009), but it is still under development as a clear framework is so far missing.

In a first step LCSA was adopted for assessing the life cycle of different types of bikes (normal bikes and Pedal Electric Cycles (Pedelec)). Within the LCA mid-point as well as end-point indicators were achieved. The economic dimension (LCC) was modeled for the consumer and manufacturer perspectives. Within the sLCA it was focused on workers, wherefore the Social Hotspot Database serves as a basis complemented by additional data and literature research.

In connection with the bikes production different countries are included, as bike parts are produced all over the world. Data were gathered due to sufficient databases, producer contacts and literature research. For the environmental dimension all bike parts, e.g. frame, could be modeled in a consistent way. For the social and economic dimension data were mainly available on country level and hardly all steps of the life cycle could be considered. It was recognized that environmental data are often easier collectable, as most people already have a good understanding. But especially, social data are difficult to gather as the insight is missing and no internal data are available beyond contracted working hours or law requirements.

RESULTS

Based on the performed case studies and further research it was found that assessing all three sustainability dimensions equally is still a challenge. Therefore a tiered approach for assessing sustainability is proposed to tackle this challenge.

A tiered approach for assessing sustainability

The experience as an LCA practitioner shows that customers mostly starting with a carbon footprint and often perform a full LCA afterwards. Consequently it can be concluded that dealing with environmental impacts or sustainable impacts is a continuous process. Thus a tiered approach is suggested beginning with assessing “basic” impacts in terms of sustainability. Therefore different levels of sustainability assessment are defined including several indicators according to the background information and available data.

Level 1: In a first step screening criteria are included, under consideration of the two limiting factors data and time. For the environmental dimension Climate Change impacts are proposed to be included measured in kg CO2eq. Therefore the complete product life cycle is to be considered. For the economic dimension material and labor costs in connection with the direct production (intermediate products and the final product) as well as consumer costs in terms of purchase measured in e.g. € are to be considered. Within the social dimension the stakeholder group worker is in the main focus. This includes in a first step the wage level for workers for the direct production compared to the non-poverty wage and the existence of labor laws on the country and/or sector level.

Level 2: A more complete picture should be derived by considering mandatory criteria to assess sustainability. Therefore direct and also indirect product data are to be included. For the environmental dimension at least the most common impact categories (climate change, eutrophication, acidification, ozone depletion and photooxidant formation (European Union, 2010)) has to be considered. Within the economic dimension beside the direct costs indirect costs for transportation and energy supply are to be included by meaning of labor costs, but also costs for transportation and energy supply from a consumer perspective. For the social dimension further stakeholder groups are to be considered, e.g. consumer and community, as they might be affected by the product or production of the product.

Level 3: Additional criteria are used to assess advanced sustainability. This includes the consideration of indirect effects for all three dimensions, as so far they are not assessed for the social dimension, e.g. working condition in energy and transport processes. Further specific criteria are to be included, like impacts on biodiversity for the environmental dimension, impacts on self-actualization for the social dimension and indicators describing external effects due to crime, accidents or environmental damages in connection with the product for the economic dimension.

DISCUSSION

Even if the proposed levels are on a very early stage, they might serve as a guide for how to proceed when assessing sustainability. Besides that they can help to increase the awareness of sustainability assessment, as important indicators are named specifically.

One might think that further indicators are to be included, but this first version is more serving as a starting point as it is to be seen as a fixed approach. Over time all levels are to be specified in more detail and developed due to improvements in data and knowledge. It has been noticed that of course this is depending on proper indicators and that a general discussion about the proper framework was so far avoided.

CONCLUSIONS & OUTLOOK

Based on the developed approach assessing sustainability might become easier, as it becomes more understandable and tangible. Further a trade-off between theory and practice was achieved, as one criterion for the used indicators is practicality.

The proposed approach is easily adaptable to new findings and additional or better indicators can be included. Therefore more research will be done by the investigation of established methodologies, e.g. Cost Benefit Analysis, to enhance the existing indicators particularly for the economic dimension targeting the development of impact indicators. In addition indicators are to be developed to consider e.g. regional or product specific problems.

Further, inquiries are under progress to differentiate more precisely between the different indicator levels. Thus, the proposed levels of the tiered approach are adjusted and improved based on the findings within the development of a new sustainability framework.

REFERENCES

Benoit, C., & Mazijn, B. (Eds.). (2009). *Guidelines for social life cycle assessment of products*. UNEP/SETAC Life Cycle Initiative.

European Union. (2010). *ILCD Handbook - Analysis of existing Environmental Impact Assessment methodologies for use in Life Cycle Assessment*. Ispra.

Finkbeiner, M., Inaba, A., Tan, R. B. H., Christiansen, K., & Klüppel, H. (2006). The New International Standards for Life Cycle Assessment : ISO 14040 and ISO 14044. *International Journal of Life Cycle Assessment*, *11*(2), 80–85.

Finkbeiner, M., Schau, E. M., Lehmann, A., & Traverso, M. (2010). Towards Life Cycle Sustainability Assessment. *Sustainability*, *2*(10), 3309–3322. doi:10.3390/su2103309

Goedkoop, M., Heijungs, R., Huijbregts, M., Schryver, A. De, Struijs, J., & Zelm, R. Van. (2009). *ReCiPe 2008 - A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level*. Den Haag.

Hunkeler, D., Rebitzer, G., & Lichtenvort, K. (2008). *Environmental Life Cycle Costing*. CRC Press. doi:10.1201/9781420054736

ISO 14044 Umweltmanagement - Ökobilanz - Anforderungen und Anleitungen (2006). Deutsches Institut für Normung e.V.

Klöpffer, W., & Grahl, B. (2009). *Ökobilanz (LCA): Ein Leitfaden Für Ausbildung und Beruf* (p. 56). John Wiley & Sons. Retrieved from http://books.google.com/books?id=5kqxzNYoXKgC&pgis=1

Social Hotspot Database. (2013). Retrieved May 3, 2013, from http://socialhotspot.org/home-about-shdb/

UNEP, & SETAC. (2011). *Global Guidance Principles for life cycle assessment databases*. Paris.

United Nations. (1987). *Report of the World Commission on Environment and Development - Our Common Future*. (World Commission on Environment and Development, Ed.). Oxford, New York, Toronto: Oxford University Press.

LIFE CYCLE SUSTAINABILITY ASSESSMENT FOR LARGE SCALE PROJECTS IN MANUFACTURING AND PLANT INDUSTRIES

Angelo Marino Huber[1], Heinz Karl Prammer[2]*
[1] *Institute for Management Accounting, Johannes Kepler University, Linz, Austria*
[2] *Environmental Management in Companies and Regions, Johannes Kepler University, Linz, Austria*
** 4040 Linz, Austria. Email address: angelo.huber@jku.at*

Keywords: Lifecycle Sustainability Assessment; Investment Controlling.

ABSTRACT

Large-scale projects like a new line-production may not only change a company's profitability, but also its environmental and social compatibility. However, for a company-specific assessment of such projects, the product-related life cycle methods are suitable to a limited extent, as the project's scope may be broader and moreover, for the implementing company not the sustainability of the project itself, but the effects on the company are of utmost interest. Thus a concept for a sustainable and firm-specific project assessment is outlined, by designing a decision-oriented Life Cycle Costing (LCC) and Life Cycle Assessment (LCA) followed by an overall Sustainability Assessment extended by a Stakeholder-Effect-Analysis.

INTRODUCTION AND GOAL SETTING

Large-scale investment projects like the implementation of a new line-production often lead to decisive changes of entire work processes. Measured against its effects on the natural environment, the employees and on the entire society as a whole, projects of this type may have a lasting effect not only on economic efficiency, but also on the environmental and social credentials of a company and its site. However, compared to a single physical product a Life Cycle Sustainability Assessment (LCSA) of such long-term projects may be far more complex. As with the definition of the functional unit, proving more complex the larger a project's focus is (Guinée, 2002, p. 7, in the context of LCA), the same especially holds true for the definition of the system boundaries, which in the course of a sustainable project life cycle assessment should take into account both, the plant - and the product life cycle (with the latter - e.g. a product manufactured by the new plant – intersecting in the plant's operating phase - see Labuschagne & Brent, 2005, pp. 162-165). For this reason, when regarding large-scale projects, accompanied by several changes in locational capacities (such as buildings, plants, …), going itself through different life cycles and involving perhaps the manufacturing of further products, thus the definition of appropriate system boundaries becomes more difficult. These challenges finally also lead to the core question from a practical, business perspective: How shall a LCSA of large-scale projects be designed and which (economic, ecological and social) effects therefore shall be assessed, in order to assist the facility operator in making sustainable investment decisions that are in line with the focus of the company? Clearly, no general answer can be given therefore, as this depends on the project and the company's motives. But yet it is evident, that at least from a business point of view a company-specific assessment approach is needed. Hence, the central goal is the development of a company-related sustainability assessment for large-scale projects, allowing the decision-maker a transparent separated assessment of the project's economic, ecological and social effects as well as its integrated evaluation with regard to chances and risks for the company.

METHODICAL FRAMEWORK

The indicated concept, containing itself different assessment methods for each sustainability dimension, has been developed in the course of a doctoral thesis (Huber, 2013). Starting from a thorough analysis of the underlying (investment-, decision making-, stakeholder- and system-) theories, followed by a general conception of sustainable project controlling and a critical literature review of possible assessment methods for its practical application, two rather new approaches have been focused on deeply:

- Design of a decision oriented LCC and LCA, by combing a periodic Cash Value Added Accounting with a project-based LCC on the economic side and analogical a corporate eco-balance with a project-based LCA on the ecological side.
- Integrated assessment of economic, ecological and social effects by means of a partially aggregated strengths-weaknesses/chances-risks profile, showing also potential implications for the operator due to the degree of economic, ecological and social performance.

RESULTS AND DISCUSSION

Life Cycle Costing and Life Cycle Assessment of large scale projects

The first approach follows the idea, that decisions on large scale strategic projects, should be based on its contribution to the company's overall performance, including financial and non-financial (e.g. organizational and ecological) implications (Hahn & Laßmann, 1993, pp. 26, 193). However, while a company's overall performance is measured periodically – as on the economic side in terms of a profit and loss account and on the ecological side by a corporate eco-balance – the project's impacts are ideally assessed along its entire life cycle. Clearly, for its possible linkage the use of similar operands and system boundaries is necessary. Regarding the former, at company and project level payments and annuities (as operands allowing also for a due consideration of compound interest and financial effects) are used to calculate the Flow to Equity (FTE), whereas indicators at midpoint level are used for the impact assessment on the ecological side. Concerning scope and time aspects, the focus is limited to decision-relevant payments/annuities (PA) and ecological impacts (EI) caused and avoided due to the project along its life cycle (e.g. additional PA/EI due to the construction of new capacities, avoided PA/EI due to decreased use or disposal of old capacities, …). Put into concrete terms, first these PA/EI are assessed by means of a project-LCC and LCA. Next they are period adjusted to one business year and in further consequence balanced with the accounted PA/EI at company level of the last business year before project planning. Finally compared to an equally modified FTE on the economic side and environmental profile on the ecological side in case of non-implementing the project (e.g. additional caused/avoided PA/EI due to an in- or decreased utilization of old, otherwise closed/continued operating activities) the project's overall effect on a company's profitability and environmental compatibility can be disclosed. Table 1 outlines the procedure and main features of this methodology.

Assessing dimension	Economy	Ecology
Method	**Differential Flow to Equity Account**	**Investment eco-balance**
Goal	Assessing a project's impact on the profitability of the company	Assessing a project's impact on the environm. compatibility of the company
Operands	• Payments / annuities	• Elementary flows (inventory analysis) • Midpoint indicators (impact assessment)
Period-adjustment	Period-adj. of inconstantly accruing payments/env.impacts through imputed items e.g. annuity depreciations + provisions	e.g. ecologic depreciations + provisions
Functional unit	1 Business Year (B.Y.)	
Scope	**Payments/Annuities (PA)** from operative + investment + financing activities ⇨ over the entire project (asset) life cycle $\sum_{t=0}^{n}$ ⇨ of the company (production site)	**Environmental Impacts (EI)** from operative + investment activities ⇨ over the entire project (asset) life cycle $\sum_{t=0}^{n}$ ⇨ of the company (production site)
Decision-oriented Life Cycle approach ⇨ Substantials:	Focus on additional caused and avoided payments/ecological impacts in the event of implementing the project compared to its non-implementation • Period-adjusted Cash Value Added Account • Project-Life Cycle Costing **Σ: Decision-oriented linkage by means of Differential Flow to Equity Account**	• Period-adjusted corporate eco-balance • Project-Life Cycle Assessment **Σ: Decision-oriented linkage by means of Investment eco-balance**
⇨ Decision-oriented linkage:	FTE $_{per\text{-}adj.}$ last B.Y. before project planning t_0 +/- Add. caused/avoided PA in case of project's implementation ⇨ $\sum_{t=0}^{n}$ period-adj. for 1 B.Y. = FTE $_{per\text{-}adj.}$ in case of project implementation FTE $_{per\text{-}adj.}$ last B.Y. before project planning t_0 +/- Add. caused/avoided PA in case of project's non-implem. ⇨ $\sum_{t=0}^{n}$ period-adj. for 1 B.Y. = FTE $_{per\text{-}adj.}$ in case of project's non-implem.	EI $_{per\text{-}adj.}$ last B.Y. before project planning t_0 +/- Add. caused/avoided EI in case of project's implementation ⇨ $\sum_{t=0}^{n}$ per.-adj. for 1 B.Y = EI $_{per\text{-}adj.}$ in case of project implementation EI $_{per\text{-}adj.}$ last B.Y. before project planning t_0 +/- Add. caused/avoided EI in case of project's non-implem. ⇨ $\sum_{t=0}^{n}$ period-adj. for 1 B.Y. = EI $_{per\text{-}adj.}$ in case of project's non-implem.
Result	➔ **Δ Flow to Equity** $_{period\text{-}adjusted}$ = FTE $_{per\text{-}adj.}$ in case of project's implemen. / FTE $_{per\text{-}adj.}$ in case of project's non-implem.	➔ **Δ environmental profile** (Env. Impacts) = EI $_{per\text{-}adj.}$ in case of project's implemen. / EI $_{per\text{-}adj.}$ in case of project's non-implem.

Table 1: Differential Flow to Equity Account and Investment eco-balance

The Differential Flow to Equity Account builds up on related decision-oriented approaches of Riezler (1996, pp. 149-161), Holzwarth (1993, pp. 172-227) combined with the Cash Value Added concept of Lewis (1994), whereas its ecological equivalent - the Investment eco-balance – ties in with the “Eco-Rational-Path-Method” of Schaltegger and Sturm (1994, pp. 207-211) combined with period-adjustments of Steven, Schwarz and Letmathe (1997, pp. 19-21, 190-192), Prammer (1996, pp.214-215) and the impact assessment of Guinée (2002).

Figure 1 gives two examples for visualising the results of the Investment eco-balance, with the left chart showing a T-diagram at midpoint-level, as once proposed by Schmitz and Paulini for a comparative product LCA (1999, p. 24) and the right chart revealing a stronger aggregated strength-weakness profile using the linear scaling of Hoffmeister (2000, p. 289).

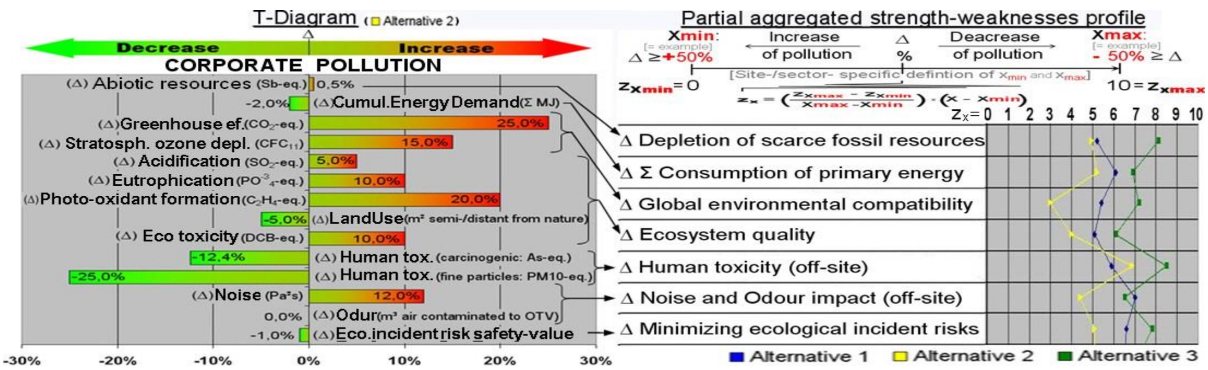


Figure 1: Options for visualizing the results of an Investment eco-balance

Certainly the latter is less objective as it demands a sector and site-specific definition of the minimum and maximum values ($z_{0/10}$), but enables therefore the integration of the Investment eco-balance in an overall sustainability assessment as described below.

Integrated assessment of a project's economic, ecological and social impacts

Once economic, ecological and social effects have been assessed separately, its results are transferred into linear-scaled targetvalues, aggregated to midpoint categories within each sustainability dimension (by arithmetic weighting) and visualised by means of a strength-weakness profile as illustrated before in figure 1 (right side) or below in figure 2 (left side).

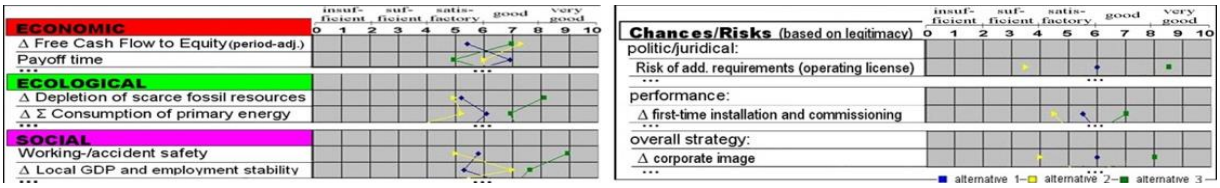


Figure 2: Strength-Weakness/Chances-Risks profile

Finally the left profile is completd by an additional profile (figure 2, right side), disclosing chances/risks associated with different project-alternatives. Based on stimulus-contributing theoretical considerations, therefore a Stakeholder-Effect-Analysis has been developed forcing the decision-maker to identify potential consequences for the company in general and the project in particular. Roughly outlined the analysis begins with a project assessment from the viewpoint of various stakeholders, linking its results to chances/risks caused by a potential change of stakeholders' contributions to the company. Designed as a strategic probability-impact analysis this approach is not necessarily sustainable in a pure altruistic manner, but gives at least incentive to avoid an isolated focus on solely monetary criteria in the first place.

CONCLUSIONS

The outlined concept is obviously only decision-oriented in a wider sense, as finally no single score is calculated. However, the advantage of the concept is its transparency, aggregating the single results only to company-specific midpoint categories and thereby supporting the company to come to sustainable and strategically conforming investment-decisions.

REFERENCES

Guinée, J.B. (2002). *Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards.* Dordrecht, NL: Kluwer Academic Publishers.

Hahn, D., & Laßmann, G. (1993). *Produktionswirtschaft - Controlling industrieller Produktion: Band 3/2: Informationssystem*. Heidelberg, DE: Physica-Verlag.

Hoffmeister, W. (2000). *Investitionsrechnung und Nutzwertanalyse.* Stuttgart, DE: Kohlhammer-Verlag.

Holzwarth, J. (1993). *Strategische Kostenrechnung?* Stuttgart, DE: Schäffer-Poeschel-Verlag.

Huber, A. M. (2013). *Die nachhaltigkeitsorientierte Investitionsentscheidung. Ein Konzept zur ökonomisch, ökologisch und sozial ausgewogenen Bewertung*. Linz, AT: doctoral thesis.

Labuschagne, C., & Brent, A.C. (2005). Sustainable Project Life Cycle Management. *International Journal of Project Management*. *23*(2), 2005, 159-168. doi: 10.1016/j.ijproman.2004.06.003

Lewis, T.G. (1994). *Steigerung des Unternehmenswertes.* Landsberg am Lech, DE: Verlag Moderne Industrie.

Prammer, H.K. (1996). *Einsatzgebiete und Leistungsfähigkeit ökobilanzieller Bewertungsverfahren* (pp. 211-243). In. Malinsky, A.H. (Ed.) Betriebliche Umweltwirtschaft. Wiesbaden, DE: Gabler-Verlag.

Schaltegger, S. & Sturm, A. (1994). *Ökologieorientierte Entscheidungen in Unternehmen*. Bern, CH: Haupt-Verlag.

Schmitz, S., & Paulini, I. (1999). *Valuation as an element of life cycle assessments.* 1999 version. Berlin, DE: German Federal Environmental Agency. http://www.umweltdaten.de/publikationen/fpdf-l/3620.pdf

Steven, M., Schwarz, E.J., & Letmathe, P. (1997). *Umweltberichterstattung und Umwelterklärung nach der EG-Öko-Audit Verordnung*. Berlin, DE: Springer-Verlag.

Riezler, S. (1996). *Lebenszyklusrechnung*. Wiesbaden, DE: Gabler-Verlag.

MULTI-CRITERIA ASSESSMENT MODEL FOR CARBON CAPTURE AND STORAGE SYSTEMS

Erik Skontorp Hognes[*,a]*, Amy L. Brunsvold*[b]*, Jana P. Jakobsen*[b] *and Simon Roussanaly*[b]
[a]*SINTEF Fisheries and aquaculture, PB 4762 Sluppen, 7465 TRONDHEIM.*
[a] *SINTEF Energy Research, Trondheim, Norway*
** Tel.: +47 40 22 55 77, E-mail: erik.hognes@sintef.no*

Keywords: CCS; hybrid LCA, sustainability assessment; multi criteria

ABSTRACT

A flexible and transparent multi-criteria model is being developed to evaluate the sustainability of carbon capture technologies and chains: to guide policy makers, investors and technology developers on important challenges and opportunities. The model is built with a techno-economic and a GHG assessment with a hybrid LCA approach. The model has demonstrated important benefits from combination of economic and process data, such as making the analysis more efficient and how a GHG assessment can expand the scope and of a techno-economic assessment.

INTRODUCTION

Carbon Capture and Storage (CCS) is considered to be one of the most promising alternatives for reducing anthropogenic greenhouse gas emissions (Rochelle, 2009). To bring CCS closer to commercial realization, its sustainability must be explored by multi-criteria assessments that take into account economic, environmental and social aspects (J. P. Jakobsen et al., 2011; J.P. Jakobsen, Roussanaly, Tangen, & Mølnvik, 2012; J. P. Jakobsen, Tangen, Nordbø, & Mølnvik, 2008).

This project is part of the international CCS research center BIGCCS (Aarlien, 2009) and its aims are to develop a model that

- Is flexible and cover several types of technologies, governing parameters (e.g. varying energy and CO_2 quota prices) and sustainability aspects

- Is transparent, coherent and efficient. The model should provide decision makers with clear and applicable information.

CCS technologies have been studied with LCA for more than ten years, but it is still a challenge to make LCA thinking and results an operational part of CCS development.

METHODS

The model is built as a set of building blocks (modules) that each model a specific part of CCS chains, such as capture, transport and storage technologies. These modules can be

combined to study different CCS chains. Each module cover a wide range of economic and environmental key performance indexes, such as: net present value of costs, potential climate impact, initial investment amount, and utilities (water, electricity and fuel) consumption. So far modules for amine based post-combustion capture and two different transport technologies are developed: onshore pipeline and shipping between harbors. The technologies that are covered are under continuous expansion.
Each module contains a techno-economic assessment and a GHG assessment based on inputs from process modeling and data found in literature. The economic assessment methodology is presented in the article "Techno Economic Evaluation of Amine based CO_2 Capture: Impact of CO2 Concentration and Steam" (Husebye, Brunsvold, Roussanaly, & Zhang, 2012).

The GHG assessments cover materials and energy used in operational and capital expenses, and is performed as a hybrid-LCA by combining physical processes data with economic data from the techno economic assessment (figure 1). A hybrid LCA approach has advantages as it ensures consistency between the economic and environmental assessments and it can compensate for the incomplete system boundaries, and underestimation of net environmental impact, that can be the result of a purely process based LCA (Lenzen, 2000; Suh, 2004). Combining data is also efficient with regards to necessary resources to perform the studies and makes it easier to build a clear and transparent model.
The process data is modeled with data from Ecoinvent 2.2 (EcoInvent, 2012) and the economic data is modeled with an environmentally extended input output database published by Carnegie Mellon University (eiolca.net, 2008).

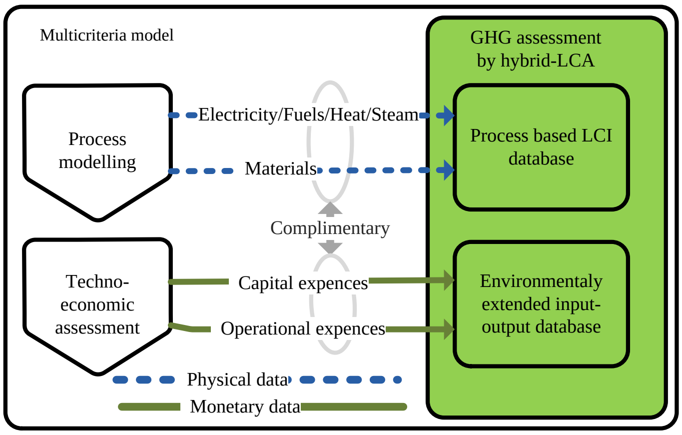


Figure 1 Illustration of hybrid-LCA GHG assessment

RESULTS AND CONCLUSIONS

The project demonstrates that cooperation between experts in CCS technology, techno-economic assessment and LCA can build a robust and efficient multi-criteria assessment model. The use of the model has also demonstrated that a multi criteria model can increase the scope and precision of each of the assessments within the model through internal exchange of data.

To study the use of the assessment model it was applied on two cases: one looking at amine post capture from flue gas with different CO_2 concentrations (Husebye, et al., 2012; Roussanaly, Brunsvold, Hognes, Jakobsen, & Zhang, 2013) and one case comparing different technologies to transport CO_2 from capture to storage (Roussanaly, Hognes, & Jakobsen, 2013). The first case study demonstrated the expected correlation between CO_2 concentrations: capturing at very low concentrations is costly both in terms of economy and GHG emissions. More interesting was to study how the results of the GHG assessment could be fed back to the economic assessment: The results of the GHG assessment was used to estimate what could be the future price of the operational and capital expenses if the GHG emissions they cause are reflected in their price: That their external climate costs are integrated into their price. Figure 2 illustrates how the cost per unit of CO_2 avoided decrease as the CO_2 concentration in the flue gas (the exhaust into the capture process) increase. The grey part is what is captured with a regular techno-economic assessment. The black part illustrates what could potentially be added if the GHG emissions caused by the capital and operational expenses of the capture process are reflected in their price.

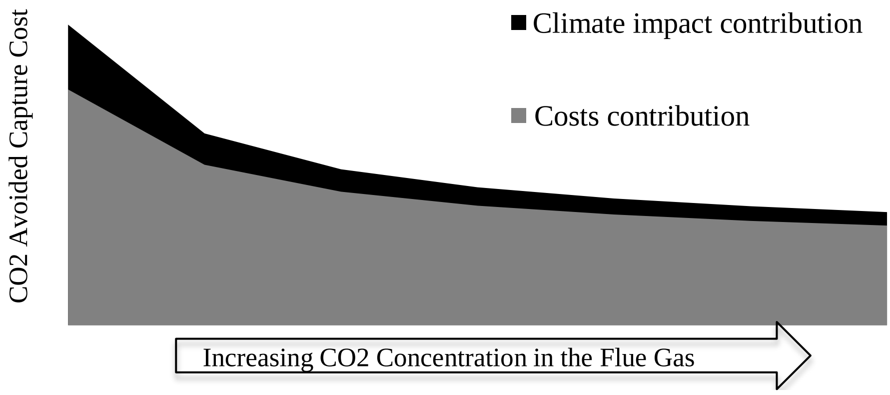


Figure 2 Illustration of the cost per unit of CO2 avoided with post amine capture for increasing CO2 concentration in the flue gas (Roussanaly, Brunsvold, et al., 2013).

DISCUSSION

Decision makers among energy producers and CCS technology developers have welcomed the model. New case studies are now being planned: To study the use of the model and how it can expand the understanding of CCS technologies and provide applicable information.

The model and its modules and assessments are under continuous expansions and improvement. The hybrid-LCA aims at expanding the selection of environmental impacts it includes. Already water consumption is partly included (Roussanaly, Hognes, et al., 2013), but the goal is to expand to a more complete range of impact assessment methods. In this phase the availability of public environmentally expanded input-output databases are challenging. Especially it is challenging to understand how and if different databases like ecoinvent and the Carnegie Melon database can be combined for different environmental impacts. They are not applicable for the exact same impact assessment methods, thus one might end up combining apples and bananas. Expansion of publically available environmentally expanded input output data is not within the scope of this project, but there are several promising initiatives to make such databases publically available, and hopefully in formats that makes it easier to combine them with the established process based LCA databases.

ACKNOWLEDGEMENTS

This publication has been produced with support from the BIGCCS Centre, performed under the Norwegian research program Centres for Environment-friendly Energy Research (FME). The authors acknowledge the following partners for their contributions: Aker Solutions, ConocoPhillips, Gassco, Shell, Statoil, TOTAL, GDF SUEZ and the Research Council of Norway (193816/S60).

REFERENCES

Aarlien, R. (2009). BigCCS International CCS Research Centre, from http://www.sintef.no/projectweb/bigccs/

EcoInvent. (2012). EcoInvent life cycle inventory database v2.2: The Ecoinvent Centre, swizz center for life cycle inventories www.ecoinvent.org.

eiolca.net. (2008). Carnegie Mellon University Green Design Institute: Economic Input-Output Life Cycle Assessment (EIO-LCA), US 1997 Industry Benchmark model], Available from: www.eiolca.net

Husebye, J., Brunsvold, A. L., Roussanaly, S., & Zhang, X. (2012). Techno Economic Evaluation of Amine based CO2 Capture: Impact of CO2 Concentration and Steam Supply. *Energy Procedia, 23*(0), 381-390. doi: http://dx.doi.org/10.1016/j.egypro.2012.06.053

Jakobsen, J. P., Brunsvold, A., Husebye, J., Hognes, E. S., Myhrvold, T., Friis-Hansen, P., . . . Torvanger, A. (2011). Comprehensive assessment of CCS chains-Consistent and transparent methodology. *Energy Procedia, 4,* 2377-2384. doi: 10.1016/j.egypro.2011.02.130

Jakobsen, J. P., Roussanaly, S., Tangen, G., & Mølnvik, M. (2012). Developing framework for multi-criteria analysis of CCS: A standardized approach to the assessment of CCS projects. *Submitted to Energy Procedia - GHGT-11 special edition.*

Jakobsen, J. P., Tangen, G., Nordbø, Ø., & Mølnvik, M. J. (2008). Methodology for CO2 chain analysis. *International Journal of Greenhouse Gas Control, 2*(4), 439-447.

Lenzen, M. (2000). Errors in Conventional and Input-Output—based Life—Cycle Inventories. *Journal of Industrial Ecology, 4*(4), 127-148. doi: 10.1162/10881980052541981

Rochelle, G. T. (2009). Amine Scrubbing for CO2 Capture. *Science, 325*(5948), 1652-1654. doi: 10.1126/science.1176731

Roussanaly, S., Brunsvold, A., Hognes, E. S., Jakobsen, J. P., & Zhang, X. (2013). Integrated techno-economic and environmental assessment of an amine-based capture. *Accepted in Energy Procedia - GHGT-11 special edition*.

Roussanaly, S., Hognes, E. S., & Jakobsen, J. P. (2013). Multicriteria benchmark of two transport technologies. *Accepted in Energy Procedia - GHGT-11 special edition*.

Suh, S. (2004). Functions, commodities and environmental impacts in an ecological-economic model. *Ecological Economics, 48*(4), 451-467.

SOCIAL ASSESSMENT OF TECHNOLOGIES: THE INNOVATIVE APPROACH OF PROSUITE

J. Fontes [1], A. Ciroth [2], J. Franze [2], A. Ramírez [3], A. Haaster [3], P. Sellke [4]*

[1] PRé Consultants, [2] GreenDeltaTC, [3] Utrecht University, [4] Dialogik

[*] Printerweg 18, 3821AD Amersfoort, The Netherlands, fontes@pre-sustainability.com

Keywords: social LCA; social assessment; technology assessment; PROSUITE.

ABSTRACT

The introduction of a novel technology can have profound impacts on nature and society. Within PROSUITE, a general methodology is developed in order to assess the sustainability impacts of a novel technology, including a methodology for evaluating on the impacts on society and social well-being. The approach includes the methodology for modelling the life cycle, guidelines for the performance assessment, description and operationalization of indicators, aggregation along the life cycle, data collection and a method for dealing with data uncertainty. Social impacts include impacts on knowledge-intensive jobs, total employment, risk perception, possibility of misuse, child labour, forced labour, trust in risk information, stakeholder involvement, long-term control functions, regional income inequalities and global inequalities.

INTRODUCTION

While the demand for transparency regarding the sustainability impacts of new and existing technologies increase, different stakeholders including policy makers, industries, SMEs and NGOs need a methodology and a tool to assess these impacts. Such methodology should enable these stakeholders to make decisions that take into account potential economic, social and environmental impacts of technologies, not only considering present impacts but also those based on future scenarios.

A well-accepted and robust methodology is still lacking. PROSUITE (PROspective SUstaInability Assessment of TEchnologies) aims to address this issue. This FP7 European project brings together European researchers with expertise in each of the three sustainability areas - economy, environment and society - and industry partners to develop a well grounded methodology, as well as a freeware open source tool to allow prospective sustainability life cycle assessment of technologies.

This paper presents the interim results of the working group that is dedicated to the social assessment within PROSUITE. A series of methodological issues have been addressed, including: i) which social aspects should be included in the assessment, ii) how to model and assess social indicators along the life cycle, and iii) which data sources are available and to which extent they can be used as proxies.

METHODS

This work is based on literature review and stakeholder consultation, i.e. following a top-down and bottom-up approach. At first, experts from social sciences were consulted in group-Delphis to help identifying the indicators that should be included in the social assessment. Following these consultations, the indicators were shortlisted and then evaluated by the project team who made the final selection of social indicators. The following tasks were developed based on the final list of social indicators and additional literature review.

RESULTS

Social aspects included in the assessment

The social indicators in PROSUITE address four midpoints: '*safety, security and tranquillity*', '*autonomy*', '*participation and influence*', and '*equal opportunities*'. As understood by the project team, these midpoints cover the most critical issue that can be associated with applications of technologies. These midpoints are then aggregated in PROSUITE in the endpoint '*social well-being*'. The social indicators are presented in Table 1.

Table 1: Social midpoints and indicators in PROSUITE

Midpoints	Indicators
Safety, security and tranquillity	Knowledge-intensive jobs
	Total employment
	Increased risk perception
	Possibility of misuse
Autonomy	Child labour
	Forced labour
Participation and influence	Trust in risk information
	Stakeholder involvement
	Long-term control functions
Equal opportunities	Regional income inequalities
	Global income inequalities

Modelling the social indicators along the life cycle

There are two types of indicators which are then modelled in different ways:

- Extensive indicators: These indicators are process-specific and can be attributed to processes in the life cycle (e.g. total employment, and child labour). They are assessed on the process level.
- Intensive indicators: These indicators are not process-specific and can only be associated with the product as a whole (e.g. possibility of misuse by terrorists, and increased risk

perception). Therefore these indicators are analyzed on the level of life cycle stages. The PROSUITE case studies of mobile phones (Judl et al, 2012) and carbon capture follow a similar approach.

Ultimately, all life cycle stages that are relevant for the investigated product should be covered in the assessment. This may include the infrastructure that is demanded by each life cycle stage, which in turn has its own life cycle as shown in Figure 1. Relevance is determined by risk assessment and it needs to be made explicit when defining the system boundaries. Usually after applying such a risk filter, a second order of a product life cycle and the related infrastructure are not going to be included in the assessment.

Assessing social indicators
The performance assessments in PROSUITE evaluates the social performance of a technology application throughout its life cycle. It is based on the application of performance reference points (Ciroth & Franze, 2011; Fontes et al., 2012) in a Likert scale (Diekmann, 2003). International conventions and sector standards are normally considered when defining the performance reference points (PRPs). Table 2 illustrates the assessment of a given process in the life cycle based on PRPs for each indicator.

Table 2: Performance assessment of a specific process of a technology application

Category	Subcategory	Score
Safety, security & tranquillity	Knowledge-intensive jobs	-2
	Total employment	+2
	Risk perception	+2
	Risk of misuse	0
Autonomy	Child labour	-1
	Forced labour	-2
Participation & influence	Trust in risk information	-2
	Involvement of stakeholders in decision making process	+1
	Trust that long-term control will is safeguarded	-2
Equal opportunities	Income distribution	0
	Global equity	0

After the performance assessment, scores are attributes to all selected indicators, either on the level of processes for the extensive indicators, or on the level of life cycle stages for the extensive indicators.

Data sources available and usability
As for any other social assessment, the issue of lack of data also holds for PROSUITE. It was found that two databases can provide data to some extent for the case studies of PROSUITE: the Social Hotspots Database (SHDB, 2013) and EXIOBASE (EXIOBASE, 2013). For PROSUITE, the main advantage of EXIOBASE in comparison to the SHDB is the fact that it can support the assessment of both current and prospective scenario. Another advantage of

EXIOBASE is that it can provide for both the economic and social assessments, ensures consistency within PROSUITE.

Moreover, five indicators are not covered by any of these two databases. As a result, these indicators can only be assessed based on literature review. Having said this, both databases can help prioritizing data collection as they can help identifying the most critical sectors and countries in the life cycle in terms of working hours or economic value.

DISCUSSION AND CONCLUSIONS

As the PROSUITE project continues to develop, the following issues are to be addressed: 1) how to relate a technology application with the scenario assessment, 2) how to carry out prospective social assessment, 3) how the social indicators should be measured, 4) how the social indicators should be aggregated in midpoints and endpoint, and 5) what normalization factors can be applied.

The prospective assessment remains particularly challenging. It demands in-depth knowledge of the technology application in the current scenario and the consequences that can be expected in the future scenario. It will inevitably require the user of PROSUITE to extrapolate data and make assumptions.

There is an evident need to test the elements of the framework that have been developed and those that are going to be added. The PROSUTE case studies will play a fundamental role on this regard.

Once integrated in the PROSUITE decision support system, this module will help assessing the potential impact of a technology regarding the well-being of individuals and society as a whole.

REFERENCES

Ciroth, A., & Franze, J. (2011). LCA of an Ecolabeled Notebook - Consideration of Social and Environmental Impacts Along the Entire Life Cycle. ISBN 978-1-4466-0087-0

Diekmann, A. (2003). Empirische Sozialforschung. *Rowohlt Deutsche Enzyklopädie*

EXIOBASE (2013). Exiobase Input Output Database, http://www.exiobase.eu/

Fontes, J., Goedkoop, M., Gupta, J.D., East, C. (2012). An approach for measuring and managing social sustainability at product level. LCA XII Conference, http://lcacenter.org/lcaxii/draft-presentations/604.pdf

Judl, J., Mattila, T., Seppälä, J., Koskela, S., & Kautto, P. (2012). Challenges in LCA Comparisons of Multifunctional Electronic Devices. *IEEE Explore*

SHDB (2013). Social Hotspot Database, http://socialhotspot.org/

TOWARDS A PRACTICAL APPLICATION OF LIFE CYCLE SUSTAINABILITY ANALYSIS (LCSA)

Henriksson PJG, Guinée JB*
**Institute of Environmental Sciences (CML), Leiden University*
Einsteinweg 2, 2333 CC Leiden, Netherlands
henriksson@cml.leidenuniv.nl

Keywords: LCSA, LCI, Asia, data collection

ABSTRACT

As part of the on-going SEAT (Sustaining Ethical Aquaculture Trade) project, an integrated approach was developed for collecting life cycle costing (LCC) and life cycle assessment (LCA) data for several actors throughout Asian aquaculture value chains. Parallel to this effort, also socio-economic data were collected, but only for grow-out farms. Because of differences in the analytical approach for socio-economic impacts, a larger sample of 35 farmers per farming system was selected for livelihood surveys. Meanwhile, a wider vertical approach was taken for LCA and LCC data at sample sizes between five and ten. Several challenges were encountered with regards to sensitive topics, from economic information on farms, to the number of children in China, to the use of controversial chemicals. However, the overall outcome was an extensive database of - what could be called - aquaculture LCSA data.

INTRODUCTION

Quantifying the economic, environmental and social sustainability of production chains is desirable in order to evaluate the overall sustainability of products. As a result of this, life cycle assessment (LCA), life cycle costing (LCC) and social life cycle assessment (SLCA) have evolved alongside each other. When implemented alongside each other, at least one dimension of life cycle sustainability assessment (LCSA) is performed (Guinée et al., 2011).

Of these three methods, LCC has the longest history while LCA has the most elaborated methodology and also a supporting ISO standard (14040-14044, 2006). SLCA, on the contrary, is the youngest and least evolved of the methods, probably because of its more qualitative nature. Each method also has its own set of challenges with regards to choice of indicators, data requirements and data evaluation. While several theoretical advancements have been made towards harmonizing the LCSA methodology (Zamagni 2012), few practical cases of its application exist (Traverso *et al.* 2012). According to the UNEP-SETAC guidelines (Valdivia et al. 2011): “The availability of data is another aspect that must be considered; this may be a critical issue in developing countries and in small and medium enterprises when conducting”.

Data collection is often one of the most time and resource consuming stages when building life cycle inventories (LCIs). Maximising efficiency by implementing a cross-

The present research is part of the EU FP7 funded Sustaining Ethical Aquaculture Trade (SEAT) project. The SEAT project aims to evaluate the sustainability and ethical aspects related to increasing imports of tilapia (Tilapia spp.), Pangasius catfish (Pangasius spp.), shrimp (P. monodon and P. vannamei), and freshwater prawns (Machrobrachium spp.) from China, Thailand, Vietnam, and Bangladesh (www.seatglobal.eu). The SEAT project involves twelve work packages (WPs), which include LCA, LCC, and livelihood surveys. Beyond this, the SEAT project includes WPs focusing on food safety and public health, global value chain analysis, ethical frameworks, risk assessment and environmental modelling, all which can provide underlying data for the LCSA.

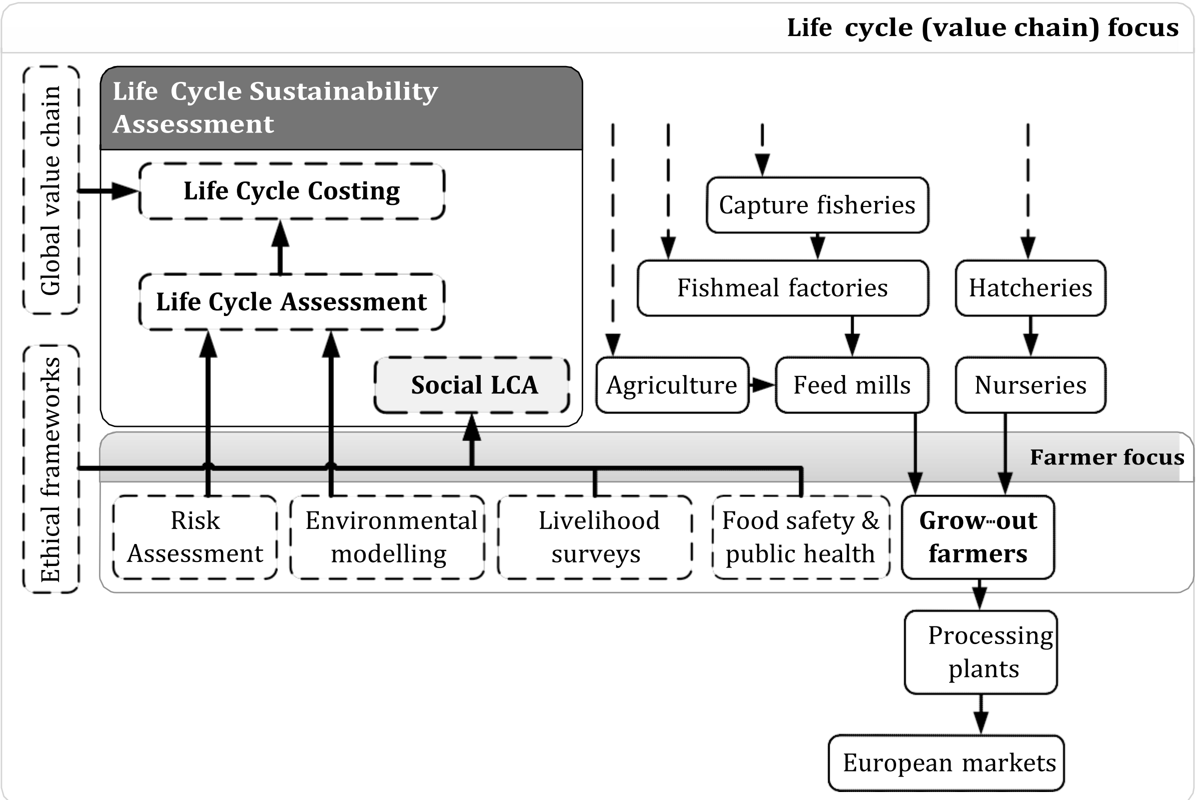


Figure 1: Structure and information flows within the SEAT project. Work packages are indicated by dashed lines and actors in the value chain by solid lines. While most WPs focus on aquaculture farmers, several work-packages have a lifecycle approach.

With most LCSA research being made on a theoretical level, the present research explores the practical hurdles that need to be overcome for efficient data collection. In this study we will focus on data collection for Asian aquaculture value chains, involving mainly small and medium enterprises. Whilst originally not intended as an LCSA exercise, the outcomes of the present research provides practical recommendations, useful when collecting and evaluating data from a lifecycle perspective.

METHODS

During late 2010 and early 2011, a project wide integrated survey was carried out, collecting basic data on 1 600 randomly selected aquaculture farms in Bangladesh, China, Thailand and

Vietnam, describing farming practices of two different species in each country (Murray et al. *in prep.*). Following this, in-depth data collection activities were started. For this, a questionnaire detailing inventory and cost data for the most relevant inputs and outputs of aquaculture farmers was developed. Information on social well-being was included in the form of a livelihood survey, detailing household structure, private possessions, family balance, social interactions with the community, as well as access to natural resources, food, and infrastructure (Kruijssen et al. *in prep*). In addition, a joint LCA and LCC questionnaire was developed for farmers and other actors in the value chain (Figure 1), while focus group discussions (FGDs) were conducted to capture socially relevant indicators beyond the farm. Trials with the questionnaires were carried out in 2011 with the ambition of reducing each interview to less than one hour and revise any questions which could be misinterpreted or inappropriate. The final questionnaires and checklists were summarised in the guidelines for data collection (Kruijssen et al. *in prep.*).

The in-depth data collection, using the guidelines, was carried out for a sub-sample of farmers from the integrated survey. The sub-sample was selected from groups of farmers, which each represented the most prominent farming practices (e.g. extensive and intensive) identified from the integrated survey. Within each group, a random sample of farms was generated and data was collected between 2011 and early 2012. The sample sizes needed for the quantitative livelihood analysis were bigger than those needed for the LCA and LCC. A minimum sample size of 35 farmers per group was determined for the livelihood surveys, in order for it to be normally distributed., Meanwhile, a minimum sample size of only 5 farms per group was deemed sufficient for LCA and LCC data. The owner of each farm/factory was targeted for the interview. However, in many cases other employees were the only persons available. Certain cut-off points needed to be implemented with regards to unique practices with negligible contributions to country-wide production, and geographically remote areas.

Beyond stating that the system boundaries should remain identical for all three assessments, the UNEP-SETAC guideline (Valdivia et al., 2011) gives little guidance on data collection. In the present study, resource limitations restricted the extent of the livelihood surveys to the aquaculture farm level. Other actors in the value chain were evaluated using key informant interviews and focus group discussions were facilitated (Kruijssen et al. *in prep.*).

RESULTS AND DISCUSSION

The most relevant data needed for the three methods were possible to collect in less than one hour. In cases where the interviews for various reasons exceeded one hour, a noticeable decline in data quality was often noticeable. The guidelines were generally applicable to all four countries without any modification. Certain questions were, however, found to be sensitive in some countries, e.g. number of children in China given the one-child policy. Some farmers also overestimated or underestimated certain variables, in order to seem more successful or to avoid risk of theft. Livelihood data proved to be the most resource demanding to collect, and also most difficult to quantify. SLCA data is also most scarce and inconsistent amongst secondary data sources, while several secondary databases are available for LCA and LCC data.

China displayed the large diversity in farming practices, and was therefore also the country where most in-depth surveys were conducted. Bangladesh, in the meantime, exhibited the longest value chains with several value additions between producers, middlemen and consumers. In Vietnam, vertically integrated companies were common, where one company owns e.g. both the farm and the processing factory. Thailand, being the most developed of the four countries, housed two distinctly different production chains, that for the domestic market, and that for the international market.

Small and medium enterprises were often more accessible than large enterprises. While most grow-out farmers were welcoming us, most large companies needed long correspondence or introductions before any physical appointment could be set up. The position in the company hierarchy of the interviewed could also influence accessibility and results. For example, a technician would be able to provide far more accurate data on more technical LCA related questions, while an office clerk could have more information on monetary LCC related data. Farm/company owners generally possessed the widest range of information, and were also most willing to share their knowledge. Employees were more reluctant to talk about company practices and policies, as they feared to give away sensitive information. The position of the person interviewed also had a strong influence on the livelihood results.

CONCLUSIONS

Inventory data collection is generally the most time and resource demanding stage of any LCSA study, especially for small and medium enterprises in less developed countries. Building upon an interdisciplinary data collection therefore optimises the inventory data collection and assures consistency amongst the three methods of LCSA. The present study showed how such a data collection could be setup, even for small and medium sized enterprises in developing countries. However, of the three methods, SLCA (livelihood) data proved to require the largest sample sizes and also proved most difficult to quantify. Culturally diverse characteristics also highlighted the importance of conducting fieldwork in order to understand and identify production practices.

REFERENCES

Guinée, J. B., Heijungs R., Huppes G., Zamagni A., Masoni P., Buonamici R., Ekvall T., Rydberg T. (2011). Life cycle assessment: Past, present and future. Environmental Science and Technology, 45, 1, 90–96. doi: 10.1007/s11367-012-0431-x

ISO 14044. (2006). Environmental management—Life Cycle Assessment— Requirements and Guidelines (ISO 14044:2006). Geneva, Switzerland.

Traverso M., Asdrubali F., Francia A., Finkbeiner M. (2012). Towards life cycle sustainability assessment: An implementation to photovoltaic modules. International Journal of Life Cycle Assessment, 17, 1068-1079. doi:10.1007/s11367-012-0433-8

Valdivia S., Ugaya C.M.L., Sonnemann G., Hildenbrand J. (editor). (2011). Towards a life cycle sustainability assessment - Making informed choices on products. ISBN:978-92-807-3175-0. Paris, France. Retrieved from http://lcinitiative.unep.fr

Zamagni A. (2012). Life cycle sustainability assessment. International Journal of Life Cycle Assessment, 17, 373-376. doi:10.1007/s11367-012-0389-8

USE OF MULTI CRITERIA DECISION ANALYSIS TO SUPPORT LIFE CYCLE SUSTAINABILITY ASSESSMENT: AN ANALYSIS OF THE APPROPRIATENESS OF THE AVAILABLE METHODS

Marco Cinelli[1,], Stuart R. Coles[1], Kerry Kirwan[1]*

[1] WMG, International Manufacturing Centre, University of Warwick, Coventry, CV4 7AL, UK

** Corresponding author e-mail address: m.cinelli@warwick.ac.uk*

Keywords: multi-criteria-decision-analysis; sustainability assessment; data integration.

ABSTRACT

Main multi criteria decision analysis methods (i.e. MAUT, AHP, ELECTRE and PROMETHEE) were assessed with 10 criteria considered pivotal in sustainability assessments, from life cycle perspective and thresholds use to uncertainty management. It resulted that MAUT and AHP are fairly simple to use and have good software support, but can only uphold a weak sustainability perspective. Concerning ELECTRE and PROMETHEE, they can enforce strong sustainability concept, deal well with thresholds, support dynamic results re-evaluation, but suffer from rank reversal and are quite complex. Overall, the analysis has indicated that multi criteria decision analysis methods are appropriate for supporting life cycle sustainability assessment.

INTRODUCTION

Life Cycle Sustainability Assessment (LCSA) represents a set of methodologies/tools that can cover different spheres, scales and objectives of sustainability (i.e. micro, meso and macro) (Cinelli et al., 2013; Zamagni et al., 2009).

Multi criteria decision analysis (MCDA) is considered an appropriate set of methods for the "assessment of sustainability" (Gasparatos & Scolobig, 2012), and this study investigates how MCDA can contribute to LCSA, analyzing the main MCDA methods, namely multi attribute utility theory (MAUT), analytical hierarchy process (AHP), ELECTRE and PROMETHEE, on the basis of 10 criteria that they should satisfy to appropriately deal with problems concerning sustainable development.

MATERIALS AND METHODS

The analysis of the MCDA methods was performed with the following criteria derived and assessed from several sources (Antunes et al., 2012; Belton & Stewart, 2002; Benoit & Rousseaux, 2003; Buchholz, Rametsteiner, Volk, & Luzadis, 2009; Munda, 2005, 2008; Polatidis, Haralambopoulos, Munda, & Vreeker, 2006; Rowley, Peters, Lundie, & Moore, 2012; Sala, Farioli, & Zamagni, 2012; Teghem, Delhaye, & Kunsch, 1989): (i) inclusion of life cycle perspective; (ii) compensation degree among sustainability spheres; (iii) weights expressed as trade-offs or importance coefficients; (iv) thresholds use to support preferences and analytical uncertainties management; (v) handling of qualitative and quantitative information; (vi) uncertainty treatment/sensitivity analysis; (vii) rankings robustness; (viii) software support and graphical representation; (ix) methods ease of use; and (x) learning dimension to support dynamic re-evaluation.

RESULTS

The results of the comparisons of the MCDA methods based on the 10 criteria are shown with the related references in Table 1 and they are briefly described below. 3 colors have been used to indicate the performance (i.e. green = good; orange = depends on the case; red = bad) of each group of methods in relation to each criterion on the basis of a sustainability-oriented evaluation perspective, specifically the strong one.

Firstly, all the MCDA methods analyzed can include a life cycle perspective.

MAUT and AHP score badly on compensation and weights as importance coefficients, since they assume a complete compensability among the criteria, whereas ELECTRE and PROMETHEE do not allow or limit such feature. ELECTRE and PROMETHEE can also handle effectively different thresholds, mixed information and uncertainty. Also AHP and MAUT score positively for the last two criteria, whereas they perform poorly on thresholds.

All the methods are supported by specific software that allow for medium/wide range of graphical results representation, except the ELECTRE ones whose graphics interface is poor.

AHP is considered as the easiest set of methods, followed by PROMETHEE and MAUT, while the ELECTRE ones are classified as fairly difficult.

Lastly, dynamic results re-evaluation is only possible in the case of the PROMETHEE methods, while MAUT is the only one which cannot be affected by rank reversals.

DISCUSSION

The analysis has shown that there is not a clear agreement among different authors concerning several criteria (see Table 1). Nonetheless, some considerations can be derived starting from the positive fact that all the methods can conceptually include all the life stages of a product.

MAUT and AHP can only use a weak sustainability perspective with trade-offs as the norm, whereas ELECTRE and PROMETHEE enforce a strong one, by limiting or abolishing the compensation among/within sustainability spheres.

All the methods can deal with mixed information and manage at different extents uncertain weights and criteria, while robust results can only be obtained with MAUT and rankings re-evaluation with PROMETHEE, leaving the others with a big disadvantage.

CONCLUSIONS

Several MCDA methods that can support LCSA are available, and in this paper, MAUT, AHP, ELECTRE and PROMETHEE were evaluated on the basis of 10 criteria crucial for

Evaluation criteria	MAUT	AHP	ELECTRE	PROMETHEE
Life cycle perspective	Possible[4]	Possible[4]	Possible[4]	Possible[4]
Compensation (i.e. weak vs strong sustainability)	Full[1,2,3,5,7,8,9,12]	Full[2,3,5,7,8,12]	Non possible[1,2,3,5,7,12] / Partial[1,2,8]	Partial[1,5,7,8] / Full[2]
Weights type	Trade-offs[3,7,8,9,10,11,12]	Trade-offs[3,7,8,12] / Importance coefficients[11]	Importance coefficients[3,7,8,11,12]	Importance coefficients[3,7,12] / Trade-offs[8]
Threshold values	Not possible[5,8] / Possible[6]	Not possible[5,6]	Possible[1,5,7,11,12]	Possible[1,5,6,7,10,12]
Qualitative and quantitative data	Possible[5,6,11]	Possible[5,6,11]	Possible[5,7,11]	Possible[1,5,7]
Uncertainty treatment/Sensi-tivity analysis	Possible[4,5,6,7,10,11]	Partially possible[5,6] / Possible[9]	Possible[4,5,7]	Possible[4,5,7,10] / Partially possible[6]
Robustness	No rank reversal is possible[5,8]	Rank reversal can occur[5,8]	Rank reversal can occur[5,8]	Rank reversal can occur[5,8]
Software support and graphical representation	Software available with wide range of graphical representation available[5,6,11]	Software available with wide some graphical representation available[5,6,9,11]	Software available, but with poor graphical interface[5]	Software available with wide range of graphical representation available[5,6]
Ease of use	High[5,6] / Low[7,8]	High[6] / Medium[5]	Low[5,7,8,11]	Medium[5,6,7,8]
Learning dimension based on software	Difficult[5,6]	Difficult[5,6]	Difficult[5]	Simple with scenario analysis[5,6]

Table 1: Comparisons of different MCDA methods ([1]: (Benoit & Rousseaux, 2003), [2]: (Teghem, et al., 1989), [3]: (Munda, 2005), [4]: (Belton & Stewart, 2002), [5]: (Antunes, et al., 2012), [6]: (Buchholz, et al., 2009), [7]: (Polatidis, et al., 2006), [8]: (Munda, 2008), [9]: (De Montis, De Toro, Droste-Franke, Omann, & Stagl, 2000), [10]: (Raju & Pillai, 1999), [11]: (De Montis, De Toro, Droste-Franke, Omann, & Stagl, 2005), [12]: (Rowley, et al., 2012))

such assessments. It emerged that all the methods can include mixed data and life cycle perspective. ELECTRE and PROMETHEE score better than MAUT and AHP in terms of enforcement of a strong sustainability approach, together with thresholds management. Nonetheless, they suffer from robustness, and partially for simplicity and software support. On the other hand, MAUT and AHP are mostly considered easier to use and their software support is wider, although dynamic re-evaluation potentials should be developed.

REFERENCES

Antunes, P., Santos, R., Videira, N., Colaco, F., Szanto, R., Dobos, E. R., . . . Vari, A. (2012). Approaches to integration in sustainability assessment of technologies *PROSUITE project*.

Belton, V., & Stewart, T. J. (2002). *Multiple criteria decision analysis; an integrated approach*: Kluwer Academic Publisher.

Benoit, V., & Rousseaux, P. (2003). Aid for aggregating the impacts in life cycle assessment. *International Journal of Life Cycle Assessment, 8*(2), 74-82. doi: 10.1065/lca2002.12.104

Buchholz, T., Rametsteiner, E., Volk, T. A., & Luzadis, V. A. (2009). Multi Criteria Analysis for bioenergy systems assessments. *Energy Policy, 37*(2), 484-495. doi: 10.1016/j.enpol.2008.09.054

Cinelli, M., Coles, S. R., Jørgensen, A., Zamagni, A., Fernando, C., & Kirwan, K. (2013). Workshop on life cycle sustainability assessment: the state of the art and research needs—November 26, 2012, Copenhagen, Denmark. *The International Journal of Life Cycle Assessment*. doi: 10.1007/s11367-013-0573-5

De Montis, A., De Toro, P., Droste-Franke, B., Omann, I., & Stagl, S. (2000). *Criteria for quality assessment of MCDA methods*. Paper presented at the 3rd Biennial Conference of the European Society for Ecological Economics, Vienna. http://www.wu.ac.at/project/esee2000/PapersPDF/H298.pdf

De Montis, A., De Toro, P., Droste-Franke, B., Omann, I., & Stagl, S. (2005). Assessing the quality of different MCDA methods. In M. Getzner, C. Spash & S. Stagl (Eds.), *Alternatives for Environmental Valuation* (pp. 99-133): Routledge.

Gasparatos, A., & Scolobig, A. (2012). Choosing the most appropriate sustainability assessment tool. *Ecological Economics, 80*, 1-7. doi: 10.1016/j.ecolecon.2012.05.005

Munda, G. (2005). Multi criteria decision analysis and sustainable development In J. Figueira, S. Greco & M. Ehrgott (Eds.), *Multiple Criteria Decision Analysis: State of the Art Surveys* (pp. 953-986). New York: Springer.

Munda, G. (2008). The Issue of Consistency: Basic Discrete Multi-Criteria "Methods" *Social Multi-Criteria Evaluation for a Sustainable Economy* (pp. 85-109). Berlin: Springer Berlin Heidelberg.

Polatidis, H., Haralambopoulos, D. A., Munda, G., & Vreeker, R. (2006). Selecting an Appropriate Multi-Criteria Decision Analysis Technique for Renewable Energy Planning. *Energy Sources, Part B: Economics, Planning, and Policy, 1*(2), 181-193. doi: 10.1080/009083190881607

Raju, K. S., & Pillai, C. R. S. (1999). Multicriterion decision making in performance evaluation of an irrigation system. *European Journal of Operational Research, 3*(1), 479–488.

Rowley, H. V., Peters, G. M., Lundie, S., & Moore, S. J. (2012). Aggregating sustainability indicators: beyond the weighted sum. *Journal of Environmental Management, 111*, 24-33. doi: 10.1016/j.jenvman.2012.05.004

Sala, S., Farioli, F., & Zamagni, A. (2012). Life cycle sustainability assessment in the context of sustainability science progress (part 2). *The International Journal of Life Cycle Assessment*. doi: 10.1007/s11367-012-0509-5

Teghem, J., Delhaye, C., & Kunsch, P. L. (1989). AN INTERACTIVE DECISION SUPPORT SYSTEM (IDSS) FOR MULTICRITERIA DECISION AID. *Mathematical and Computer Modelling, 12*(10-11), 1311-1320. doi: 10.1016/0895-7177(89)90370-1

Zamagni, A., Buttol, P., Buonamici, R., Masoni, P., Guine'e, J. B., Huppes, G., . . . Rydberg, T. (2009). Blue Paper on Life Cycle Sustainability Analysis; Deliverable 20 of the CALCAS project.

END OF LIFE MANAGEMENT

Wednesday, Aug 28: 8:30 am - 10:00 am

Session chairs: Laura Cutaia, ENEA, Italy

Christer Forsgren, Stena Recycling International, Sweden

COMPARISON OF DIFFERENT OPTIONS FOR SEWAGE SLUDGE DISPOSAL USING MULTICRITERIA ANALYSIS AND LIFE CYCLE ASSESSMENT

Frischknecht Rolf*, Büsser Sybille, treeze Ltd., Bättig Michèle, econcept Inc., von Schulthess Reto, Holinger Inc.
*treeze Ltd., Kanzleistrasse 4, 8610 Uster, Switzerland, frischknecht@treeze.ch.

Keywords: sewage sludge, multi-criteria, mono-burning, phosphorous recycling, LCA

ABSTRACT

In this study several disposal options for sewage sludge are compared. Among others mono-incineration, co-incineration in a municipal incineration plant, incineration in the cement industry, gasification, wet oxidation, co-fermentation and application in agricultural are investigated. The systems include the whole wastewater and sewage sludge treatment and refer to 1 population equivalent (PE, 80 g COD/d). The evaluation of the options takes account of environmental, economic and social criteria with standardized cost-benefit scores. Disposal in a cement plant and mono-burning of the sludge with further treatment to recycle phosphorous are more favorable compared to the other scenarios investigated.

INTRODUCTION

A Swiss sludge operator operates a sludge incinerator which is in need of replacement. To enable a future-proof system decision to be reached, various disposal routes had to be examined, innovative in some cases (Bättig et al., 2011). Tab. 1 shows the options identified for analysis. Important questions arise: Should a plant for recycling of phosphorus from the sludge ash be operated in the future? Should more innovative sludge treatment and recycling processes be included in the technical evaluation? Is direct recycling of phosphorus and nitrogen an issue for the long term? Are the results applicable to other treatment plants? The options were compared by means of an extended cost-benefit analysis called multicriteria analysis. The evaluation of the options takes account of environmental, economic and social criteria with standardised cost-benefit scores.

METHODS

The evaluation of the options is conducted with a multicriteria analysis which takes account of environmental, economic and social criteria with standardised cost-benefit scores (Bättig, Dettli, Klingler, Frischknecht, & Tuchschmid, 2008). All options include the whole wastewater and sewage sludge treatment and refer to 1 population equivalent (PE, 80 g COD/d).

Data were collected with extensive questionnaires directly from the sludge operator. Data were provided for energy and material consumption, wastewater and sewage sludge constitution, monoburning ash constitution as well as production of products such as biogas, electricity, and heat. The phosphorous recycling and wet oxidation operation data are collected with questionnaires from two plant operators. Other data stem from literature and expert estimates. Ecoinvent v2.2 (ecoinvent Centre, 2010) is used as background database.

The options produce different products such as biogas, electricity, heat, phosphorous and fertilizer. These products are taken into account by credits as they compete with products from conventional production such as natural gas. The credits are composed of costs and environmental impacts of conventional production.

The basis for evaluation of the environmental impact is a life cycle assessment for each option. Because sludge is characteristically a highly nutrient-rich waste product, the following criteria were selected and weighted by a group of experts: Conservation of non-renewable energy sources, conservation of non-renewable resources, climate change, diffusion of hormonally active substances, eutrophication, human toxicity, ecotoxicity, and highly radioactive waste volumes. In terms of economics, the disposal costs and security criteria and the financial risk were evaluated. In social terms, local acceptance (odour, noise), acceptance by society and security of supply were evaluated. Criteria-related quantitative indicators (loads, costs) or qualitative indicators (expert estimates) were used.

A cost-benefit score is determined for every criterion and summarized to one final score. The final score is in the range of 0 (no benefit) and 1 (highest benefit).

Tab. 1: Description of options investigated

No.	Description	Sub-option	
1.1	WWTP as existing, mono-incineration on the WWTP site	1.1.a 1.1.b	Immediate P recycling Monofill, P recycling later
1.2	Co-incineration in a new CHP plant at the site of the LUcerne waste incineration plant	1.2.a 1.2.b	Immediate P recycling Monofill, P recycling later
2	WWTP without digestion, mono-incineration on the WWTP site	2.a 2.b	Immediate P recycling Monofill, P recycling later
3	Co-incineration of sludge in a waste incineration plant	-	-
4	Sludge incineration in the cement industry	4.a 4.b	Sludge drying at WWTP Drying at cement works
5	Sludge gasification at the WWTP	5.a 5.b	Immediate P recycling Monofill, P recycling later
6	Wet oxidation at the WWTP	6.a 6.b	Immediate P recycling Monofill, P recycling later
7	External anaerobic digestion at an existing plant with agricultural substrate, application in agriculture	-	-
8	Application of the sludge from the WWTP in agriculture	-	-

RESULTS

The results of the multicriteria analysis are shown in Fig. 1. The option with drying and disposal in the cement industry (4b) achieves the highest cost-benefit score. The critical dimensions are the environment (energy efficient process, resources and energy sources are substituted) and the economics (low acceptance prices).

The "mono-incineration" options (1.1a – with immediate phosphorous recycling, 1.1b current situation, ash in monofill, phosphorous recycling follows later) are only slightly behind option 4b. Their advantages are the good economics and reliability of the process and the high social acceptance. Phosphorous recycling from the monofilled ash will then follow when it becomes economic as phosphorus prices rise.

The technically innovative processes "wet oxidation" (option 6) and "sludge gasification" (option 5) lag well behind. The reasons are the relatively low benefit for the environment and the high costs of these processes.

The options with immediate phosphorus recycling generally have lower cost-benefit scores than the corresponding options with monofill and later phosphorous recycling. This is because the environmental benefit is the same (it is not timing dependent), but a plant for phosphorous recycling performs less well in the "economics" dimension.

Because the timescale to be considered for this study is defined as 20 to 40 years, disposal routes with agricultural recycling were also examined, even though the use of sludge as an agricultural fertilizer has not been permitted since 2006 in Switzerland. Option 8 (direct application in agriculture) is in the top half of the options studied and achieved average scores for all three dimensions. Option 7 (external anaerobic digestion and application in agriculture) is ranked lower. In terms of the environment it should be mentioned that direct input of organic pollutants into the soil through sludge discharge could not be considered, whereas dissemination of hormonally active substances into the environment could.

A sensitivity analysis was carried out considering alternate weighting factor for all criteria, optimal energy efficiency, application of the method of ecological scarcity (Frischknecht, Steiner, & Jungbluth, 2009) instead of the environmental indicators mentioned above, considering “new technologies” as “established technologies” and high price for phosphorous fertilizers. The sensitivity analysis carried out showed that the evaluation obtained is quite robust, even with different assumptions.

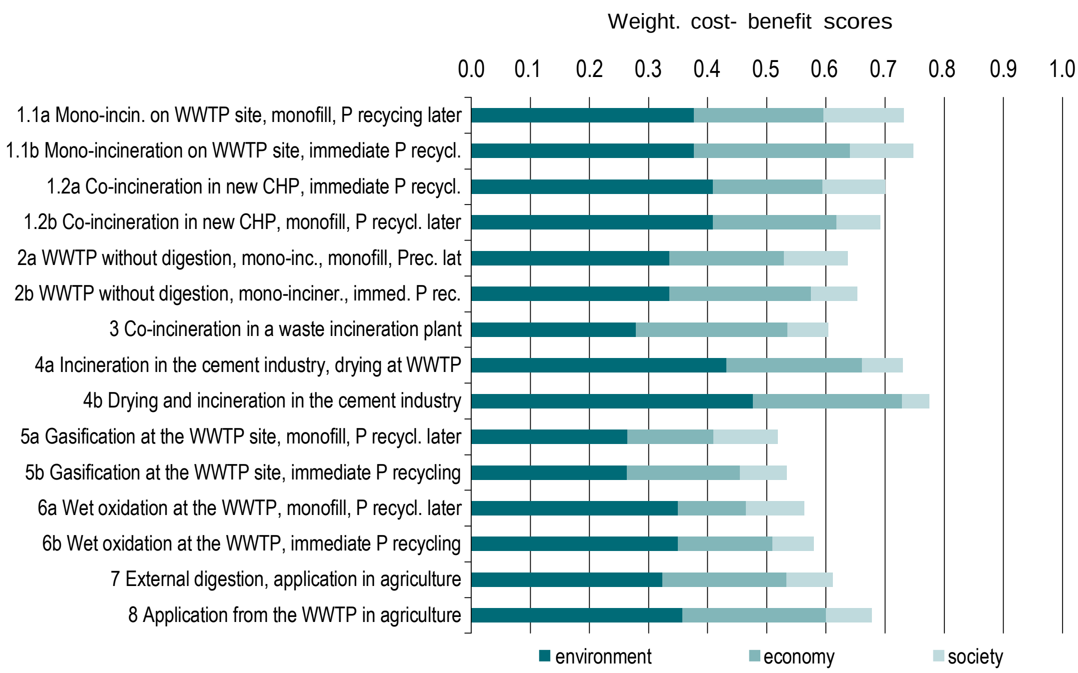


Fig. 1: Results of the multicriteria analysis.

CONCLUSIONS

To conclude, the study showed that mono-incineration is a suitable and future-proof process for sludge disposal. But also recycling at a cement works is an equivalent alternative. Furthermore, a plant for phosphorus recycling is not indicated for the time being. The sludge ash should be deposited in a monofill so that phosphorous recycling at a later date can be ensured. The study also showed that investment in sludge gasification or wet oxidation is not recommended from today's perspective.

The results obtained are guaranteed to be transferable to other treatment plants in Switzerland because sludge treatment and disposal are largely independent of the location. Some differences occur due to varying transport distances, potential for district heat output and the plants already in existence.

REFERENCES

Bättig, M., Dettli, R., Klingler, G., Frischknecht, R., & Tuchschmid, M. (2008). Bewertungsmethode für Technologien zur Nutzung von biogenen Abfällen und Hofdünger. Swiss Federal Office of Energy (SFOE).

Bättig, M., Klingler, G., Büsser, S., Frischknecht, R., Schulthess, R. v., & Küttel, P. (2011). Comparison of different options for sewage sludge disposal in the Lucerne area using multicriteria analysis and life cycle assesment. Federal Office for the Environment (FOEN), Kanton Luzern, Dienststelle Umwelt und Energie (uwe), Recycling Entsorgung Abwasser Luzern (REAL).

ecoinvent Centre. (2010). ecoinvent data v2.2, ecoinvent reports No. 1-25. Swiss Centre for Life Cycle Inventories.

Frischknecht, R., Steiner, R., & Jungbluth, N. (2009). The Ecological Scarcity Method - Eco-Factors 2006: A method for impact assessment in LCA. Federal Office for the Environment (FOEN). Umwelt-Wissen Nr. 0906.

CONCEPTION OF AN AUTOMATED PLANT FOR THE DISASSEMBLY OF LITHIUM ION BATTERIES

*Prof. Dr. Michael Weyrich, Nirugaa Natkunarajah, M.Sc.**
**Paul-Bonatz-Str.9-11, 57068 Siegen, Germany*
nirugaa.natkunarajah@uni-siegen.de

Keywords: automated disassembly; lithium ion batteries; End-of-Life Management

ABSTRACT

Due to the increasing number of electric cars and consequently lithium ion batteries, the automation of disassembly becomes vital. Therefor information on lithium ion batteries referring to components, geometries, materials and joining technologies are collected and a concept for the automated disassembly is deduced. In this context, the applications of sensors for the identification of batteries, as well as actors for the cutting are evaluated.

INTRODUCTION

With the development and distribution of electric cars and the associated high quantities of lithium ion batteries, the recycling of batteries gains more importance. Lithium ion batteries comprise valuable raw materials such as lithium, cobalt and aluminum (Martens, 2011). Due to lack of raw materials their recovery is very important, especially for resource-poor EU-countries. For the recovery of these materials, the batteries should be fully dismantled and broken down into their basic components to enhance the efficiency of the down streamed material recycling (Martens, 2011). The challenges in the automation of the battery disassembly lie in their varieties, the ignorance of technical condition in the End-of-Life (EoL), hazardous materials and safety reasons.

Currently there are no approaches for the automation of disassembly processes for lithium ion batteries. This analysis defines criteria for automated disassembly and opens a new dimension to the End-of-Life management of electrical waste by the example of lithium ion batteries.

AUTOMATED DISASSEMBLY OF LITHIUM ION BATTERIES

Lithium ion batteries

The modular design of the lithium ion batteries enables an individual assembly according to the type of electric vehicles. The structure of battery packs, the battery modules and their components are depicted in figure 1a. The components of the battery pack and the battery module are connected by different joining technologies such as welding, soldering, bonding and screw or snap connections. There are three different cell designs: cylindrical, prismatic and pouch cells which are especially developed for the electromobility. Furthermore the cell components anode, cathode, separator and electrolyte consist of variant materials (Daniel 2008). The dimensions, the materials and the way of assembly lead to variant battery systems which have to be considered in the disassembly (see figure 1b).

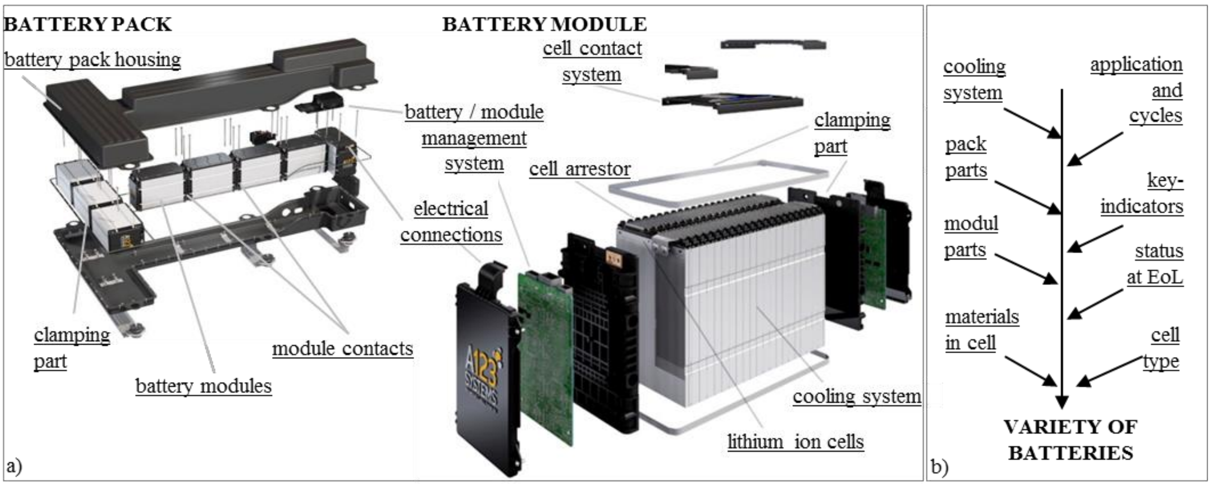
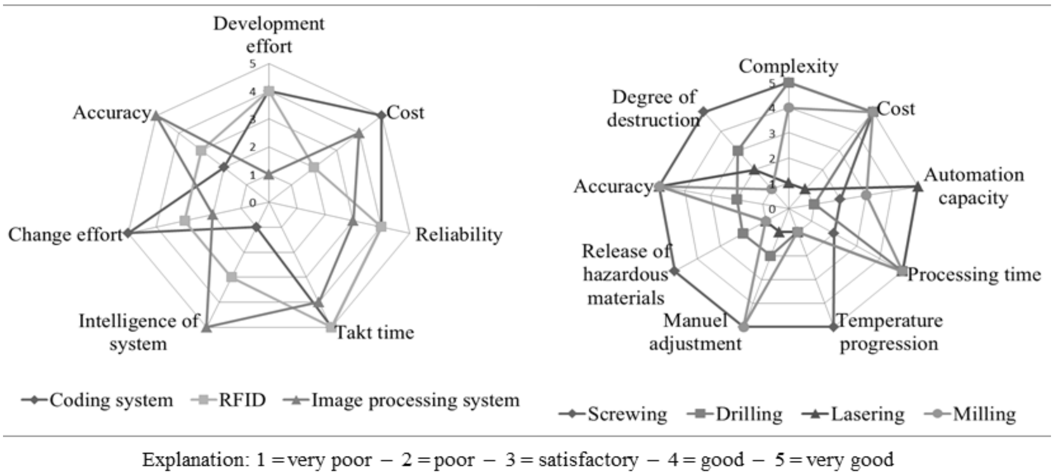


Figure 1. Composition and variety of a lithium ion battery [A123-System Inc.[1]]

Evaluation of sensors and actors for the disassembly

For the development of the automated disassembly plant, sensors for the identification of variant battery systems and actors for the actual cutting have been assessed. The defined criteria have been ranked from very poor to very good (see figure 2).

Figure 2. Evaluation of sensor and actors for the disassembly



---

[1] 2013 A123 Systems, LLC. All rights reserved.

The analysis has shown that image processing is the most suitable technology for the identification of variant products. The image processing can be programmed and developed to be adaptive. Lasering and milling have been identified as the most suitable technologies for an automation, whereby the lasering is more flexible and scalable. However a fully automated system can only be realized by high standardization in combination with a disassembly database, further intelligent actors and sensors. Because of these reasons and the low quantity of lithium ion batteries today, a semi-automated disassembly plant, which can be modularly established to a fully automated system, is an appropriate solution. In the following, a semi-automated concept for the disassembly is presented.

Concept of a semi-automated disassembly plant

The automated disassembly processes today are tailored to a specific product. A modularized disassembly, consisting of separation-, detection-, control- and sub modules, increases the flexibility of the disassembly system (Kopacek, 2003, Knoth et al., 2001). In figure 3 the concept of a semi-automated disassembly of a lithium ion battery into its basis components is presented.

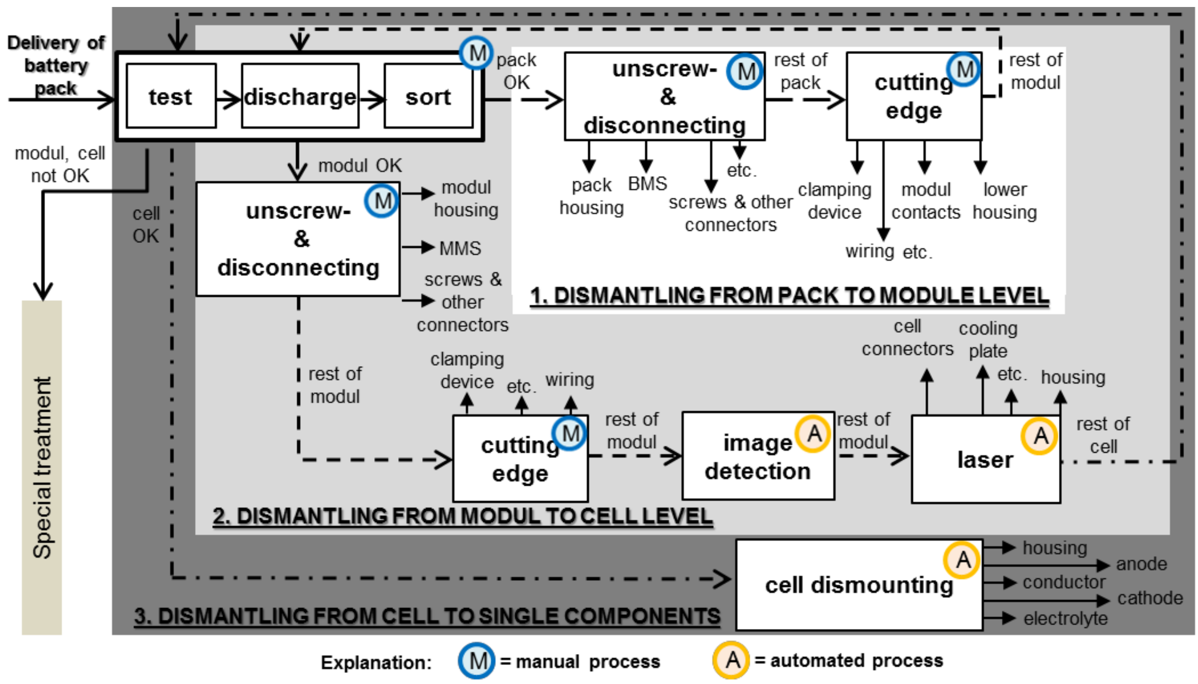


Figure 3. Concept of a semi-automated disassembly

The process starts with the delivery of the various battery packs to the companies that are responsible for the disassembly. There, the quality of the batteries is tested via voltage and visual control. In this concept, all damaged batteries are sorted to a special treatment where they are disassembled fully manually. The disassembly process is divided into three levels of dismantling procedures:

1. dismantling of pack to modules (white box in figure 3);

2. dismantling of module to cells (light grey box in figure 3);

3. dismantling cell into single components (dark grey box in figure 3).

The condition of the batteries is checked between every level. The undamaged batteries are discharged according to the defined safety regulations.

Due to the unknown variants of battery packs in current use, the process steps testing, discharging and sorting are executed manually. These process steps can be passed by all battery levels, as it is adjustable to different discharging parameters. The screwed and clamped elements are also manually dismounted, as the automation of these processes requires expensive intelligent image processing and complex grippers. All non-rigid components such as cables and clamping elements are manually cut. For the disassembly of the battery module, a laser combined with image processing is applied. The cells are dismounted by pyrolysis at the current state. In future this step should also be dismounted mechanically step by step in its single components.

CONCLUSIONS

In this paper a semi-automated concept for the disassembly of lithium ion batteries is presented. For the development of a flexible disassembly cell, several sensors and actors for the disassembly are evaluated and a modular approach with separation-, detection-, control- and sub modules is applied. The image processing is chosen for the identification of batteries. The most flexible and scalable disassembly technology is the lasering method, which is applied for the dismounting of battery modules. In the semi-automated disassembly plant, following modules are employed: laser cutting, manual cutting, test-, discharge- sorting- and vision modules.

For the realization of the above concept, database and data exchange systems have to be developed to handle the variants of lithium ion battery systems. Furthermore specific laser systems and laser parameters have to be deduced from experiments. The image processing has to be programmed and tested. With the selected image processing and robotics the semi-automated plant can be developed step by step to a fully automated disassembly plant.

REFERENCES

Martens, H (2011). Recycling von Elektro- und Elektronikgeräten. In H. Martens, *Recyclingtechnik* (pp.294-299). Heidelberg, Germany: Springer-Verlag.

Daniel, C. (2008). Materials and Processing for Lithium-ion Batteries. *JOM, 60 (9),* pp.43-48.

Kopacek B. (2003). Semi-automatisierte Demontage für Elektronikschrottrecycling. *e&i Elektrotechnik und Informationstechnik, 5* , pp. 149-153.

Knoth R., Hoffmann M., Kopacek B. & Kopacek P. (2001). Intelligent disassembly of electr(on)ic equipment. *IEEE Environmentally Conscious Design and Inverse Manufacturing. Proceedings EcoDesign 2001. Second International Symposium* (pp. 557-561).

CONSTRAINS AND OPPORTUNITIES IN THE END OF LIFE MANAGEMENT OF ELECTRICAL AND ELECTRONIC EQUIPEMENT IN ITALY

Cutaia L.[1], Scagliarino C.[2], Brunori C.[1], La Marca F.[2], Mancuso E.[1], Fontana D.[1], Jorizzo M.[1], Pietrelli L.[1]; 1 – ENEA (IT), 2 – University of Rome "La Sapienza"; *ENEA, CR Casaccia, Via Anguillarese 301 – 00123 Santa Maria di Galeria, Roma (IT) - laura.cutaia@enea.it*

Keywords: WEEE, Italy, recycling, reuse, collecting system

ABSTRACT

The present paper concerns critical situations and opportunities of the WEEE (Waste Electrical and Electronic Equipment) life cycle in Italy.

Presenting the major players dealing with WEEE end of life treatments and following their processes from the collection to recovered materials, major weaknesses of regulations and plant engineering are outlined and analyzed.

Loss during collection, theft (so called *"cannibalization"*), unjustified complexity of recovery targets evaluation, poor choices of waste management systems, illegal exports, give to the Italian WEEE system large areas of improvement.

The recoverable materials (rare earth elements, precious metals) make the WEEE supply chain very interesting both economically and strategically. In this paper, we propose economic forecasts and engineering solutions to improve the Italian WEEE system.

INTRODUCTION

The European directive 2002/96/CE on WEEE (EU, 2003) was implemented in Italy in 2005 with legislative decree 151, in which the "constrained subjects" and the concept of 'producer's responsibility' were defined and the Collection System was chosen as the organizer of the system financed by the producers.

The Collection System deals with collection, transportation and treatment of the waste in an attempt to maximize the material's recovery. In addition to this, the decree ratified specific recovery targets, valid until the coming into effect of the new European directive 2012/19/EU (EU, 2012), which will have to be implemented in Italy by 2014.

The supply chain of the WEEE in Italy is organized by the Collection Systems (SC) under the supervision of the WEEE Coordination Centre (CdC) and the Vigilance Committee (Ancitel and CdC RAEE, 2011). The legislation would also consider other authorities, but these have never been activated because of a lack of implementation decrees.

The collection takes place in the waste separation and recycling areas (so called *"Isole Ecologiche"*) or in the retail stores when a new device is purchased *('one to one')*. The collection and transportation to the plants are made by SC and coordinated by the CdC, which should guarantee uniform operating conditions in the whole country. The collection is sorted in accordance with the different kinds of WEEE, which are divided into 5 groups (R1: refrigerating devices, R2: large household appliances, R3: TVs and monitors, R4: PED, CE, ITC, etc., and R5: light sources). For every group, different targets of recovery have to be reached. The calculation of these targets is simple only for the first 2 group, while in the other cases it is based on the samplings of the input at the plants, which makes the results often not reliable (Scagliarino, 2012).

DISCUSSION

The first critical situation of the system is due to a lack of implementation decrees. This circumstance does not allow the supply chain to develop completely, after 8 years of the issuing of the Law 151/05. According to the new European legislation (EU, 2012), the collection's targets should be proportional to the devices introduced in the market, depending on the type of the products. Generally, at least the 70% of the WEEE should be collected, a value which is way below the percentage of the today's collection rate, which does not exceed the 30% on average (Fondazione per lo sviluppo sostenibile – Fise Unire, 2013).

The loss of the end-of-life products is caused on the one hand by a bad disposal of the users, on the other by the illegal collection made by some operators, who are external to the supply chain and illegally dispose of the waste collected. These devices are sent abroad, to developing countries (Asia and Africa) as 'out-of-order' devices (therefore subject to different laws) or with illegal shipment (Scagliarino, 2012).

The WEEE collected through the official supply chain may sometimes not be intact. Quite often they are *'cannibalized'*, which means that the parts with an economic value are stolen, making the products less interesting. The percentages change according to the different Italian regions, but they can sometimes reach 50% of the devices, which means that one device out of two is deprived of some parts (Ancitel and CdC RAEE, 2011). It should remembered that very valuable materials such as platinum, gold, silver, etc. and very rare components like rare earth elements etc. may be found in this kind of waste. The economic potential of this kind of waste has been appraised by calculating the total amount of the material obtainable, according to the data of the WEEE collected. It has been calculated that 20% of the devices are cannibalized in the collecting area, therefore the economic damage can be quantified.

Depending on the prices of materials recovered and on the potential of reuse of WEEE collected, it has been estimated that €150 million can be earned from 260000 tons collected. Subtracting the operating cost, there is a theoretical margin of €0,40 per kg. Eliminating the loss due to the leakage of the devices from the official supply chain and the loss of the parts of economic interest caused by the cannibalization in the waste separation and recycling areas ("*Isole Ecologiche"*), would result in a considerable increase of the economic potential of this waste (Scagliarino, 2012; WRAP, 2011).

Another aspect, which would improve the performances of the supply chain, could be an incentive to the efficiency of the procedure and the plants. In Italy, there are a lot of first level plants, which deal with a pre-processing process including the disassembly, separation and recovery of the different parts. They are well-distributed on the whole territory, although they are usually inadequate because of the uncertain and economically not interesting supply system. With regards to the second level plants, which deal with the extraction of the material, particularly metals, precious metals and rare earth elements, they are usually inadequate and not well- distributed on the territory; for example, there are 18 plants for the recovery of precious metals: 8 of them are in the same region (in Central Italy), 7 in the North and only 3 in the South and Islands. This lack of second level plants has encouraged sending the pre-processed materials to foreign plants, which are technologically more advanced and administratively better organized. None of the Italian plant carries out the complete treatment *"from the device to the ingot"*.

There are some developing treatments for the extraction of metal that could make the final treatment of the WEEE very advantageous: heat treatment (pyro-metallurgy) and wet treatment (hydrometallurgy). This highlights that, with regards to the plants, some good results are achieved, but they are not developed in practical terms, except by a few factories.

CONCLUSIONS

The present work shows the aspects that have to be analysed to increase the WEEE supply system. We have demonstrated that it's an interesting system at an economic level, both for recoverable materials and for the possible development, as the market of the electrical and electronic equipment is always increasing. The first objective to be achieved is attempting to collect all the waste in the official supply chain and limit the cannibalization. The issue about the WEEE's property is still unsolved.

As the materials inside of the WEEE are very precious and economically interesting, we can't ignore the importance of valuing the WEEE, both economically and strategically. This circumstance should persuade Italy to upgrade the plant system which is not well developed, both for the geographical distribution and the technology, and to invest in the supply chain.

We should also consider the potentiality of reusing the devices, in particular the small ones, which are often discarded before their end of life, just because new models are launched or because they have small damages which could be easily and cheaply repaired. In particular, the new European directive 2012/19/EU explicitly requires achieving specific objectives regarding devices reusing.

REFERENCES

EU (2003), *Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE)*, Official Journal of the European Union 13/02/2003.

EU (2012), *Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE)*, Official Journal of the European Union 24/07/2012.

Ancitel and CdC RAEE (2011), *Il fenomeno della cannibalizzazione. Indagine sulla qualità dei Raee consegnati ai sistemi collettivi*. Roma – IT.

Fondazione per lo sviluppo sostenibile – Fise Unire (2013), *L'Italia del riciclo 2012*, Roma IT.

Scagliarino C. (2012), *La filiera del fine vita delle apparecchiature elettriche ed elettroniche in Italia: aspetti tecnici, giuridico/amministrativi ed economici*, Environmental Engineering Degree final thesis, University of Rome "La Sapienza" - ENEA, Tutors: Ing. L. Cutaia, F. La Marca.

WRAP (2011), *Realising the Reuse Value of Household WEEE*, Justin French-Brooks UK.

END-OF-LIFE MANAGEMENT: LCA OF TEXTILE WASTE RECYCLING

Bahareh Zamani, Magdalena Svanström, Gregory Peters*

zamanib@chalmers.se

Chalmers University of Technology Devision of Chemical Environmental Science SE-412 96 Göteborg, Sweden

Keywords: Textile waste recycling, End-of-life management, Life cycle assessment, Global warming potential. Primary energy usage

ABSTRACT

Textile and apparel consumption is increasing because of global population growth and higher living standards. In Sweden, approximately 130,000 tonnes of textiles are consumed annually and end up as waste. This paper describes a preliminary investigation of textile recycling techniques which can potentially replace incineration - the dominant waste management method in Sweden. Life cycle assessment is performed to explore the potential environmental benefits of the textile recycling techniques. The investigated recycling processes are: remanufacturing, separation of cellulose from polyester using N-methylmorpholine-N-oxide; and chemical polyester recycling. The results show that incineration has the highest global warming potential and primary energy usage of compared alternatives. The other options thus seem to be promising alternatives since they also replace products from primary resources.

INTRODUCTION

Global population growth and improvements in living standards have caused an increase in the production and consumption of textiles during the past few decades (Wang, 2006) Furthermore, the accelerating fashion cycle results in more frequent replacement of the products with fresher and more modern goods which in turn results in generation of more textile waste (Fletcher, 2008).

In Sweden, the predominant method of textile waste treatment is incineration. Presently, a lack of recycling techniques that have proven to be cost-effective at full scale and the existence of cheap fabrics on the market, limit the interest in recycling. Moreover, the large variety of fibers and colours used in fabrics are considered limiting factors in textile recycling, since they challenge the sorting processes and decrease the quality of recycled materials (Palm, 2011).

However, new technologies for recycling textile waste are being developed. Chemical approaches for textile recycling include dissolution and separation of cellulose from polyester by using N-methylmorpholine-N-oxide (NMMO) (Jeihanipour, Karimi, Niklasson, & Taherzadeh, M, 2010) and degradation of polyester to dimethyl terephthalate (DMT) for repolymerization and spinning new polyester fibre (Patagonia Inc., 2011).

METHODS

This paper reports on an environmental life cycle assessment (LCA) that was performed to quantify the energy usage and climate change impact of different emergent textile recycling technologies.

Functional unit

The functional unit used in the calculations is 'waste treatment for one tonne of household textile waste' by each technique. The model waste considered in this study is discarded household textiles, consisting of 50% cotton and 50% polyester.

System boundaries and description of the technical systems

The environmental impacts are assessed from the moment where the collected textile waste enters the recycling facilities until treatment of the residues generated in each recycling system and the use of by-products have been accounted for. All the recycling technologies and the entry on the market of the new products are assumed to be located in Sweden. In order to correct for differences in functions between the systems, system expansions (substitutions) are applied for products and by-products. In the expanded system, manufacturing of textile fibers and products from primary resources are assumed to take place in China.

Energy recovery

Incineration with energy recovery is the dominant textile waste treatment technology in Sweden. The technology considered is a combined heat and power incineration plant with advanced flue gas treatment based on the SWEA model (Palm & Ljunggren Söderman, 2010).

Material reuse

Remanufacturing is the practice of taking reusable textile waste material and transforming it into a new product. In this process, the whole collected textile waste flow is first washed and dried. Afterwards, reusable textile pieces with high enough quality are separated manually, cut, and sent to a sewing machine for manufacturing of new products. Manufacturing of textile bags is considered because it is a simple pattern for which relatively small pieces of textile are needed. The textile residue from cutting and the unused textile waste is sent to incineration.

Separation of cellulose from polyester using NMMO solvent

In this process, NMMO is mixed with the textile waste. The cellulose fraction dissolves, and the solution is pumped through filters to separate the cellulosic solution from the polyester which remains undissolved. The remaining polyester is assumed to be in a form that makes it possible to direct to spinning machines; 100% of the remaining polyester is assumed to be recovered by twisting and extending the fibers and turning them to yarns. The solution of NMMO and cellulose, is forced through showerhead spinners where long strings of fibers come out through small holes. The cellulosic fibers are washed and yarns can be freed from NMMO by passing through a washing process and finally, water is removed by drying (Shen & Patel, 2010) (Shen, Worrell, & Patel, 2010).

Recycling of polyester
In this process, discarded garments and fabrics of polyester are first separated manually from the rest of the textile waste. They are then cut into smaller pieces and further broken down until only small granules remain. A reaction with a chemical is employed to break the granules down into molecules of dimethyl terephthalate (DMT). Subsequently, DMT is chemically treated and polymerized to produce polyester granules, which are melted and spun into polyester yarns. It is assumed that 100% of the polyester is recovered in this process. The other 50% of the textile waste stream from the sorting step, i.e. all of the cellulosic material, is directed to incineration.

RESULTS: LIFE CYCLE IMPACT ASSESSMENT

A fuller description of this work is under review by a scientific journal. The total performance of the recycling systems per tonne of treated textile waste in terms of global warming potential and primary energy usage is illustrated in Figure 1. The black bar in each column represents a sensitivity analysis that was performed for each recycling technique. In the material reuse process, the yield was varied from 45% to either 20% or 70%, which greatly affects the results. For the cellulose/polyester separation process, the amount of thermal energy required for the dissolving step is assumed to be high. Therefore, it was varied by ± 50%, combined with a change of thermal energy source from natural gas to Swedish average district heat. Neither of these changes strongly affect the results. For the polyester recycling process, the amount of thermal energy required for the polymerization step was varied by ± 50%, combined with a change of thermal energy source from natural gas to Swedish average district heat. Neither change had an important effect.

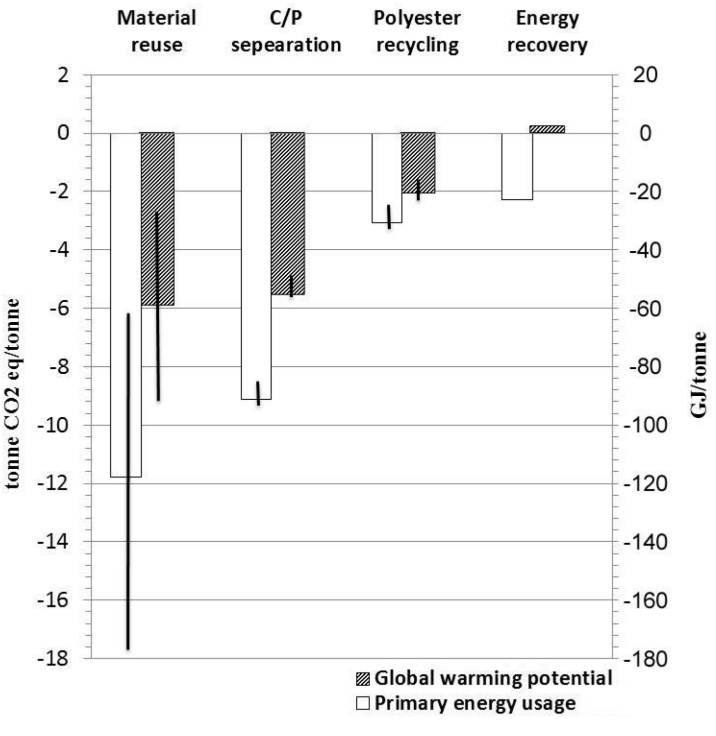


Figure 1: Comparison of environmental performance of textile waste management technologies in terms of net global warming potential and net primary energy usage, including results from sensitivity analysis illustrated by error bars

The dominant textile waste management option in Sweden, incineration, is seen to have the highest global warming potential and primary energy usage of the compared alternatives. The analysis shows that material reuse allows for considerable savings in global warming potential and energy usage, mainly due to the avoided production of a textile bag from primary resources. Both the polyester recycling and the cellulose/polyester separation processes, production of cellulose/polyester fibers from primary resources are energy intensive processes that strongly influence the savings that are possible for these technologies.

CONCLUSION

All of the emergent textile recycling technologies thus exhibited a more beneficial environmental performance than incineration also when some critical parameters were varied. This is an explorative LCA, the results are applicable only for a preliminary environmental assessment, since most of the data was based on either assumptions, literature data or was approximated with data from similar processes. However, the positive results indicate that textile recycling options should be studied in more detail in order to find out how to best reduce the environmental footprint of the textiles used in society.

REFERENCES

Fletcher, K. (2008). Sustainable fashion and textiles: design journeys. *London: Earth scan.*

Jeihanipour, A., Karimi, K., Niklasson, C., & Taherzadeh, M, J. (2010). A novel process for ethanol or biogas production from cellulose in blended-fibers waste textiles. *Waste Management*, *30*(12), 2504-2509.

Palm, D. (2011). Improved waste management of textiles. *Retrieved from www.ivl.se/download/18.7df4c4e812d2da6a416800080103/B1976.pdf,*

Palm, D., & Ljunggren Söderman, M. (2010). Bearbering och beräkning av data från modellen SWEA (In english: processing and calculation of data from SWEA model),*Stockholm*.

Patagonia Inc. (2011). Patagonia´s common Treads Garment Recycling Program: A detailed analysis. *Retrieved from www.patagonia.com/pdf/en_US/common_threads_whitepaper.pdf*

Shen, L., & Patel, M. K. (2010). Life cycle assessment of man-made cellulose fibres. *World* (Vol. 88, pp. 1-59). *Retrieved from http://igitur-archive.library.uu.nl/chem/2011-0401-200353/LB_88_2010_paper_1.pdf*

Shen, L., Worrell, E., & Patel, M. K. (2010). Open loop Recycling Environmental impact assessment of man-made cellulose fibres. *"Resources, Conservation & Recycling"*, *55*(2), 260-274. Elsevier B.V. doi:10.1016/j.resconrec.2010.10.001

Wang, Y. (2006). Textile recycling. *Cambridge: Woodhead Publishing Ltd.*

ENVIRONMENTAL IMPACTS OF INFORMAL REUSE

Obersteiner G., Scherhaufer, S., Pertl A. *University of Natural Resources and Life Sciences Vienna, Institute of Waste Management, Muthgasse 107, A-1190 Wien; gudrun.obersteiner@boku.ac.at*

Keywords: informal, LCA, reuse, bulky waste

ABSTRACT

In Europe informal collectors from new EU member states are collecting commodities (WEEE; textiles and bulky waste) in one of the economically well-developed EU 15 member states and bring it to their home countries to sell the items at flea markets. Reuse is seen as a promising waste prevention measure and environmental benefits are expected in most cases compared to the use of new items. But the environmental benefit of these informal transnational activities was doubt especially for WEEE. Thus, the impact of this informal type of reuse was investigated in detail during the Central Europe project TransWaste for 13 different products exemplary presented in this paper for a refrigerator and a plastic garden chair.

INTRODUCTION

The existence of informal waste collection activities as a remarkable contribution to re-use in Central Europe has more or less been neglected to date. The European informal collectors are collecting commodities in one of the economic well-developed EU 15 member states, bring it to their home countries (in most of the cases they come from CEE countries) and sell it at flea markets. Compared to the traditional industry and services, the informal sector is often called the “black” or “hidden economy”. Informal means “without formal assignment, not official” and refers to all economic activities by workers and economic units that are not or insufficiently covered by formal arrangements. In contrast to the situation in developing countries, where recyclables are collected and recycled, mainly bulky waste, metal, WEEE and textiles are collected and reused.

Figure 1. Example for informal collected and transshipped goods in Austria

Reuse in general is seen as a promising waste prevention measure and environmental benefits are expected in most cases compared to the use of new items. Nevertheless especially this transborder reuse is seen as environmentally questionable by Western Europe waste management authorities as they assume worse waste management conditions in Eastern

European countries. To verify this argument the environmental impacts of the collection of goods in Austria and reuse Hungary were investigated in detail during the Central Europe project TransWaste (www.transwaste.eu) for 13 different indicator products (hazardous and non-hazardous items) and results are presented in this paper exemplary for a refrigerator and a plastic garden chair.

MATERIALS AND METHOD

The chosen indicator products represent items that are mainly collected by informal collectors cover the whole array of collected goods from WEEE to furniture or bulky sports equipment. Environmental effects for a plastic garden chair at and a refrigerator containing CFCs as cooling and foaming agents, as it was considered that the appliance is from 2000, are estimated using the methodology of Life Cycle Assessment (LCA) for formal and informal waste collection and treatment scenarios. Ecoinvent® v2.2 was used as data inventory for material production and assembly. Additionally literature based data was taken for illegal disposal. Data from project specific investigations was considered for informal sector activities. GaBi 5 was used to support the calculations.

The following environmental categories (according to CML 2001) were applied:

- Abiotic Depletion (ADP) [kg Sb-Equiv.]
- Acidification Potential (AP) [kg SO2-Equiv.]
- Eutrophication Potential (EP) [kg Phosphate-Equiv.]
- Global Warming Potential (GWP 100 years) [kg CO2-Equiv.]
- Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Equiv.]
- Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]

The scenarios cover both formal and informal activities. The formal scenario is necessary to provide a baseline scenario without informal collections at all. The informal scenario shows the status quo of informal collection, transborder shipment and reuse of collected goods as well as assumed inadequate disposal. The formalised scenario is similar to the informal scenario in the case of reuse but considering proper disposal technologies. It was assumed that 30% of the devices cannot be sold and be therefore dismantled (cables are removed) and dumped in uncontrolled sites. 70% of the devices are sold and reused. At the end of the second lives both products are properly disposed in the receiving country. The ratio between illegal disposal and reuse and the influence of these end-of-life possibilities is considered in the assessment. For the formalisation scenario it was assumed, that the former informal collectors get a training concerning legal and environmental issues (Obersteiner et al., 2012) and act in a legal way. As far as possible only use- and sellable items are taken. Therefore it was estimated that a share of 95% of reused products may be realistic. This implies that only 5% need to be disposed of without reuse. It comes along with a decrease of illegal dumping

RESULTS AND DISCUSSION

The plastic garden chair shows environmental benefits in the formalized scenario for the most categories except for EP and ODP. Landfilling dominates EP in receiving countries, which is still the most common disposal option for garden chairs. In the informal scenario the disposed amount in receiving countries increases as more materials have to be transferred due to lower product quality which leads to 30% loss of materials. However the total environmental impacts in case of EP are lowest in the formalized scenario, as the reuse benefits occur and the disposal of unsold products is less than in the informal scenario. For ODP benefits of thermal recovery of plastic is decisive. It decreases the total emissions of the formal scenario significantly. These benefits are missing in the informal and formalized scenario as the disposal takes place in receiving countries, where landfilling is dominating. Additionally, the transport by collectors to receiving countries is an important factor.

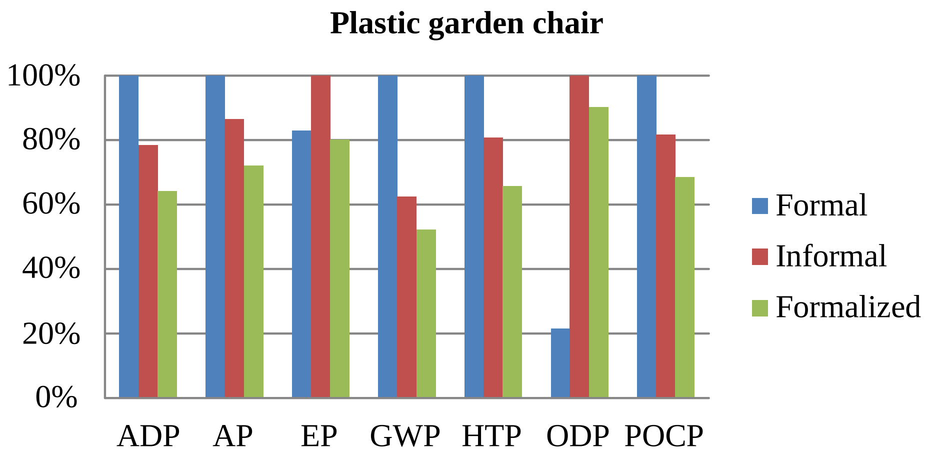


Figure 2. Relative results of one piece of plastic garden chair over all environmental categories

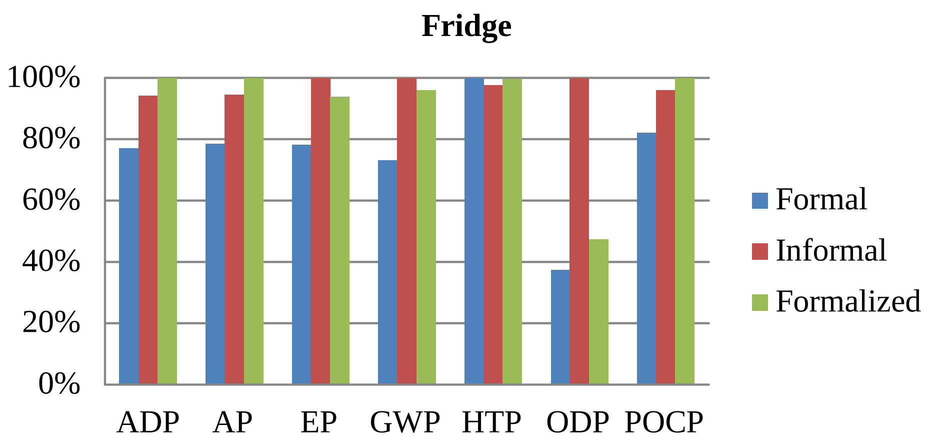


Figure 3: Relative environmental impact of one refrigerator over all environmental categories

Electronic equipment studies state that the environmental advantage of reuse is depending on various critical parameters in this area (Ökopol, 2008; Sahni et al., 2010). Environmental benefits of reuse are largely depending on the use phase and energy efficiency of the product e.g. refrigerators show decreasing energy consumption in recent years.

Figure 3 shows that contrary to the plastic garden chair for the refrigerator the formal scenario shows the fewest emissions. The refrigerator shows significant environmental burdens in case of reuse. The formalized scenario shows 20% (EP) to 31% (GWP) more emissions compared to the formal waste management scenario. The emissions of the total life cycle are determined by the use phase (Pertl et al., 2010). The use phase of an old fridge has much higher emissions than from a new fridge. This concerns the informal as well as the formalized scenario. The more refrigerators are reused the worse the environmental effects. The formalized scenario shows therefore in most of the categories more emissions compared to the other scenarios except for EP, GWP and ODP. Those categories are affected by the illegal disposal in the informal scenario. In these cases the informal sector shows the worst results in view of the environment.

CONCLUSIONS

As a conclusion for the environmental assessment it can be stated for non electronic products that the status quo of the informal sector produces less emissions for the environment than the theoretical solely formal scenario. This is due to the effect that reuse of goods avoids the production of new goods and therefore emissions which would occur in the production process. Compared to the formalisation scenario the status quo produces slightly more emissions as more goods are collected which can’t be resold and therefore not reused anymore. All formalisation scenarios have the advantage that fewer goods are disposed off without reuse. For electronic devises the environmental impact of reuse depends on the use phase and on the energy efficiency of new devices compared to reused items. Additionally the use phase as well as the EoL phase is determined by the different electricity mix in each country Production phase was modelled in terms of global or European conditions depending on the data set, as the least products are produced in the considered countries. Different results are therefore based on the different electricity mix in the use phase and the different recycling and disposal habits for each country.

As overall conclusion it can be stated that the most relevant parameters influencing the results are the energy efficiency from the reused item compared to a new product and the illegal disposal activities. If the energy efficiency compared to a new product is not much different and illegal disposal activities can be banned in the formalisation ideas, then the reuse is advantageous.

REFERENCES

Ökopol (2008): ReUse und Ressourcen- und Klimaschutz (ReUse and resource and climate protection), Brief report provided for bag Arbeit e,V,

Sahni, S,; Boustani, A,; Gutowski, T,G,, Graves, S,C, (2010): Reusing personal computer devices – good or bad for the environment?, Proceedings of the 2010 IEEE International Symposium on Sustainable Systems and Technology, ISSST 2010

Obersteiner, G; Linzner, R; Pertl, A; Scherhaufer, S; Schmied, E (2012): The informal sector in waste management and it`s contribution to Re-Use in Central Europe .[6th annual international experts conference Enviro-Management 2012, New Forest, UNITED KINGDOM, OCT 9-11, 2012

Pertl A., Obersteiner G. Scherhaufer S., Den Boer, J. (2010): Ecological and economic informal waste management strategies - A case study. [Crete 2010 - 2nd International Conference on Hazardous and Industrial Waste Management, Chania, Crete, Greece, October 5-8, 2010] In: Gidarakos E., Cossu R., Stegmann R. (Eds.), Crete 2010 - 2nd International Conference on Hazardous and Industrial Waste Management. Executive Summaries., Abstract p.65-67; full paper on CD

ENVIRONMENTAL IMPROVEMENT OF CONSTRUCTION PROJECTS BY REUSE AND RECYCLING

Pertl A., Obersteiner G. *University of Natural Resources and Life Sciences Vienna, Institute of Waste Management, Muthgasse 107, A-1190 Wien; andreas.pertl@boku.ac.at*

Keywords: LCA; reuse; recycling; construction; demolition

ABSTRACT

Environmental impacts of the construction industry are of high relevance worldwide. A possible way to lower the environmental impact is to raise the recycling quota in the end-of-life-phase, the recycling content of the input materials and to enable reuse of construction materials. Data is based on European case studies conducted within the FP7-funded ZeroWIN project. The paper presents GWP-results for the improvement of three different materials compared to the state of the art. Reuse could be identified as best option to reduce the impact on climate change.

INTRODUCTION

The environmental impacts of the construction and demolition industry are of major importance worldwide as 60% of the extracted raw materials from lithosphere are consumed in this sector (Durão et al., 2011). Therefore new innovations or environmentally sound construction networks can enable high emission reductions if these ideas will be applied in a wider context.

One of the biggest problems of improving the construction sector are the very heterogeneous conditions which means that most of the buildings are different in design and function with high influence of the geographically context. It is obvious that the use of timber instead of concrete for the construction of a house would show environmental benefits. However, such capital changes are often impossible as the design is already given or restricted by legislative and technical reasons. To overcome these limitations environmental improvements on a material specific level are necessary. An important basic principle for all environmental innovations of construction products is to fulfill the quality requirements as least as good as conventional products.

A contribution to this research is done in the course of the project "ZeroWIN" funded by the EU 7th Framework program. The project`s goal is to enable the use of present waste flows as by-product or recycling material flows in the future. Five case studies in three EU-countries are the basis for the development and implementation of reuse and recycling measures in the construction and demolition phase of buildings.

This paper is presenting results of the impact on global warming potential (GWP) of three construction materials comparing a status quo scenario to possible improvements by raising the input- and output-related recycling content of the products.

METHOD AND MATERIALS

The method of life cycle assessment (LCA) is applied for the calculation of the environmental impacts of the status quo – presenting the state of the art - and improved scenarios. Impacts are calculated mid-point-related choosing Recipe as methodology for the life cycle impact assessment. This paper is focusing on GWP results only, whereas the underlying study is considering AP, HTP, ODP and other categories (Obersteiner et al., 2010). The functional unit is defined by 1 ton of a specific construction material.

The end-of-life (EOL) phase is most important in the considered scenarios. The outputs of secondary materials and products are different for all scenarios. Therefore attention was laid on methodological aspects of environmental credits from recycling and reuse to enable a proper comparison. The calculation is based on the recycling potential method described in Pflieger and Ilg (2007). The recycling potential describes the ecological value of a material´s accumulation in the technosphere. It states how many environmental burdens may be avoided in relation to a new production of the material (avoidance of primary metal production). The same methodology is applied vice versa if the recycling material content of the material is higher than the EOL recycling. Thus burdens have to be allocated for stopping the recycling cycle. Allocation of burdens was necessary for input materials with a "reuse- or recycling-origin". Therefore the allocation procedure given in the ILCD-handbook (European Commission, 2010) and described in Pertl et al. (2011) between the first and second life of a product was applied. Waste processing was allocated to the first product until a change from a negative to a positive market price is achieved. Emissions from final disposal on landfill or by incineration are considered including credits for energy from waste incineration and landfill gas treatment.

The life cycle inventory was developed by the support of the case study partners from construction industry. Data on materials and transport distances was delivered directly from partners and completed by literature research. Most material related datasets are taken from two different databases namely ecoinvent 2.2 (Frischknecht und Jungbluth, 2007; Hischier et al., 2010) and GaBi 5.0 (PE-International, 2011). As supportive tool GaBi 5.0 was used.

RESULTS

The scenarios are created based on the given examples in practice by the case study partners. Table 1 is showing the differences between the scenarios. Two parameters are varying which is the recycling quota in the EOL phase and the recycling material content of input materials in the production phase. If a reuse quota is assumed, than the recycling quota or material composition is given for the remaining material (e.g. 15% blocks are reused and 85% blocks are recycled by a quota of 95%). The substituted primary materials are gravel for concrete blocks, blast oxygen furnace (BOF) steel for steel and gypsum and low quality paper for gypsum plasterboard. In scenario Improved A 100% electric arc furnace (EAF)-steel is used. This type of steel consists of nearly 100% recycled steel and can be therefore seen as 100% recycling content.

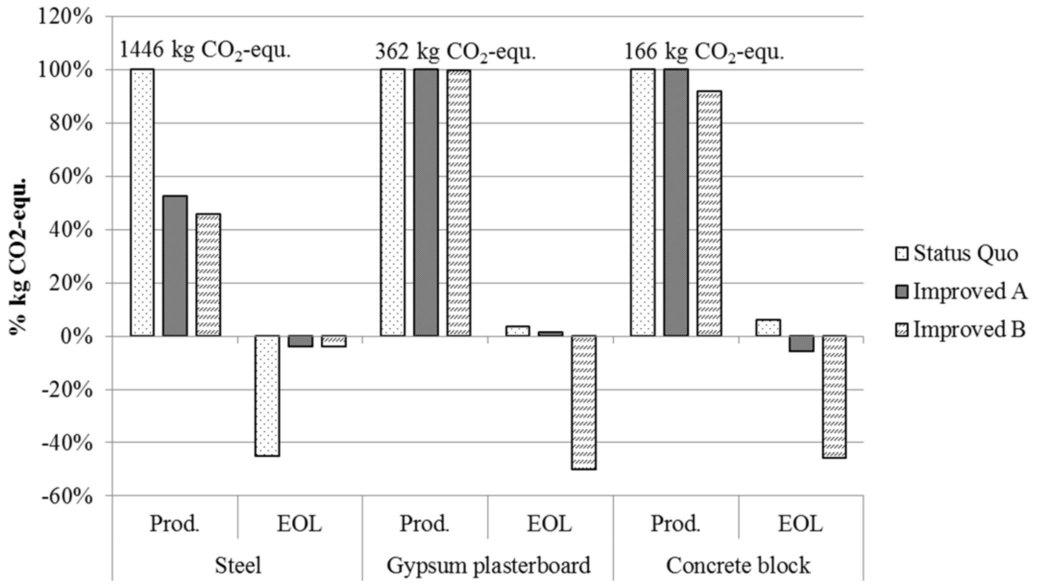
Reuse enables a 50% emission reduction, due to the assumption, that a reuse product has the same properties as a new product (Pertl et al., 2011) and can be reused for the same average lifetime than the new product. Material which is not recycled or reused is disposed according to the legal framework (landfill or incineration). The authors are aware that a recycling quota of 100% is impossible in practice. Nevertheless this assumption was done to understand the bandwidth of possible effects.

Table 1. Scenario description for three construction materials

Material	Phase	Status Quo	Improved A	Improved B
Steel	Prod.	37% EAF, 63% BOF	100% EAF	100% EAF 25% reused steel
	EOL	95% recyc. quota	100% recyc. quota	100% recyc. quota
Gypsum plasterboard	Prod.	25% recyc. gypsum	25% recyc. gypsum	80% recyc. gypsum 100% recyc. paper
	EOL	100% landfill	100% recyc. quota	50% reuse 100% recyc. quota
Concrete block	Prod.	Standard concrete	Standard concrete	80% recyc. aggregate
	EOL	75% recyc.	15% reuse 95% recyc. quota	100% reuse

Results in figure 1 are showing the production and EOL impacts on GWP for improved scenarios of the selected materials in relation to the status quo production impact. The results on steel show high improvement potential in the production phase if EAF steel is used. For gypsum plasterboard the high recycling content in “Improved B” is generating an impact reduction of 0.3% only. The same low effect can be seen for the production of concrete blocks. It is obvious that high impact reductions in the EOL phase are only possible by reuse. In the recycling scenarios of gypsum plasterboard and concrete blocks the EOL impacts are nearly negligible. The applied recycling potential method leads to higher impact reduction if steel with higher BOF (primary route) content is recycled.

Figure 1. Comparison of GWP-results (% kg CO_2-equ.) for 1 ton of construction material



DISCUSSION AND CONCLUSIONS

The three materials presented in this study can be seen as core materials of the construction industry. Concrete which is not presented in the paper shows comparable results to concrete blocks. It can be noticed that the already very high recycling rates in the status quo disable improvement possibilities in the EOL phase. The recycling content in e.g. steel products enables very low production related emissions but due to the method of recycling potential additional improvement in the EOL phase by raising the recycling quota is limited. For these three materials higher recycling material content in the production does not lower the GWP impact significantly as the energy demand and related environmental impacts for recycling (e.g. crushing of concrete) are comparable to the efforts of the extraction of primary materials (e.g. gravel or gypsum).

The only solution to overcome these barriers is to implement possibilities of reuse for construction materials whenever possible. Depending on the reuse quota emission reductions up to 50% are possible. This result leads to research demand in the future. On the one hand existing construction sites have to be screened with the focus on reusable materials. On the other hand the idea of Design for Reuse should be better implemented especially for buildings with an expected short lifetime.

The presented results are valid for countries with a well-developed recycling system only and cannot be transferred to countries where landfilling is the common way of disposal.

REFERENCES

Durão, V., Caixinhas, J., Osório-Peters, S. (2011): Case Studies 5 and 8. Concept paper for all networks / pilot applications. Deliverable 6A.1 of the project ZeroWIN. Grant Agreement Number 226752.

European Commission (2010). ILCD handbook: General guide for Life Cycle Assessment - Detailed guidance. First edition March 2010, EUR 24708 EN, Luxembourg, Publications Office of the European Union; Joint Research Centre - In-stitute for Environment and Sustainability.

Frischknecht R., Jungbluth N. (2007). Ecoinvent reports, Ecoinvent Centre, Swiss Centre for Life Cycle Inventories, Data v2.0 (2007)

Hischier R., Althaus H.-J., Bauer C., Doka G., Frischknecht R., Jungbluth N., Nemecek T., Simons A., Sutter J., Stucki M. (2010). Documentation of changes implemented in ecoinvent Data v2.1 and v2.2. ecoinvent report No. 16. Swiss Centre for Life Cycle Inventories, St. Gallen.

Obersteiner G., Pertl A., Scherhaufer S., Beigl P. (2010): Measuring the Success of the ZeroWIN Vision. Going Green. CARE INNOVATION 2010: "From Legal Compliance to Energy-efficient Products and Services". 8th International Symposium and Environmental Exhibition, Vienna, Austria, November 8-11, 2010; In: International CARE Electronics Office (Hrsg.), Going Green - CARE INNOVATION 2010. Abstract Book, p. 42; full paper on CD

PE International GmbH (2011). GaBi 5.0 prof database and software.

Pertl A., Obersteiner G., Salhofer S. (2011). Life cycle assessment aspects of reuse products. In: Technische Universität Berlin, LCM 2011 - Life Cycle Management Conference. full paper online (http://www.lcm2011.org/papers.html) and on CD

Pflieger J., Ilg R. (2007). Analyse bestehender methodischer Ansätze zur Berücksichtigung des Recyclings von Metallen im Rahmen der Ökobilanz. Projektbericht. Universität Stuttgart. Hrsg. Forschungszentrum Karlsruhe, Institut für Technikfolgenabschätzung und Systemanalyse –Zentralabteilung Technikbedingte Stoffströme.

FEASIBILITY STUDY OF AN ALUMINIUM PRODUCT BUSINESS MODEL USING LITHOGRAPHIC ALUMINIUM IN A CLOSED LOOP PROCESS

A. Vercalsteren, K. Boonen, V. Van Hoof and M. Vanhulsel, VITO, Belgium.*

**Boeretang 200, 2400 Mol, Belgium, an.vercalsteren@vito.be, +32 14 33 58 55*

Keywords: Life cycle assessment, business model, life cycle thinking, closed loop

ABSTRACT

This paper describes the assessment of the environmental performance of a new cradle to cradle business model using LCA-methodology. An important issue is the trade-off between environmental credits due to the avoidance of the use of primary aluminium, and additional environmental impacts resulting from the extra transport steps needed to collect the aluminium waste, bring it to an aluminium production plant for recycling and re-use into new aluminium coils. The study shows that the additional transport steps have a very limited environmental impact compared to the manufacturing of the product. It is thus environmentally advantageous to recollect aluminium scrap even at larger distances to be able to increase the recycled content of the product.

INTRODUCTION

A consortium between different industrial partners, resp. a producer and a user of aluminium consumables, the aluminium industry and logistic service providers, and VITO was set up to assess the feasibility of closing the loop of scrap aluminium into new products. This research is performed in a MIP (environment innovation project) project that, motivated by both economic and social responsibility triggers, has the objective to study the feasibility of a business model using aluminium in a cradle to cradle process. The feasibility of this business model is evaluated on business level, on technical level and on corporate social responsibility level.

The request for this feasibility study came from one of the core industrial partners, who deems it important to monitor and improve the environmental performance of their aluminium products. To further improve the performance, the effect of closing the aluminium loop is assessed in this research project. An important issue is the trade-off between environmental credits due to the avoidance of the use of primary aluminium, and additional environmental impacts resulting from the extra transport steps needed to collect the aluminium scrap waste, bring it to an aluminium production plant for recycling and re-use into new aluminium coils.

METHODS

The environmental performance of the new business model is assessed using the LCA-methodology according to ISO 14040 and 14044 and keeping in mind the PEF guidelines. The manufacturing of the product, the use of the product by the client, the processing of the waste and all transport steps are included in the functional unit. Data are collected from project partners, customers and scrap dealers. The modelling of the environmental impact of the different transport steps is done with specific transport emission models. Background processes were taken from the Ecoinvent 2.2 database. Environmental profiles are calculated using the ReCiPe v1.07 midpoint (H) impact assessment method and the software package SimaPro 7.3.3.

For recycling of waste various methodological approaches can be followed, of which we selected three for this study (the recycled content approach, the end of life recycling approach and the Product Environmental Footprint Guide approach).

In the recycled content approach, at the beginning of the life cycle both the impacts of the aluminium recycling process (e.g. energy) as well as the credits of the recycling process (saving virgin material) are taken into account for the amount of recycled aluminium that is used in the product. The benefit of the recycled content approach is that it allows to monitor improvements regarding the input of recycled lithographic aluminium in the production process (closing the cycle) and the possibility to benchmark the product with competitors (who apply the recycled content approach).

In the end of life recycling approach, the impacts of recycling of the aluminium and the avoided production of virgin aluminium (by bringing the recycled material on the market, independent from the place where it will be used), are taken into account at the end of the life cycle. At the beginning of the life cycle neither credits nor impacts of the recycling process are taken into account for the amount of recycled materials, since these impacts and credits have already been allocated to the previous life cycle of the material. The advantage of the end of life recycling approach in this case is that it allows including the possibility of using recycled lithographic aluminium consumer scrap as a high quality substitute for virgin aluminium. This approach is logical from the perspective of the aluminium industry sector.

The third approach, considered in the Product Environmental Footprint Guide, is situated in-between the two previously described approaches. It allocates the impacts and credits due to recycling equally between the producer using recycled aluminium and the producer making a product that will be recycled at the end of its life: 50/50 allocation split.

RESULTS AND DISCUSSION

The environmental impact of four scenarios is analysed: business as usual (BAU), alternative alu (AA) scenario and two Cradle to Cradle (C2C 1 and C2C 2) scenarios. In the BAU scenario, no recycled aluminium is used for the product and at the end of the life cycle the plates become available on the regular open scrap market. In the AA scenario, no recycled aluminium is used for the product and at the end of the life cycle a fraction of the plate scrap (eg. 15%) is guided to dedicated scrap partners. The C2C scenario builds on the AA scenario; the fraction of the scrap that is guided to dedicated scrap partners eventually could be recycled into lithographic aluminium by the producer and an aluminium converter, and replace x% of the primary raw aluminium of the product. In C2C 1, a recycled content of 20% is considered. In C2C 2, more aluminium scrap is bought on the market to be able to reach a recycled content of 100%. Like in the AA scenario, it is assumed that at the end of life 15% of the volume of the product goes to dedicated scrap partners.

Environmental burdens of the business as usual scenario, according to the recycled content approach, are largely due to the production of the lithographic aluminium, except for agricultural land occupation (which is caused by the use of pallets to transport the product). The impact of the transport steps is relatively small. The transportation of the product to the customers contributes to up to 8% of the total environmental impact, depending on the category considered. The impact of the use phase is insignificant for almost all environmental impact categories.

A comparison of the four scenarios for the recycled content approach is presented in figure 1. For readability reasons, only the human health related categories are shown. Results are similar for ecosystems and resources related environmental impact categories. Per environmental impact category, the scenario with the largest contribution is set at 100%, the contribution of the other scenarios is presented relative to that 100%.

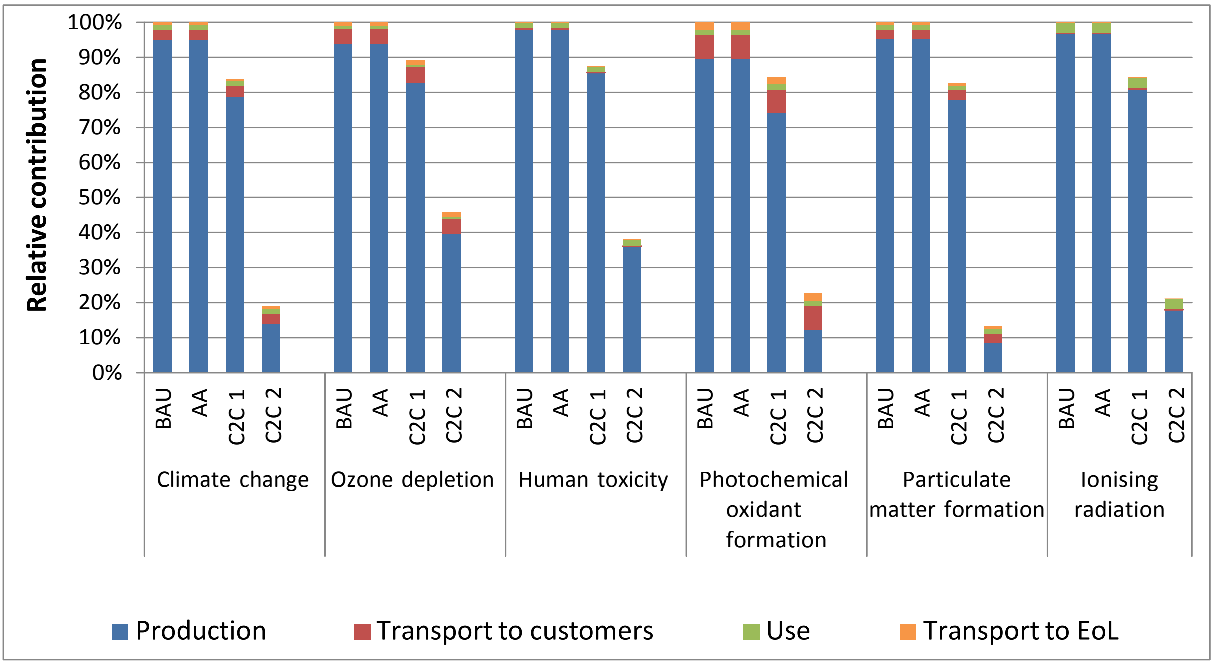


Figure 1: Environmental profile of the product in the 4 scenarios, according to the recycled content approach, for human health related categories.

The difference of the AA scenario and the BAU scenario is negligible (around 0,01%). The C2C 1 scenario has a smaller environmental impact in all impact categories (2 to 18% reduction), as the impact of the production of secondary aluminium is much lower than the impact of primary aluminium production. Since only secondary aluminium is used in the C2C 2 scenario, its impact is the smallest (10 to 88% reduction compared to the AA and BAU scenario).

When the same comparison of the four scenarios is made for the end of life recycling approach, the results for all scenarios are very similar. Indeed, equal credits for recycling are given in all scenarios, as lithographic aluminium consumer scrap will always be reused in other products. The impact of the additional transport needed to recollect the aluminium scrap is still the same as for the recycled content approach, but has become relatively more important as the total impact has decreased. However, the difference of the AA and the BAU scenario is still negligible (around 0,1%).

CONCLUSIONS

This study shows that the additional transport steps needed to collect the aluminium scrap waste and to bring it to an aluminium production plant for recycling and re-use have a very limited environmental impact compared to the manufacturing of the product. It is thus environmentally advantageous to recollect aluminium scrap even at larger distances to be able to increase the recycled content of the product (when using the recycled content approach).

Even when using the end of life recycling approach, recollecting scrap to be used in the product again will not add much to the environmental impact. It has to be noted that guiding the scrap to dedicated scrap partners was only considered for 15% of the volume of the product, when the location of the customer and amount of product used allows for this pathway.

To check whether it results environmentally beneficial for an additional client to enter one of the scenarios other than BAU, an excel tool is developed that allows the producer of the aluminium product to estimate the environmental impacts while adapting the values of recycling and transport parameters.

REFERENCES

Frischknecht R. (2010). LCI modelling approaches applied on recycling of materials in view of environmental sustainability, risk perception and eco-efficiency. Int J Life Cycle Assess, Volume 15, Issue 7, pp 666-671. DOI 10.1007/s11367-010-0201-6.

Goedkoop M.J., Heijungs R., Huijbregts M., De Schryver A., Struijs J., Van Zelm R. (2009). ReCiPe 2008, A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level, First edition Report I: Characterisation. Retrieved from: http://www.pre-sustainability.com/download/misc/ReCiPe_main_report_final_27-02-2009_web.pdf

JRC (Joint Research Centre of the European Commission). (2013). ANNEX II: Product Environmental Footprint (PEF) Guide to the Commission Recommendation on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations. Retrieved from: http://ec.europa.eu/environment/eussd/smgp/pdf/annex2_recommendation.pdf

Ntziachristos L., Samaras Z. (2010). EMEP/EEA emission inventory guidebook 2009, updated June 2010: Exhaust emissions from road transport. Technical report No 9/2009.

FENIX: A COMPREHENSIVE ON-LINE TOOL FOR EVALUATING PACKAGING WASTE MANAGEMENT OPTIONS IN SPAIN AND PORTUGAL

Alba Bala, Marco Raugei, Pere Fullana i Palmer, Cristina Gazulla*

UNESCO Chair in Life Cycle and Climate Change, ESCI-UPF
Pg. Pujades 1, 08003 Barcelona, Spain

** e-mail: alba.bala@esci.upf.edu*

Keywords: life cycle assessment; LCA; waste management; packaging; integrated tool.

ABSTRACT

Life Cycle Assessment is increasingly being applied to assist decision making in waste management policy and planning throughout Europe. Most of the existing software tools are either too general in scope, or not flexible enough. The goal of the LIFE+ project 'FENIX – Giving Packaging a New Life' was to create an *ad-hoc* software tool for evaluating alternative scenarios for the management of post-consumer packaging waste. Now finalized, such tool allows a large degree of flexibility, all the while ensuring the physical soundness of the underlying model, by enforcing a rigorous mass balance, and by pre-defining the most representative processes and technologies among which the user is allowed to choose.

INTRODUCTION

Light packaging waste accounts for approximately 38% by weight of the total municipal solid waste generated in the EU-27, and this figure is on the rise [Eurostat, 2011]. Packaging waste merits special attention since it is energy-intensive to produce, entails complex collection and transport logistics (partly because of its typically low density), lends itself to a wide range of possible end-of-life treatments (landfilling, recycling and incineration with energy recovery), and, in the latter two cases, has potential for high material and energy recovery rates. Life Cycle Assessment (LCA) has largely established itself as the methodology of choice for the evaluation of the potential environmental impacts of human-dominated processes and systems along their full life cycles, 'from the cradle to the grave' (or even 'from the cradle to the cradle', thereby explicitly including material recycling to give birth to second-generation product systems). LCA is especially useful in analysing alternative options, highlighting the trade-offs between them, and thereby helping to single out the most preferable one(s) overall, while avoiding the pitfall of unintentional impact shifting (between different geographical areas, life cycle stages or impact categories).

The waste management sector is a particularly complex type of system due to its multi-branched structure and its being closely intertwined with primary and secondary material and energy production systems. It is thus especially important to apply a rigorous LCA approach to its analysis, in order to arrive at sound and objective conclusions on its environmental performance. Most of the existing software tools, however, are often either too general in scope, requiring specific knowledge to set up and operate, or on the other hand not flexible enough to fully take into account the broad spectrum of available options (specifically, the waste collection phase is typically only accounted for by means of relatively crude deterministic models, which are of limited value in predicting the environmental performance of alternative collection methods or routes).

In order to make the most of the potentiality of LCA for the strategic planning of waste management options (as suggested by the EU Thematic Strategy on Waste Prevention and Recycling), and for light packaging waste in particular, it was recognized to be necessary to develop a new flexible and user-friendly software tool based on high-quality technical and scientific data. The 'FENIX – giving packaging a new life' project ensued, funded by the European Union's LIFE+ programme, and carried out by a consortium of four main partners: UNESCO Chair in Life Cycle and Climate Change of ESCI-UPF, Spain; Ecoembalajes España, Spain; Sociedade Ponto Verde, Portugal; PE Internationa, Germany.

METHODS

From the start, it was deemed a strict requirement that the whole of the FENIX project be firmly rooted in sound Life Cycle Thinking (LCT) principles. Specifically, the following methodological steps were taken.

Data base development

Most of the data to be used in the FENIX software tool were derived from the first-hand investigation of waste management processes and technologies representative of those currently deployed in Spain and Portugal. Data for background processes such as the electricity production mixtures, the production of virgin materials, and the production of chemicals used in the treatment of the waste flows, were instead sourced from existing LCA databases [PE international, 2011; JRC, 2011; Ecoinvent, 2011] and adapted to the local (Spanish and Portuguese) conditions whenever appropriate.

Development of individual LCI models

Individual life cycle inventory models were first developed for all the key processes that form part of the long waste management chain, with the help of thirteen collaborators among universities, technological institutes and research centres in Spain and Portugal.

Structuring of overall waste management model

The individual LCI sub-models listed above have been integrated into a common framework according to the general flowchart illustrated in Figure 1. The tool was designed to allow a large degree of flexibility in terms of mixing and matching the different processes and defining specific waste collection routes. At the same time, the physical soundness of the underlying model is guaranteed at all times, by enforcing a rigorous mass balance, and by pre-defining the most representative processes and technologies among which the user is allowed to choose.

Last but not least, the issue of correctly estimating the impact reductions afforded by recycling was taken into utmost consideration, with special attention directed at ensuring strict methodological consistency across the different materials.

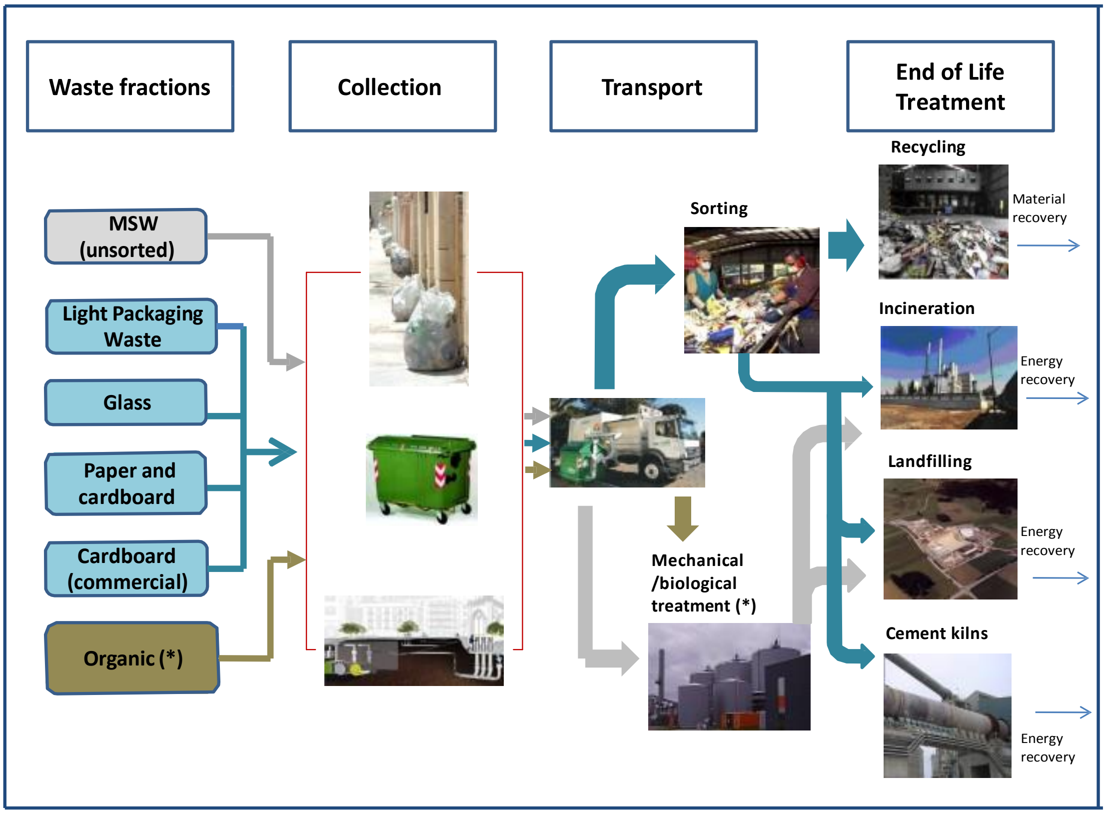


Figure 1. FENIX model flowchart.
(*) Organic waste (present both in the 'organic' waste fraction and in the other fractions as unsolicited waste flow) is only taken into account in so far as its mass affects the *dimensioning* of the collection and transport systems; however, the direct impact associated to its collection, transport and treatment is not accounted for (all impacts are calculated per unit of individual waste flow). Likewise, biological treatment and composting is only included in the boundaries of the FENIX analysis to account for the impact associated to the final disposal of the residual packaging waste that is separated out of the organic waste entering these processes.

Life cycle impact assessment
The following environmental impact categories were selected to be included in the FENIX software tool:

- CML 2002 [Guinée et al., 2002]: global warming potential (GWP - standard characterization factors were modified to exclude the contribution of biogenic carbon), acidification potential (AP), eutrophication potential (EP), ozone depletion potential (ODP), photochemical ozone creation potential (POCP);
- USETox [Rosenbaum et al., 2008]: human toxicity potential (HTP), eco-toxicity potential (ETP).

RESULTS

As originally envisaged, the final outcome of the project has been an *ad-hoc* software tool for evaluating alternative scenarios for the management of post-consumer packaging waste, enabling the selection of more sustainable waste management practices, in accordance with the current European policy principles. The tool is intended to be used directly by the local municipalities and waste management entities in Spain and Portugal, and therefore a special effort was devoted to developing a user-friendly on-line interface whereby the user is allowed to build their own scenario by simply typing in the waste quantities and selecting the appropriate collection, sorting and treatment (recycling, landfilling and/or incineration) processes. Up to three different and independent waste management scenarios can be defined. A large number of parameters may be adjusted, such as: initial waste composition, type(s) of collection system(s) and relative distances, collection frequency/-ies, type(s) of transference plant(s), selection plant(s) efficiency/-ies, and final EoL treatment options (recycling, incineration, landfill). Access to the tool is web-based and free of charge (but restricted to registered users) and available in three languages (English, Spanish and Portuguese); three categories of users are pre-defined, each enabling access to increasing levels of model complexity.

DISCUSSION

All the individual steps leading up to the FENIX tool (new data base entries, LCI sub-models) were subject to rigorous external review by internationally renowned LCA and waste management experts. In parallel, a number of seminars were held to openly discuss and vet all key assumptions and methodological decisions, so as to achieve the widest possible agreement and contribute to the advancement of the state of the art in the LCA of waste management systems.

CONCLUSIONS

After the successful closure of the project, the FENIX software tool is now on the verge of being adopted by the Spanish and Portuguese Green Dot Holders, and it is expected to play a major role in improving the management of packaging waste in those countries, based on sound life cycle principles. With minor adaptations, its transferability to other European countries is also a foreseen possibility for the near future, with the Czech Republic being identified as the first likely candidate in this sense.

REFERENCES

Ecoinvent, 2011. Ecoinvent 2.0 database. http://ecoinvent.org

Eurostat, 2011. http://epp.eurostat. ec.europa.eu/.

Guinée, J B (Ed.) Gorrée M, Heijungs R, Huppes G, Kleijn R, de Koning A, van Oers L, Sleeswijk A W, Suh S, Udo de Haes H A, de Bruijn J A, van Duin R, Huijbregts M A J (2002) Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards. Series: Eco-efficiency in industry and science. Kluwer Academic Publishers. Dordrecht, ISBN 1-4020-0228-9; Paperback, ISBN 1-4020-0557-1

JRC, 2011. ELCD database. http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm

PE International, 2011. GaBi LCA database. http://www.gabi-software.com/databases/gabi-databases/

Ralph K. Rosenbaum, Till M. Bachmann, Lois Swirsky Gold, Mark A. J. Huijbregts, Olivier Jolliet, Ronnie Juraske, Annette Koehler, Henrik F. Larsen, Matthew MacLeod, Manuele Margni, Thomas E. McKone, Jérôme Payet, Marta Schuhmacher, Dik van de Meent, Michael Z. Hauschild 2008. USEtox—the UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment. *Int.J LCA* 13(7):532-546

HOW TO DEAL WITH THE END-OF-LIFE OF BIO-BASED PLASTICS IN A LCA: CURRENT CHALLENGES AND PROPOSALS

Antonio Dobon, Anne-Sophie Le Meur, Mercedes Hortal. Packaging, Transport and Logistics Research Center (ITENE), Spain. *Parque Tecnológico, C/ Albert Einstein, 1. 46980 Paterna, Valencia (Spain). E: adobon@itene.com*

Keywords: bio-based plastics, LCA, end-of-life, modeling, uncertainty.

ABSTRACT

Bio-based plastics are gaining market share and forecasts shows that the demand of these materials will rise up to 178% in Europe by 2015. In case of biodegradable bio-based plastics there is an increasing concern about the different end-of-life options, since there are still not specific routes and these materials may affect other end-of-life schemes. Furthermore, discussions on the end-of-life regulations of bio-based plastics in the EU are becoming a matter of interest. Moreover the end-of-life LCA data about most of the bio-based plastics is based on estimations and even unavailable, being a challenge for LCA practitioners. This study explores the current end-of-life routes on a life cycle perspective and provides proposals to ensure a proper modeling for bio-based plastics.

INTRODUCTION

Among bio-based materials, the development of biodegradable packaging materials based on renewable resources has received increasing attention, particularly in EU countries (Davis 2006). This has driven to an increase of bio-based packaging applications (Davis, 2006) especially for single use/disposable applications. In spite of such interest, almost all the environmental impact information on bio-based materials (including bio-based plastics) is concentrated in the production stage although relatively little data about their waste treatment is available (Hermann, 2011) (Madival, 2009). There are many life cycle assessments of bio-based and biodegradable materials where the post-consumer waste treatment phase is deliberately neglected because of a lack of consistent data (Hermann, 2011), even though the end-of-life (EOL) may strongly influence the conclusions (Madival, 2009) (Patel, 2005) (Guo, 2012). One reason is that such materials have not been produced on a large scale yet or if so only for a short time. However, taking decisions with LCA implies a wider point of view and therefore there is a real need to expand the systems to include, or at least to estimate, what would happen with bio-based plastics when introduced in common EOL waste treatments.

METHODS

Main scientific literature has been reviewed, including also grey literature. Several approaches for dealing with the end-of-life were found. For instance, Hermann (2011) developed probably the widest analysis performed to date on the EOL of bio-based materials. The work of Hermann (2011) was partially based on the use of analogies as the best option to create estimated scenarios for the EOL, as he made for starch, PLA, starch/polycaprolactone and PHA. On the other hand, Madival (2009) has suggested the use of generic 100% mixed plastic waste inventory data for the EOL of PLA, whereas surprisingly only incineration, recycling and landfilling were considered and composting was directly omitted due to the lack of data. Furthermore, Madival (2009) has recognized that most of the EOL scenarios in its study considered were hypothetical. On the contrary Khoo (2010) suggests the use of site-dependent impacts of the EOL stage in order to make the results more meaningful. Guo (2013) has tried to overcome such drawbacks by considering meta-data analysis of literature of EOL options combined with lab tests and some industrial data, although his outcomes only applied to starch-PVOH blends derived from maize, potato and wheat. The literature review performed has led us to the conclusion that there is a lack of reliable data related to the EOL of bio-based plastics and several key issues were identified which are discussed below.

RESULTS & DISCUSSION

The influence of the thickness and the limitations for certain EOL waste treatments

When bio-based plastics are considered one should take into account that the thickness of the material influences the behavior of the material in waste treatments with the exception of incineration processes (Hermann, 2011). Therefore, the biodegradability of materials depends on the chemical composition of the materials considered as well as on the final product (Nampoothiri, 2010). Bio-based plastics products have also certain limitations to some kinds of waste-treatment processes. That’s the case of recycling, where for biodegadable bio-based plastics the biodegradation process has been triggered during service life or in the waste stream (Davis, 2006). There are some exceptions like the bio-based PE, PET and PP which deliver a plastic material with identical physical and chemical properties to their fossil counterparts, giving an identical EOL behavior (European Bioplastics, 2013) (Shen, 2009). Several positions have been found in the literature in the discussion around if the biodegradable plastics (most of them bio-based) either harm or not the plastics recycling industry. Davis (2006) said that this argument is unfounded, at least in the UK, although clarified that suitable mechanisms for clear and unambiguous labeling of biodegradable packaging together with infrastructure for certification and joint collection of biodegradable packaging with organic waste are necessary. On the other hand Plastics Europe (2012) stresses that “the benefits of biodegradability can only be obtained in appropriate composting facilities”. Song (2009) stated that plastics that enter the municipal waste stream may add complications for existing plastic recycling systems.

The limits of biodegradation of bio-based plastics

A key factor when creating EOL LCA scenarios is that not every bio-based plastic can be treated by composting and/or digestion. One common example is PLA, which is only capable to biodegrade under certain industrial composting conditions with temperatures of 60ºC and above (Shah, 2008), being inadequate for home composting (Davis, 2006) (Hermann, 2011). Furthermore, process conditions for composting (temperature, humidity, oxygen, etc.) must be strictly controlled to produce suitable compost (Gironi, 2011). Therefore LCA practitioners should take into account such limitations whenever an EOL scenario is created. Furthermore, bio-based biodegradable plastics are generally unsuitable for landfilling (Davis, 2006). In case landfilling of biodegradable plastics is considered, Häkkinen (2010) suggests assumed that

PLA behaves similarly to lignin, or polyesters such as PET, and does not degrade in well-engineered landfills where there is little moisture or warmth.

Carbon storage, avoided impact and credits

During biological waste treatment, the materials are metabolized, so a part of their embodied carbon is emitted into air and the remainder is stored as compost or digestate (Hermann, 2011). Theoretically long-term carbon sequestration from compost can be calculated by laboratory assays, even though these results are uncertain since the extraction of humic substances from soil is difficult (Hermann, 2011). Indeed, carbon credits can considerably affect the results (Hermann, 2011) (Pawelzik, 2013), but there are significant uncertainties in how they are calculated. Guo (2011, 2012, 2013) has decided to use a carbon counting approach based on carbon stoichiometry. The compost or digestate can replace soil conditioners supporting humus formation (Hermann, 2011). In fact, the common practice is to assume that the compost produced substitute peat or straw, fertilizers as well as act as a way for carbon sequestration in soil (Razza, 2009) (Hermann, 2011). Furthermore, several authors have stated that not all the N in compost is available for plants considering ranges between 10 to 35% (Hansen, 2006) (Hermann, 2011). Therefore, variations due to avoided impacts and credits strongly depend on the methodological choices considered by the LCA practitioner as it was recognized by Madival (2009). In the absence of bio-based plastics specific data for composting, it seems scientifically sound the approach suggested by Hermann (2011) which is based process emissions from existing industrial composting processes of vegetable, fruit and garden waste and material-specific biodegradation levels. However, LCA practitioners should be aware of the large differences about biodegradation rates for some bio-based plastics declared by several authors as well as the variations on the composting technologies which affects mainly to the amount of C as CH_4 (Hermann, 2011).

Table 1. State-of-the art of data sources & assumptions in selected LCA of bio-based plastics.

Author	Area	Bio-based plastic	Industrial composting	Home composting	Landfilling	Inci-neration	Recycling	Anaerobic digestion
(Razza, 2009)**	IT	Mater-Bi	a)					
(Madival, 2009)	US	PLA			b)	b)		
(Häkkinen, 2010)	EU	PLA						
(Leceta, 2013)	EU?	Chitosan						
(Guo, 2011)*	UK	Starch-PVOH blends						
(Guo, 2012)* (Guo, 2013)*	UK	Starch-PVOH blend						
(Khoo, 2010)**	SG	PHA						
(Gironi, 2011)	EU?	Mater-Bi	Not specified					
(Edwards, 2012)***	UK	Starch-polyester			b)	b)		
(Liptow, 2012)	BR+EU	Bio-PE						

Database	Literature	Own calculation	Theoretical calc.	Lab scale results	Ind. scale results	Meta-data analysis	Not specified

*Full EOL LCI available. WRATE database used for infrastructure processes
Partial EOL LCI available / * Litter was also considered

a)Italian I-LCA database
b)Ecoinvent

Uncertainty issues and modeling of the EOL of bio-based plastics

Uncertainty is one of the key issues in every LCA, specifically when comparative assertions are considered. For instance, in case of PLA, the uncertainties regarding biodegradation in a landfill have a substantial impact on the estimates of GHG emissions (Patel, 2005) (Hakkinen, 2010). Furthermore such uncertainty is significantly increased when readers look at the assumptions made by many authors to define the EOL scenarios for the assessment of bio-based plastics. For instance, Miller (2013) considered that the anaerobic digestion of PHVB can be assumed as the same process for cellulose. In some cases (Häkkinen, 2010) (Leceta,

2013) (Gironi, 2011), the origin of the data used to model the EOL has not been specified, thus increasing the uncertainty of the LCIA results (Table 1). Guo (2011) has also pointed out the uncertainties of the use of laboratory trials related to anaerobic digestion.

CONCLUSIONS & RECOMMENDATIONS

The main conclusions & recommendations that can be achieved from our research have been: (a) there is not a general rule to take decisions about the use and EOL of bio-based plastics. Our recommendation is to perform a case-by-case analysis since the LCA results are highly sensitive to the different biodegradability behavior/rates of bio-based plastics as well as to the methodological choices; (b) the development of standard/globally accepted procedures for the LCA of bio-based plastics and other bio-based materials should be very useful to define common criteria for EOL modeling, reducing dissimilar and contradictory conclusions; (c) more knowledge about the real behavior of bio-based and biodegradable materials during final disposal and waste management technologies is needed. In fact, for most bio-based plastics this information is unknown and very few LCI datasets are available to date. Acknowledgements: The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007- 2013) under grant agreement n° 265096: LCA to go project.

REFERENCES

Davis G., Song J.H. (2006) Ind Crop Prod 23: 147–161
Edwards C, Parker G. (2012) A LCA of oxo-biodegradable, compostable and conventional Bags. Intertek report
European Bioplastics (2013). Benefits of biobased rigid packaging. Fact sheet April 2013.
Guo M, Trzcinski AP, Stuckey DC, Murphy RJ. (2011) Bioresource Technol 102: 11137–11146
Guo M, Murphy RJ (2012) J Polym Environ 20: 976–990
Guo M, Stuckey DC, Murphy RJ (2013) Bioresource Technol 127: 256–266
Häkkinen T., Vares S. (2010) J Clean Prod 18: 1458-1463
Hansen TL, Bhander GS, Christensen TH, Bruun S, Jensen KS. (2006) Waste Manage Res 24(2):153-66.
Hermann B.G., Debeer L., De Wilde B., Blok K., Patel M.K. (2011) Polym Degrad Stabil 96 1159-1171
Gironi F, Piemonte V (2011) Energ Source Part A, 33:21, 1949-1959
Khoo HH, Tan RBH (2010) Int J Life Cycle Assess 15: 338–345
Leceta I, Guerrero P, Cabezudo S, de la Caba K. (2013) J Clean Prod 41: 312-318
Liptow C, Tillman AM (2012) J Ind Ecol 16 (3): 420–435
Madival S., Auras R., Singh SP., Narayan R. (2009) J Clean Prod 17, 1183–1194.
Nampoothiri KM, Nair NR, John RP (2010) Bioresource Technol 101: 8493-8501
Miller SA, Billington SL, Lepech MD. (2013) J Clean Prod 40: 190-198
Patel, M., et al (2005). Biopolymers Online DOI: 10.1002/3527600035.bpola014
Pawelzik P., et al (2013) Resour Conserv Recy 73 211– 228
Plastics Europe (2012). Bioplastics - 2012 update. http://www.plasticseurope.org/ (accessed April 2013)
Razza F, Fieschi M, Degli Innocenti F, Bastioli C (2009) Waste Manage 29: 1424–1433
Shah AA, Hasan F, Hameed A, Ahmed S. (2008) Biotechnol Adv 26, 246-265
Shen L, Haufe J, Patel MK (2009) http://www.epnoe.eu/research/Life-Cycle-Analysis (accessed March 2013)
Song JH, Murphy RJ, Narayan R, Davies GBH (2009) Phil. Trans. R. Soc. B 2009 364

MFA AS A TOOL FOR PRODUCT END-OF-USE MANAGEMENT

Derek Diener, Anne-Marie Tillman. *Environmental Systems Analysis, Chalmers University of Technology, Rännvägen 6B, Göteborg, Sweden, SE 412 96, derek.diener@chalmers.se.*

Keywords: MFA; product end-of-use management; company-level; closed loop

ABSTRACT

Material flow analysis (MFA) has been widely used as a tool to assess national and regional material flows. Using a case study, this paper demonstrates one other way to use MFA: as a tool for a company's product end-of-use (EoU) management. Three main activities emerged during the study with valuable results: (1) the *traditional MFA* provided flow diagrams, (2) *inflow analysis* allowed basic feasibility analysis of EoU product capture, and (3) *product chain description* provided a rough sketch of key actors and their decisions. Together, results can be used as the foundation for understanding product fate and reveal potential avenues and barriers to improving a company's EoU management.

INTRODUCTION

As part of a larger life cycle management (LCM) initiative, an international steel component manufacturer (*the company*) declared an interest in understanding the end-of-use (EoU) of its products. The company's questions included: "*What is the fate of our products after use?*" and "*Are there opportunities to prevent losses?"* Material flow analysis (MFA) was identified as a tool to help answer these questions. Thus the questions addressed by this paper are, "*Is MFA valuable for use on a company's downstream flow?"* and "*If so, how can it be used?*

Product EoU management is the subject of the study, whereas MFA is the tool used to assess it. EoU management (*how to handle EoU products*) encompasses both technical and management research areas. In the technical arena, EoU is addressed in many subjects, from theoretical limits to metals recycling (Reuter et. al. 2005) to eco-efficiency gains from remanufacturing (Kerr and Ryan 2001). The management research area focuses primarily on business strategies and operational issues related to extended producer responsibility (e.g. Steger 1998). MFA, on the other hand, has been widely used as a tool to assess the flows and stocks of regions, countries (e.g. Davis et. al. 2007), and industrial sectors or areas (e.g. Sendra et. al 2011). This paper presents how MFA was used as the first step for assessing a company's product EoU management. Hence, it offers one way in which MFA can be used at the company-level.

METHODS

The MFA in question was designed using guidelines from Brunner and Rechberger (2004). Starting with the company's question statements, flows, processes and system boundaries were determined. Three non-consumer business segments were chosen as subjects for the investigation based on internal interest and information availability. Product and raw sales data were gathered for the segments of interest. Product weights were added to the sales data for use in this study. Substances of interest were chosen from selected product compositions. Initial substance flow from the company was determined by multiplying product substance composition with sold amount of product. Sales data were also analyzed based on product type, sales value, weight, and size as well as customer, customer location, and customer type.

Key processes were identified and included: product use, remanufacturing, material handling (separation), steel production, and slag handling. With these key processes in mind, information sources were identified. Company representatives, customers, and material handlers (brokers) were the three categories of informants. Informal interviews with company representatives provided details about remanufacturing and described sales and market aspects. Seven customers were approached with a six-question product EoU questionnaire. Questions were both quantitative and qualitative in nature. With customer responses, follow-up discussions were conducted. In-person discussions were conducted with representatives from one large Swedish material broker. Literature, two company representatives, and one metallurgist researcher provided data related to steel metallurgy and slag handling.

Quantitative data was compiled in a simple spreadsheet-based, linear model. Scenarios were generated based on customer responses to determine varying product fates. Software was used to display results in Sankey diagrams. Descriptions provided by informants were compiled to make an overall understanding of the system and relevant actors. These descriptions also yielded indications of potential opportunities and barriers to improved EoU management.

RESULTS

Some results from the case study are presented briefly. First, flows are displayed showing losses and revealing opportunity. This provides an indication of *the magnitude of the problem or opportunity* (namely what losses there are and where they can be mitigated). Then, sales data analysis provides a *rough feasibility assessment* of the opportunities. Finally, review of discussions with actors reveals *potential barriers and opportunities.*

Sankey diagrams from two scenarios are shown in Figure 1 (next page). Product (material) fate varies greatly. Either (*Good)* - the product is used multiple times and most of recycled material ends up in alloyed steel or (*Bad)* - the product is used one time (60% more material is needed to deliver the same function achieved in *Good*), most of the recycled material ends up in carbon steel, in which full alloy function is not realized. Also, more material is lost to disposal or slag. Differences between the two scenarios highlight two potential *opportunities to mitigate losses*, steel scrap segregation and remanufacturing.

Now, given an idea of what losses occur and what general opportunities there may be, questions can be posed, *"What is the feasibility of these opportunities?"* and *"How many products are we talking about?"* or *"What is the potential to remanufacture more?"* Analysis of the sales data (i.e. the initial material flow) yields at least some indications. One example is presented here: analysis of the *potential to remanufacture more*. Currently, remanufacturing is performed successfully and profitably by the company, albeit at a limited scale. Size is used as an indication of remanufacturing feasibility – bigger products are preferred in the remanufacturing process. The company has established guidelines for which size of products to remanufacture, here referred to as *minimum*, *promoted*, and *profitable*. Figure 2a (next page) displays what percentage of the material would be gathered if all products of a certain size and greater were captured. For example, if all *promoted* (and greater) sized products were captured, over 50% of the material would be captured. This appears to be considerably greater than the currently achieved capture, which indicates a potential. Figure 2b shows that the products greater than the *promoted* size represent a majority of the weight but only a fraction of the product count (pcs). This can be used as an indication of feasibility of capture.

Figure 1: Two modeled scenarios, a *Good* and a *Bad*, displaying ultimate fate of materials. Realized material function decreases from top to bottom.

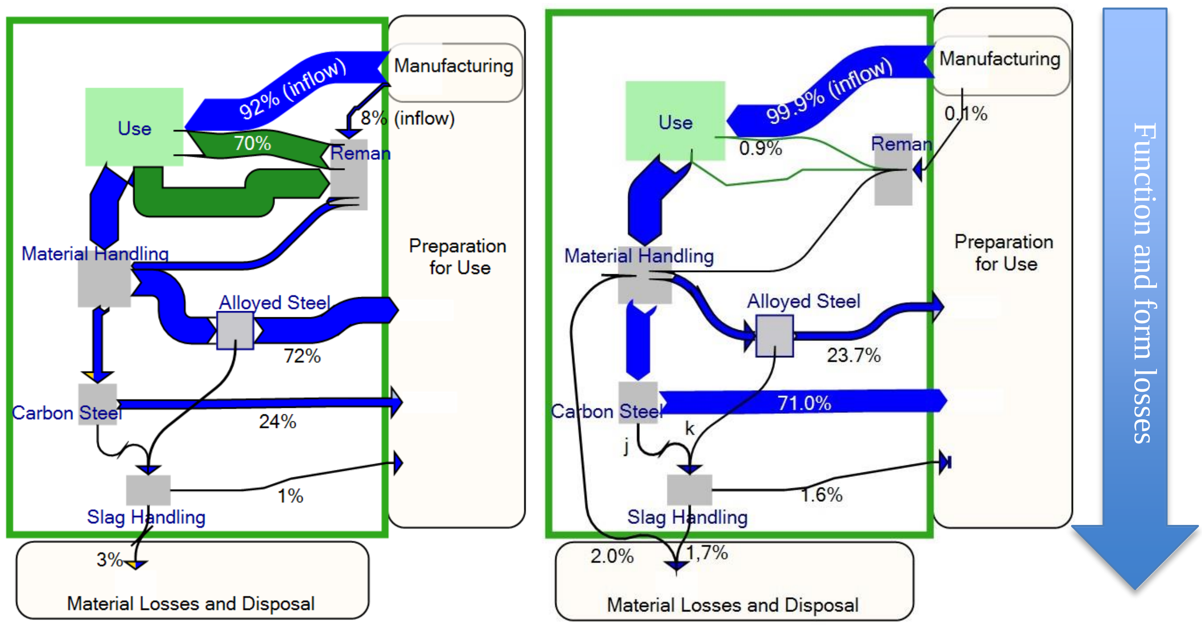
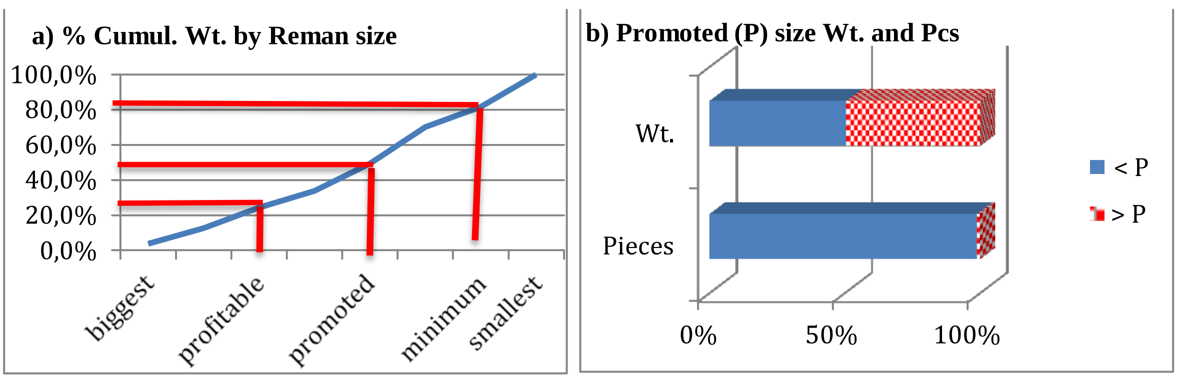


Figure 2: (a) Share of material captured if all products of a particular reference size (and greater) were captured and (b) Share of weight and product count (pcs) of products greater than or equal to the size *promoted* for remanufacture



With an indication of both the size of the problem (fates) and the feasibility of solutions, it is possible to assess non-technical aspects. The level of utilization of remanufacturing is one example. Remanufacturing appears to be a good solution to increasing resource efficiency and it appears that more products can be remanufactured than currently being done. *Why then, are more products not remanufactured?* Discussions with company representatives and customers revealed some hints. They include: (1) there may be a lack of customer confidence in remanufactured products, (2) company incentives may be more aligned to new product sales, and (3) distributors may not have incentives to offer remanufacturing. Indications yielded during the course of the MFA can be investigated further using other methods.

DISCUSSION

Although not originally planned, three main methodological activities emerged in conducting the MFA (as named here): (1) the *traditional MFA*, (2) *inflow analysis*, and (3) *product chain description*. Each of these activities was found to be necessary given the context of the study – product EoU management. The *traditional MFA* was strictly focused on defining the system boundaries and determining the physical flows in the system. This activity provided an answer to the question, "*What is the fate of our products after use?*" The *inflow analysis* involved analyzing *raw* sales data (Note: if "already-pruned" sales data had been received instead, many insights would likely not have been revealed) based on many characteristics potentially relevant to EoU management. The *product chain description* included noting basic non-technical aspects of the system, such as actors, their activities and decisions, market factors, and organizational aspects. Together, the *inflow analysis* and *product chain description* helped reveal potential answers to the question, "*Are there opportunities to prevent losses?"* At that point, the MFA appears to have reached its limits. Further investigation into product chains leads to other disciplines or tools.

CONCLUSIONS

It is found that MFA is a valuable tool and a good first step to investigating a company's product EoU management. MFA allows a manufacturer to document the effects that external processes, such as recycling processes, have on their product. Visual results provide an indication of "the size of the problem" and serve as a platform for further discussion. Assessing sales data, which represents initial flow, provides a gauge of feasibility (or value) of additional product accountability or capture. Finally, MFA demands some knowledge of processes and interaction between actors in the product chain. Acquiring this knowledge can yield a preliminary indication of what barriers or opportunities exist. Ultimately, MFA appears to serve as a catalyst to further investigation.

REFERENCES

Reuter, M.A., van Schaik, A., Ignatenko, O., de Haan, G.J. (2006). Fundamental limits for the recycling of end-of-life vehicles. *Minerals Engineering*, *19* (5), 433-449.

Kerr, W., Ryan, C. (2001). Eco-efficiency gains from remanufacturing: A case study of photocopier remanufacturing at Fuji Xerox Australia. *Journal of Cleaner Production*, *9* (1), 75-81.

Steger, U. (1996). Managerial issues in closing the loop. *Business Strategy and the Environment*, *5*(4), 252–268.

Davis, J., Geyer, R., Ley, J., He, J., Clift, R., Kwan, A., Sansom, M., Jackson, T. (2007). Time-dependent MFA of iron and steel in the UK, Part 2. *Resources, Conservation and Recycling*, *51*(1), 118-140.

Sendra, C., Gabarrell, X., Vicent, T. (2007). Material flow analysis adapted to an industrial area. *Journal of Cleaner Production*, *15*(17), 1706-1715.

Brunner, P.H., Rechberger, H., (2004). *Practical Handbook of Material Flow Analysis*. Boca Raton: Lewis Pub.

RECYCLING OF GLASS FROM END OF LIFE VEHICLES: ENVIRONMENTAL IMPACT ASSESSMENT OF DIFFERENT SCENARIOS

S. Manshoven, D. Nelen and A. Vercalsteren, VITO, Belgium.*

**Boeretang 200, 2400 Mol, Belgium, saskia.manshoven@vito.be, +32 14 33 56 89*

Keywords: End of life management, life cycle assessment, ELV glass

ABSTRACT

This study examines the environmental impacts of the current end of life vehicle (ELV) recycling practice in Belgium of shredding and compares this with selective glass dismantling and recycling, using life cycle assessment (LCA). Different policy scenarios are assessed for ELV recycling in Flanders, showing the vulnerable balance between benefits from improved recycling and burdens from additional transport requirements.

INTRODUCTION

In the European Directive 2000/53/EC concerning ELV, targets are established for the reuse, recycling and recovery of ELV. Annex I of this Directive presents some treatment operations to promote recycling, including the removal of glass. As the way in which the glass should be removed is not specified, each EU member state can make their own interpretation.

In 2011 about 170,000 ELV were treated in Belgium. In the current recycling practice, ELV glass remains in the vehicle and is shredded together with the other materials. A series of post shredder technologies (PST) separate the different materials, leaving a mineral rest fraction which contains most of the glass, stones, concrete porcelain, etc. This fraction is of insufficient purity to be reused as cullet in glass production. Instead, it is used as building material, e.g. landfill cover. An alternative treatment route for ELV glass would be selective dismantling prior to shredding, which might also significantly increase the environmental benefits of ELV recycling (Belconsulting, 2006; OVAM, 2008) as the resulting glass fraction can be processed by glass recyclers into high quality cullet that can be reapplied in the glass industry. In addition, laminated windscreens contain a plastic polyvinyl butyral (PVB) interlayer, which can also be recycled into a replacement for PVC in carpet production (among other applications).

In this study, commissioned by the Public Waste Agency of Flanders (OVAM), the environmental impacts of both recycling routes for automotive glass are compared. It is important to note that this study departed from the current organizational and logistic situation of ELV treatment in Belgium and was performed in close collaboration with the stakeholders along the chain.

METHODS

To quantify the environmental impacts of ELV glass recycling a so-called 'gate to grave study' is performed, using attributional and comparative LCA. In order to narrow down the comparison to the burdens and benefits specifically associated with the glass flow, streamlining between the alternatives is applied. As the treatment of the ELV carcass is independent of the chosen treatment for the glass, all burdens and credits related to the treatment of the ELV carcass are excluded from the comparison. The data inventory was performed in close cooperation with all stakeholders involved in the ELV recycling chain and complemented by literature (CARE, 1999; European Commission, 2013). Background processes were taken from the Ecoinvent 2.2 database. Environmental profiles are calculated using the ReCiPe midpoint method and the software package SimaPro 7.3.3.

RESULTS AND DISCUSSION

Environmental profiles of the separate ELV glass recycling routes

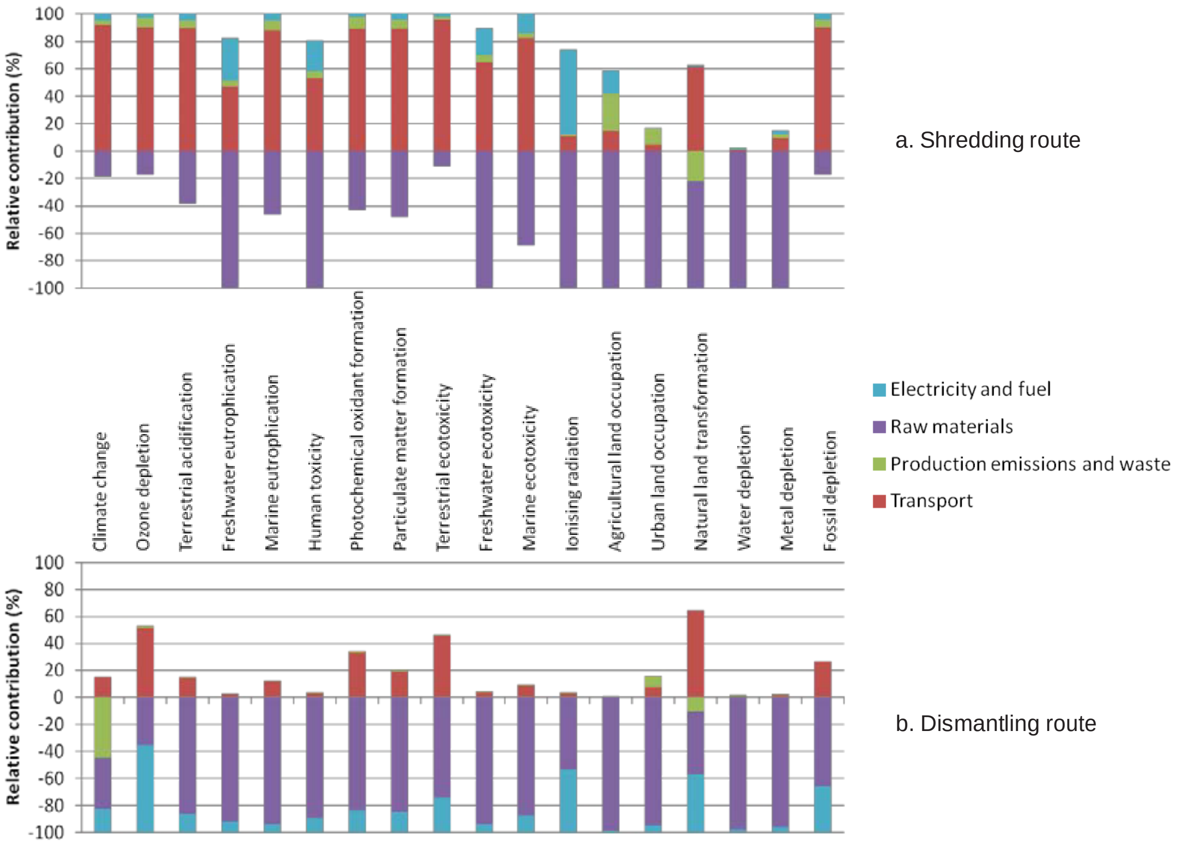


Figure 1: Comparison of the environmental profiles for shredding (a) and dismantling (b).

Figure 1 presents the environmental profiles for both treatment routes under study. The functional unit is “the treatment of 1 kg ELV glass”, starting from the depolluted ELV at the depollution center and ending at the reapplication of the recycled glass in new products. Depending on the impact category, the **shredding/PST** route has a net environmental burden or benefit. Burdens are largely due to transport operations (diesel production and consumption) between the consecutive recycling steps. The recycling processes themselves contribute to a lesser extent and burdens are typically due to emissions occurring during electricity production and to the disposal of waste from the PST. The benefits arise from the reapplication of the mineral fraction as landfill cover, avoiding the mining of virgin sand.

Dismantling, resulting in recycled cullet and PVB, has a net environmental benefit in all impact categories. Burdens are due to transport between process stages, while the emissions of the recycling processes themselves are negligible. The benefits are mainly linked to the replacement of raw materials (mainly soda and silica sand) in glass production. PVB recycling from windscreens also contributes significantly to the environmental benefits. The energy use of recycling operations is largely compensated by energy savings in glass production, resulting in a net benefit for electricity and fuel use. One eye-catching detail is the savings in carbon dioxide process emissions due to the glass formation reaction that is avoided when recycled cullet is used in glass melting.

Scenario analysis

ELV glass is lost from ELV due to accidents or spare part removal. In addition, the way in which ELV are transported to the depollution center determines to what degree the windows will remain available for dismantling. In Belgium two main transport modes are currently in use. About half of ELV are transported using car transporters, harboring 8 vehicles. With this type of transport, the ELV typically arrive at the depollution center with windows intact. Alternatively, the ELV are transported by scrap truck, equipped with a grapnel that crushes part of the windows while loading the ELV, making them unsuitable for dismantling.

The functional unit for the policy scenario comparison is defined as “the treatment of an average ELV”. As the transport between the last owner of the ELV and the depollution center has an influence on the amount of glass that can be dismantled, the system boundary is expanded to include the transport step towards the depollution center. Streamlining is applied for the EoL treatment of all non-glass related parts in the ELV, which are assumed to be treated in the same way, regardless of the scenario. Three different policy scenarios for ELV glass recycling are assessed .

- 0: Business-as-Usual: current practice of shredding all automotive glass together with the rest of the ELV;
- 1: Dismantling when possible: all automotive glass that arrives intact at the depollution center is dismantled, using the current transport modes to the depollution center.
- 2: Maximal dismantling of ELV windows: for the ELV that used to be transported to the depollution center by scrap wagon, the transport mode is adapted in order to assure that ELV windows remain intact during transport. As this change affects the transport of the full ELV, the impacts of the ELV carcass treatment are different from scenarios 0 and 1. In order to maintain equivalence between the scenarios, a streamlining correction is applied to scenario 2 to account for this transport change.

The results of the scenario comparison are shown in Table 1. The environmental impacts of scenario 0 (BAU) are relatively small compared to scenarios 1 and 2. While scenario 1 generates environmental benefits on all impact categories, the result of scenario 2 is mixed as benefits are significantly reduced or transformed into burdens, due to the altered transport.

Table 1: Comparison of the environmental impacts of the studied scenarios

		Scenario comparison		
Impact category	**Unit**	**Scenario 0 (per ELV)**	**Scenario 1 (per ELV)**	**Scenario 2 (per ELV)**
Climate change	kg CO2 eq	0,3	-6,6	-4,0
Ozone depletion	kg CFC-11 eq	3,8E-08	-1,1E-07	5,8E-07
Terrestrial acidification	kg SO2 eq	7,1E-04	-0,020	-0,016
Freshwater eutrophication	kg P eq	-3,2E-06	-0,0011	-0,0014
Marine eutrophication	kg N eq	2,8E-05	-0,0011	-9,3E-04
Human toxicity	kg 1,4-DB eq	-0,0042	-1,2	-1,3
Photochemical oxidant formation	kg NMVOC	8,2E-04	-0,009	0,005
Particulate matter formation	kg PM10 eq	2,3E-04	-0,0054	-0,0018
Terrestrial ecotoxicity	kg 1,4-DB eq	6,2E-05	-2,6E-04	1,0E-03
Freshwater ecotoxicity	kg 1,4-DB eq	-4,9E-05	-0,027	-0,031
Marine ecotoxicity	kg 1,4-DB eq	2,2E-04	-0,021	-0,016
Ionising radiation	kg U235 eq	-0,015	-0,64	-0,85
Agricultural land occupation	m2a	-5,5E-04	-0,21	-0,28
Urban land occupation	m2a	-0,010	-0,024	-0,022
Natural land transformation	m2	-1,0E-04	-3,3E-04	5,1E-04
Water depletion	m3	-0,039	-0,15	-0,18
Metal depletion	kg Fe eq	-0,011	-0,21	-0,25
Fossil depletion	kg oil eq	0,10	-1,1	-0,025

CONCLUSIONS

This study shows that the dismantling of ELV glass has significant environmental benefits over the current practice of shredding the glass together with the ELV. Environmental burdens of recycling are mainly related to transport operations (and the associated assumptions made), while the benefits associated with the avoided raw materials determine the net environmental result. A careful balance should be made between the benefits of closing the glass loop and the additional transport impacts that are generated by doing so, in order to avoid burden-shifting. If improvements in PST technology would achieve in a glass fraction that meets the requirements of the glass industry, the overall environmental profile of the shredding route could be improved significantly.

REFERENCES

Belconsulting. (2006). Recyclage van glas uit afgedankte voertuigen (Recycling glass from end-of-life vehicles). study commissioned by Febelauto, Coberec, Febiac.

CARE. (1999). Glass Recycling. An automotive perspective. Retrieved from: http://www.seas.columbia.edu/earth/RRC/documents/glass_recycling_an_automotive_perspection.pdf

European Commission. (2013). Best Available Techniques Reference Document for the manufacture of Glass. Retrieved from: http://eippcb.jrc.ec.europa.eu/reference/BREF/GLS_Adopted_03_2012.pdf

OVAM. (2008). Gevaarlijke componenten in afgedankte voertuigen (Hazardous compounds in end-of-life vehicles. D/2008/5024/76. Retrieved from: http://www.ovam.be/jahia/Jahia/cache/offonce/pid/176?actionReq=actionPubDetail&fileItem=1802

SUSTAINABLE VALORIZATION OF PIGGERY WASTES FOR RESOURCE EFFICIENCY AND GREENER ENVIRONMENT

Ife Adewumi, Niger Delta University, Wilberforce Island, Nigeria; Adesuji Adejuwon, Obafemi Awolowo University, Ile-Ife, Nigeria; Olayinka Adebayo, Obafemi Awolowo University, Ile-Ife, Nigeria; Wemimo Oluwasola,, Obafemi Awolowo University, Ile-Ife, Nigeria; Oswald Olatunbosun, , Oke-Aro Piggery Farms Estate, Lagos, Nigeria.*

**Corresponding author's full postal address: Prof Ife Adewumi, Department of Civil Engineering, Faculty of Engineering, Niger Delta University, Wilberforce Island, Nigeria. Email: ife.adewumi@mail.ndu.edu.ng and ife.adewumi@gmail.com*

***Keywords**: end of life valorization; piggery wastes recycling; feed recovery; briquettes and biogas as biofuels; life cycle management*

ABSTRACT

Valorization of piggery wastes samples from a commercial farm site and two institutional Research farms was done using five standard methods: biomethanation; feed recovery from the wastes by washing, sieving and sterilizing with steam; briquetting of the raw manure into solid fuels; activating the manure to adsorbent; and processing digester liquor and slurry into organic fertilizer. The study recovered 390± 45 kg dry matter feed/mT of the wastes with 9.32% Protein and other nutrients; recorded good yield of biogas and briquettes that burnt with energy of 65.43 MJ/g; activated carbon (AC) with good adsorbent property; stabilized sludge and liquor with high content of plant micro- and macro-nutrients useful as organic fertilizer all showed hope for sustainable management of piggery wastes.

INTRODUCTION

To those who eat pork, pig production represents the substantial percentages of the global meat products given as 37% in 2007 (FAOSTAT, 2009) and projected to be 31% in 2020 (Rosegrant *et al*, 2001). During pig production, pig manure was determined as the most significant negative impacts on the environment in terms of global warming, eutrophication and acidification (Jongbloed *et al*., 1999; Dalgaard, 2007; Gac *et al*., 2007). Biogas potentials from anaerobically digested pig manure have been studied extensively (Maraseni & Maroulis, 2008).

Folayanka *et al* (2012) and Ogunniyi *et al* (2012) studied biomethanation of piggery wastes into biogas and stabilized organic fertilizer and optimized the minimum digestion period that would destroy the pathogenic or hazardous microorganisms require a minimum of 75 days. Where large volume of such waste is produced daily, even though biogas production may be attractive the size of digester capacity required to handle such wastes will leave substantial volume of the biomass untreated. Other means of treatment such as briquetting into solid fuels will then be imperative.

Manure is a by-product containing many plant nutrients and organic matter. The slurry from its digestion and its mixture with other organic biomass has been known to provide useful organic fertilizer to farmers (Adewumi, 1995; Adewumi *et al*, 2005). Besides providing valuable macro- and micronutrients to the soil, manure supplies organic matter to improve the soil's physical and chemical properties.

The challenge of this study was the large volume of piggery wastes at Oke Aro Piggery Estate in Lagos State, Nigeria reputed to be the largest piggery farm estate in Africa with over 3,500 farms crowded on a 47 ha land space with average of 175 pigs per farm producing more than 890 mT of manure daily. Lack of waste management in the Estate resulted in the outbreak of swine fever recently. The paper reports the efforts taken at valorization of the manure in piggery farms in particular with a view to sustainable management of the daily volume of manure.

MATERIALS AND METHODS

Laboratory Modeling

Feed recovery: This was modeled by dissolving and washing known mass of the manure in water to recover the insoluble solids that is then sterilized and dried. The Proximate analyses of the recovered feeds were determined according to standard methods (Pearson, 1976; AOAC, 1990; Onwuka, 2005). The raw manure and dried recovered feed samples were cultured to confirm sterility and safety of reuse of the recovered feed. This was replicated several times.

Biogas production and organic fertilizer: The washed out liquor from feed recovery mixed with some of the raw manure was channeled into a biogas digester unit for biogas production for 30-40 days. Flame test was used as qualitative analysis of the biogas produced. The liquor from the biogas tank and the slurry were then processed into dry form and tested as *organic fertilizer* for its quality and content of macro- and micro-nutrients useful for plant growth.

Briquettes as solid fuel: The compression of known mass of the manure into *briquettes* and oven drying at $102^{O}C$ for 24 h was also modeled as a major method of recycling and valorization of the piggery wastes as cheap alternative to wood biomass. The produced briquettes then had their calorific values determined using standard methods.

Activated carbon: Some of the briquettes were also carbonized at $400^{o}C$ and activated at about $600^{o}C$ in an alkaline medium to produce *active carbon* as an adsorbent for water and wastewater treatment. The adsorbent's quality was tested using the single methylene blue value method to evaluate both the interstitial surface area and activity (Adewumi, 2009).

RESULTS AND DISCUSSION

Feed Recovery Management Modeling

The laboratory study showed 560 kg ±0.04 kg Recovered Feed (RF) of wet sludge/mT of raw manure was recoverable which after sterilization and drying gave valorization of 400 ± 50 kg RF/mT manure. The sterilized recycled feed had no microbial count after sterilization with steam. The Proximate analysis result in Table 1 showed an average protein content of 8.64±

3.7 % while the mean non fat extract and crude extract was respectively 50.3± 9.6% and 10% except in three outliers. This will save the farmers a lot of fund and serve as a cheap source of feed if commercialized. Adding dried single cell algae that will be produced from the effluent of biogas digester and washings for feed recovery as protein source will enhance feed quality.

Table 1: Proximate analysis Results of Recovered Feed from piggery manure wastes

Samples	1	2	3	4	5	6	7	8	9	10	Mean, %
Content in %	Percentage of content in whole sample										
Ash	8.6	8.8	9.2	8.5	11.5	10.3	7.8	8.9	8.4	8.6	9.06± 0.6
Crude fiber	5.7	32.2	13.4	23.6	16.5	16.2	15.3	9.2	6.7	8.2	14.7± 9.0
Ether Extract	7.6	1.5	4.4	5.6	3.5	2.3	5.3	1.5	7.6	8.5	4.8± 3.04
Moisture	16.3	8.9	10.5	8.8	8.6	14.5	9.9	15.6	8.9	8.9	11.1± 2.5
Protein	14.1	6.6	12.3	10.5	12.8	7.7	7.9	6.8	6.8	7.7	8.64± 3.7
Non-Fat Extract	47.7	42.0	50.2	43.0	47.1	49.0	46.2	58	61.6	58.1	50.3± 9.6
Total (%)	100	100	100	100	100	100	100	100	100	100	100

The sludge's high moisture content (11.09±2.5 %) will be useful to engineers in designing the dryer unit for the extruded briquettes (Fig 1).

Fig 1: Extruded briquettes being air dried (Left picture) and activated in a furnace (central picture) for production of activate carbon (right picture).

Briquettes and activated carbon production from piggery wastes

The briquettes in Fig 1 and others produced in the laboratory had good fuel energy of 65.43 MJ/g that can serve as cheap source of fuel wood for the majority of households that depend on firewood presently. The low moisture of the dried briquettes makes transportation and storage easier. The experimental comparison of it with wood fuel showed it boils water faster and with less smoke than the conventional dry wood fuel. Production of this will not only create jobs but will also reduce deforestation and Green House Gas (GHG) effect on the environment. The activated carbon (AC) adsorbent produced had a carbon rating of 32 with surface area >980m^2/g. There is no known industry where AC is produced in Nigeria despite the very high demand for this engineering material by almost all industries (Adewumi, 2006; 2009).

Biogas and organic fertilizer production

The qualitative analysis of the biogas yield showed a gas that burns with blue flames and confirmed earlier studies (Adewumi, 1995; Folayanka *et al*, 2012). The biogas is planned to be used as a source of electricity generation. Liquor from the washing of the pig wastes for recovery of feed with some of the remaining wastes were digested into biogas and the effluent liquor and the slurry at the bottom of the digester can be used as liquid organic fertilizer or dried and used as granular organic fertilizer. These two can be packaged and sold to farmers as soil conditioner.

CONCLUSIONS

The results above showed that piggery wastes could be effectively managed by valorization into five useful products studied in this work. The outcome of the results is being used to develop processing plants for the production of these five valuable products for sustainable management of piggery wastes. The most promising of the five methods is briquetting which can process more than 80 % of the waste into solid biofuels. This work is useful to engineers who work in the area of environmental engineering

REFERENCES

Adewumi, I.K. (1995). Determination of Parameters for the Design of Biogas Digesters, *Ife Journal of Technology*, 5(1):.9 –15.

Adewumi, I.K, Ogedengbe, M.O., Adepetu, J.A. and Aina, P.O. (2005), Aerobic Composting of Municipal Solid Wastes and Poultry Manure, *Journal of Applied Sciences Research*, (1) 3: 292 –297.

Adewumi, I.K. (2006) Characterisation and Specification of Activated Carbon Produced from Palm Kernel Shells for Water Treatment, *Unpublished PhD Thesis, Civil Engineering Department, Obafemi Awolowo University, Ile-Ife, Nigeria.*

Adewumi, I. (2009). A simple method for the determination of surface area and activity of activated carbon, *Toxicological and Environmental Chemistry*, Taylor and Francis, London, **91**(5):955 -962

AOAC (1990). Official Methods of Analysis, *Association of Analytical Chemists, 14th edn. Washington, USA, 22209*

FAOSTAT, (Food and Agricultural Organization, 2003). FAO Statistical Databases. *The United Nations <http://faostat/fao.org>*

Folayanka, A.A., Adewumi, I.K**.**, Ogunniyi, T.A.B. and Achudume, A.C. (2012) "Comparative analysis of biogas yield and parasite density of fermented piggery manure from different collection sites", *Agricultural Science Research Journal, 2(7): 374-378*

Gac, A. Beline, F., Bioteau, T. and Maguet, K. (2007), A French Inventory of Gaseous Emissions (CH_4, N_2O, NH_3) From Livestock Manure Management Using A Mass Flow Approach. *Livestock Science, 112, 252-260)*

Jongbloed, A.W., Poulsen, H.D., Dourmad, J.Y and van der Peet-Schwering, C.N.C. (1999), Environmental and Legislative aspects of pig production in the Netherlands, France and Denmark. *Livestock Production Science, 58, 243-249.*

Maraseni, T.N. and Maroulis, J. (2008), Piggery: From environmental pollution to a climate change solution. *Journal of Environmental Science and Health, Part B, 43, 358-363.*

Ogunniyi, T.A., Adewumi, I.K., Folayanka, A.A., Achudume, A.C. (2012). Parasite Count and Survival during Piggery Fecal Waste Fermentation. *Journal of Tropical Medicine and Parasitology, 35(1):6-13*

Onwuka, G.I. (2005), Food analysis and Instrumentation (Theory and Practice). *Napthali Prints, Nigeria , pp95-96*

Pearson, D. (1976). The Chemical Analysis of Foods, 7th edn, *Churchill Livingstone, New York, pp 11-15*

LCM AND DECISION MAKING - WHAT WE HAVE LEARNT

Wednesday, Aug 28: 8:30 am - 10:00 am

Session chairs: Jim Petrie, University of Sydney, Australia
James Fava, PE International, United States of America

APPROACHES FOR ACTIVE DECISION MAKING AND DESIGNING WITH LIFE CYCLE ASSESSMENT: SIMPLIFYING/STREAMLINING, DIAGRAMMING, AND SEGMENTED SETTING OF THE SYSTEM BOUNDARY

*Tomohiro Tasaki**
National Institute for Environmental Studies
16-2 Onogawa, Tsukuba, Ibaraki, 305-8506, Japan. tasaki.tomohiro@nies.go.jp

Keywords: strategic management; action-oriented assessment; streamlined LCA; discriminant function; scoping.

ABSTRACT

The processes of decision making and development of new products and systems are complex and dynamic. It is not simple to apply current life cycle assessment (LCA) approaches in such processes. This paper presents three LCA approaches that can be applied to enhance the decision-making and design processes: (1) simplifying/streamlining, (2) diagramming, and (3) segmented setting of the system boundary. Each method is briefly described and the advantages of the methods are also discussed.

INTRODUCTION

Life cycle assessment (LCA) is a useful quantitative analytical tool for identifying hot spots of environmental impacts caused by a product or system and to compare and determine which, if any, product or system might cause less environmental impact. However, LCA is not fully utilized in processes of designing a product or system, at least in part because of the practicality of conducting the assessment. Conducting detailed LCAs is costly and time consuming, and often limited in its application (SETAC Europe, 1997; SETAC North America, 1997). Simplifying and streamlining of the LCA process is worth addressing so as to improve the practical use of LCAs. In addition, a simplified methodology is also needed for life cycle sustainability assessment (LCSA) (e.g., Personen & Horn, 2012). A second reason for the limited use of LCAs is a lack of methodologies. Although the ISO 14040 standard supposes that the interpretation of LCA results involves iterative processes and is interrelated to the other phases of conducting LCA, methodologies actively applying LCAs in decision-making processes have not been developed sufficiently.

In an effort to make the decision-making and design process concerning products and systems more effective, this paper examines three approaches: (1) simplifying/streamlining, (2) diagramming, and (3) segmented setting of the system boundary.

SIMPLIFYING/STREAMLINING

The first approach is simplifying/streamlining. Tasaki, Oguchi, Kameya, and Urano (2007) classified existing assessment methods into four types according to their simplicity and then compared the four types in terms of certainty, relevance, applicability, readiness, and other factors. The results showed that simple and detailed assessments have different advantages and that a simple assessment can be useful in some cases. I categorized simplified and streamlined methods and approaches through a literature review (including those listed in the References) as shown in Table 1. The benefits of a simplified approach include the following: (1) the results are easily understood (simplicity of results), (2) traceability is ensured (simplicity of methods), (3) a reduced amount of time is required to do the assessment, (4) fewer resources are required to do the assessment, and (5) the method is widely distributed and accepted due to its simplicity. The first three reasons benefit decision makers whereas the last two do assessors and developers, respectively.

Table 1. Categorization of simplified/streamlined methods

Characteristics of simplification/streamlining → Type of simplification/streamlining approaches in the literatures ↓		Quantitativeness			Type of simplicity			
		Qualitative	Semi-quantitative	Quantitative	Simplicity of results	Simplicity of methods	Less time consuming	Fewer resources required to assess
Simplification	Matrices	X	X		X	X	X	X
	Checklists	X				X	X	X
	Diagram	X			X	X	X	X
	Benchmarking against similar assessments		X	X			X	X
	Interview of panel of experts	X	X	X		X	X	X
Streamlining	Focusing/eliminating boundaries and items	-	-	-			X	X
	Focusing changes of impacts, etc.	X	X	X			X	X
	Use of threshold values		X	X			X	X
	Use of qualitative data	X					X	X
	Use of secondary databases or similar data		X	X			X	*
	Use of summary data		X	X			X	*
	Estimation		X	X			X	
	Establishing "showstoppers" criteria	-	-	-			X	X
	Simplifying models	-	-	-		X	X	X
	Simple indicators with advanced modeling			X	X		X	X
Both	Simple or key indicators		X	X	X	X	X	X
	Computation	-	-	-			X	*

*: depends on the situation, -: irrelevant item

DIAGRAMMING—AN APPROACH USING DISCRIMINANT FUNCTIONS

The second approach utilizes an "option diagram". This diagram is similar to a phase diagram used in chemistry, in which a discriminant line (function) shows conditions under which a substance changes its phase. The difference is that the phases of substances are replaced with options selected by decision making. This type of approach was applied to study consumers as decision makers in judging the appropriateness of replacing products such as TVs and refrigerators with new and more energy-efficient ones (Tasaki, Motoshita, Uchida, & Suzuki, 2013). In this case, the option diagram shows a line dividing two areas where replacing a product respectively either increases or reduces energy consumption. That is, the line shows a discriminant line on which the environmental loads are equal between different replacement scenarios or cases. Tasaki et al. (2013) called this the “iso-e vironmental-load [IEL] line”. This approach generally involves three steps as shown in Figure 1. (1) An assessor sets the system boundary and collects Life Cycle Inventory (LCI) data. (2) The assessor then produces a line graph (an option diagram) by taking selected influential variables related to the options as the horizontal and vertical axes and draws discriminant lines. (3) Finally, the assessor plots given scenarios or cases on the graph and decision makers note the location of the plotted area, that is, whether an option increases or decreases an environmental load in each case. An important advantage of this approach is that one can understand how the variables affect the preferability of options just from looking at the line graph. Such insight would facilitate decision making in cases where a variety of scenarios need to be assessed.

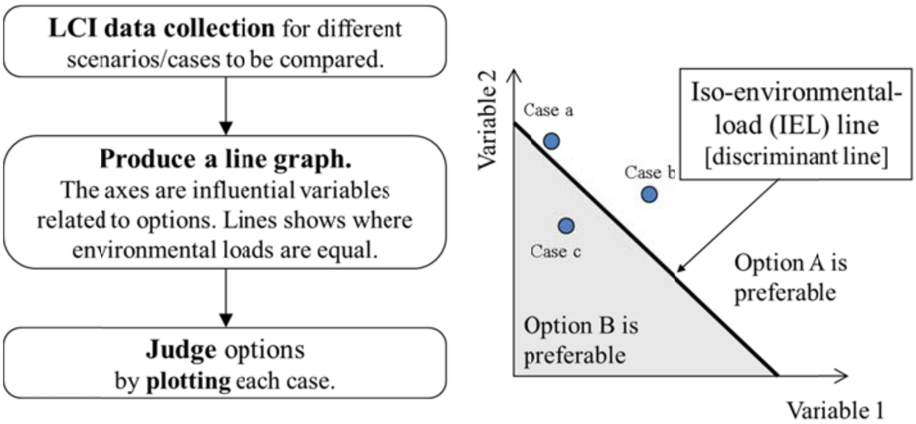


Figure 1. Procedure and outline of a diagraming approach using discriminant functions (lines).

SEGMENTED SETTING OF THE SYSTEM BOUNDARY

The third approach is segmented setting of the system boundary. Usually, a system boundary is set so as to cover the entire system of concern. However, with a segmented approach, an assessor divides the system into two parts and conducts an LCA of one of the subsystems that is relatively established. The assessor then derives the required conditions of the other subsystem from the first results and can develop and design the latter subsystem as shown in Figure 2.

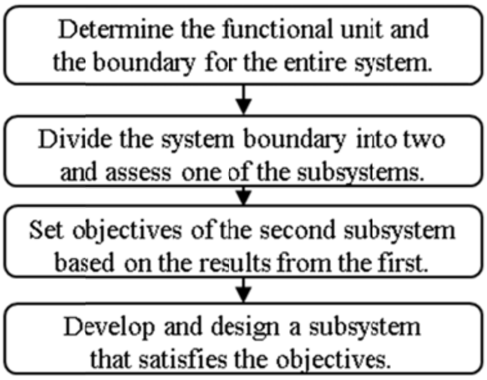


Figure 2. Procedure for segmented setting of the system boundary.

This approach is useful, with the precondition that the entire system consists of multiple subsystems (which complicates the analysis), in two cases: (1) when the system includes undeveloped parts, and (2) when part of the data for the assessment is not readily available. In the first case, the aim is to set goals of developing a relatively-uncertain subsystem based on the results of the assessment of a relatively established, existing subsystem. This should activate and expedite the decision-making process as related to designing a system. In the second case, the aim is to reduce the burden of collecting data by identifying the goals of the subsystem that was not assessed and narrowing the assessment options for that system. This approach would streamline the LCA process and speed up the process of phased management by clarifying the objectives of the second subsystem in the next step.

CONCLUDING REMARKS

In this paper, I addressed three approaches for improving active and effective decision making in the design of products and systems through the use of LCAs. The three approaches were (1) simplifying/streamlining, (2) diagramming, and (3) segmented setting of the system boundary. As these approaches are actually applied, new data will be generated and our understanding of the approaches will deepen. Therefore, the use of these approaches should be promoted.

REFERENCES

Bretz, R., Frankhauser, P. (1996) Screening LCA for large numbers of products - Estimation tools to fill data gaps. *Int. J. LCA, 1*, 139-146.

Fleischer, G, Schmidt, W.-P. (1997) Iterative screening LCA in an eco-design tool. *Int. J. LCA, 2*, 20–24.

Graedel, T.E. (1998) Streamlined Life-Cycle Assessment. New Jersey, USA: Prentice Hall.

Hochschorner, E., Finnveden, G. (2003) Evaluation of two simplified Life Cycle assessment methods. *Int. J. LCA, 8*, 119–128.

Mori, Y., Huppes, G., Hellas A. Udo de Haes, H.A., Otoma, S. (2000) Component manufacturing analysis - A simplified and rigorous LCI method for the manufacturing stage. *Int. J. LCA, 5*, 327–334.

Pesonen, H.-L., Horn, S. (2012) Evaluating the Sustainability SWOT as a streamlined tool for life cycle sustainability assessment. *Int. J. LCA*, doi: 10.1007/s11367-012-0456-1

SETAC Europe (1997) *Simplifying LCA: just a cut?*

SETAC North America (1997) *Streamlined life-cycle assessment*. A final report from the SETAC North America streamlined LCA workgroup.

Tasaki T., Oguchi M., Kameya T., Urano K. (2007) Screening of Metals in Waste Electrical and Electronic Equipment Using Simple Assessment Methods. *Journal of Industrial Ecology, 11*, 64-84.

Tasaki T., Motoshita M., Uchida H., Suzuki Y. (2013) Assessing the Replacement of Electrical Home Appliances for the Environment - An Aid to Consumer Decision Making. *Journal of Industrial Ecology, 17*, 290-298.

Weidema, B. (1998) Application Typologies for Life Cycle Assessment - A Review. *Int. J. LCA, 3*, 237–240.

Wenzel, H. (1998) Application dependency of LCA methodology - Key variables and their mode of influencing the method. *Int. J. LCA, 3*, 281–288.

DATA PROVISION AND USE IN LCM: RESPONSIBILITIES OF STAKEHOLDERS CONCERNING ADEQUATE DATA

Martin Baitz, Peter Shonfield*

PE INTERNATIONAL .m.baitz@pe-international.com,

Hauptstr. 111-113, 70771 Leinfelden-Echterdingen, Germany.

Keywords: Databases; data supply; data use, responsibilities

ABSTRACT

Science has no targets, brings up new questions, needs any data, widens results and hates timely decisions. Management approaches have targets, love timely decisions based on relevant data only and aims for continuous improvements. Decision support in business and industry needs to be based on realistic life-cycle-systems and supply-chains, and must support the identification of issues or sensitivities and responsible communication to stakeholders. Adequate selection and use of data is necessary to meet these requirements. Stakeholders in academia, industry and politics may have different data requirements but each has a role to play in provision and use of adequate data to support the whole LCA community. Better understanding of data requirements is essential to determine the adequate kind of data and whether own or background data should be used in different parts of the model. The correct use of adequate data reduces the reputational risk to practitioners and organizations.

INTRODUCTION

No data, no result. Data are the fuel for results. However in LCA we have known for many years that different "planets" of users exist (Klöpffer W, Heinrich AB, 2001); each with different backgrounds but believing that they are talking about the "same" issues and concepts. As a result, professional stakeholders have sought to develop approaches that can reduce misunderstandings and improve credibility (e.g. Rebitzer G, 2001). However, unfortunately the misunderstanding of "thinking to talk about the same issue" between different stakeholders holds still true a decade later, (Baitz M et. al., 2012). Stakeholders all aim to support LCA, but each has a different interpretation of what this means. Three stakeholder groups concerning LCA data provision and use are: 1) industry & business, 2) academia & science, 3) regulative, declarative or political bodies & NGOs. All of the stakeholders use data, some of the stakeholders provide data, fewer stakeholders maintain data and in the end all stakeholders communicate (internal or external) based on data. So data are essential for all stakeholders. But do all stakeholders: have the same goal? Need the same kind of results? Have comparable responsibilities concerning information and data? Need to take critical decisions on data? No! "Adequacy" of data is the "missing link" to enable LCA data to be used in decision support. This develops the first sentence of this paragraph further into: *No adequate data, no adequate result, no use of LCA results in decision support.* Therefore it is important to understand the different requirements and responsibilities of the different stakeholders in LCÁ.

DATA USE AND PROVISION OF DIFFERENT STAKEHODERS

Political bodies, academia and industry communicate, use, provide and maintain data in different intensity and with different priorities. Table 1 gives a qualitative estimate of the priorities in data work of the stakeholders from the view point of a software and database provider (GaBi, 2013) publishing and re-publishing data for and from any of the stakeholders.

Table 1. Varying priorities and features in the LCA work of different stakeholders

	Political bodies /NGOs	academia / science	Industry / business
External communication on data	core feature	core feature	some
Use of data	some	core feature	core feature
Provision of data	N/A	some	core feature
Maintenance of data	N/A	some	core feature

Communication
Political bodies and NGOs mainly communicate to consumers or regulative bodies aiming for clear, simple, reproducible messages for non-experts. Academia and science (rather) do report (than communicate) into diverse groups of stakeholders, with rather less information that is directly suitable for a broader audience or non-experts. Industry and business communicate mainly just within their organizations or supply chain; sometimes to governmental bodies.

Use
Political bodies use data to quantify policy measures as basis of regulations or to quantify product performance for end users. Academia and science use data to verify and benchmark new scientific methods. Industry and business use data to develop new products, improve their own products and processes and to justify investments or their choice of suppliers.

Provision
Political bodies and NGOs normally do not provide data by themselves. Academia and science do provide data to some extent (mainly LCIA). Industries, businesses and associations see data provision as a core topic (often via associations, sometimes company-specific).

Maintenance
Political bodies and NGOs do not maintain data by themselves. Academia and science does maintain data to some extent (often sporadic). Industries, businesses and associations push for the maintenance of own and background data as a core topic of reliable LCA data.

For a software & database provider consistency, continuity and reliability are core features of technology development, provision and maintenance. The challenge is to manage the different inputs of stakeholders in a way that valuable data can be commercialized while immature or fuzzy data are filtered out. If stakeholders take their responsibility regarding data provision and use this would ensure that more adequate data would be available and confusion about data “differences” would be reduced. Furthermore, users could more easily assess the quality of data that they use .

BASICS OF RESPONSIBLE DATA PROVISION AND USE

Data provision and use should be understood from any stakeholder as part of the “normal” management cycle: Plan-Do-Check-Act (or, to translate into the LCA data world, maybe: Plan-Implement-Maintain-Review).

In planning of data provision “demand” is the core driver. What data are needed for which purpose? New technologies, regulations, standards or new market regions are decisive.

The core aspects concerning implementation of data are (overall) relevancy, (methodological) consistency and (technical) adequacy. Data implementation needs some LCI experts and many engineering experts to generate adequate (data) results.

Concerning maintenance of data, the frequency, the possibility of auto-updates of own-developed user systems and the proactive update or fade-out of older data is essential.

A “review of the current situation” is closing the loop. Did something change in relation to the plan? Did the world, the industry or the economy change? Further also the “review of data” by suitable parties and the users groups with the related improvement input is a core aspect for the new planning of the next update cycle.

If all stakeholders providing data into the LCA community applies their own management cycle and takes their responsibility seriously, the time taken up by the many odd data or methodological discussions of the past could be put to better use. Responsibility is often not favorite topic for some stakeholders. However the following responsibilities may be considered by different stakeholders (comments are welcome as the goal is to inspire an open discussion):

In most cases political bodies judge, use or communicate data rather than seeing intrinsic value in understanding the background of technical, economic and methodological dynamics behind different data. To exaggerate somewhat: it must be simple and reproducible forever, while also being very reliable. However, making complex structures too simple is often simply wrong and reliability is asking for a certain kind of ability to manage natural change. Nobody can foresee technologies, markets, crisis, inventions and its consequences; even not the best “methodological” invention. Political bodies are well educated to pinpoint facts on paper. However improvements in reality are needed rather than on paper. Political bodies may consider taking more responsibility regarding rules and regulations that actually can be implemented on the basis of existing information systems and knowhow. Further Political bodies may consider promoting or advocating for rules and regulations that are applicable in reasonable time frames, with transition periods and technical background; not only on paper.

Academia and science are also important stakeholders in LCA. Science is using and producing data. In most cases the data is useful for science but less so for management purposes or for broader user groups. Academia may consider taking more responsibility regarding the promotion of data originating from new methods, immature (untested in practice) approaches or one-time-research-projects (like abandoned PhD topics with no follow-up). Key to LCA success is data on realistic supply chains and useful new scientific methods; not dogmatic or pseudo-revolutionary approaches that can only be interpreted by the inventers. Further, certain schools tend to enlarge systems; fine if the extended system leads to an improvement of the results. It may be also considered to reduce systems to the relevant (the famous “Einstein style”) and try to avoid extension of systems with meaningless, coarsely estimated or guessed information. Free LCA science and responsible provision of (applicable) data is possible. Modern LCA universities like TU Berlin, University of Tokyo, University of Stuttgart, and UC Berkeley and others already do “applicable science for LCA” or work on the principle of “Separation of methodology development and LCA application for good science and good application” (Baitz M et. al. 2012).

Industry and business are the main users and providers of LCA data and have maintenance of data on their agenda. Industry and business may consider contributing more into validation and standardization of approaches. Further these stakeholders may communicate more issues and problems of daily application to method developers and data providers. The responsibility of industry and businesses is to facilitate data of their real life supply chains and to feed back into science and industry about issues of practical application in use of data and methods.

CONCLUSION

Synergy of science, industry and politics in LCM is possible. Life Cycle Management can be done responsibly in a co-existence and co-operation of the different stakeholders, if the modular systematic and the related responsibilities are understood and taken (Baitz M, Gabriel R, Betz M, Deimling S (2007).

Continuous improvement cycles concerning LCM in many organizations are already in place or about to be launched. If one would like to play a role as a stakeholder, one should know their responsibility first and take it.

REFERENCES

Baitz M et. al. (2012): LCA’s theory and practice: like ebony and ivory living in perfect harmony? Editorial in the International Journal of Life Cycle Assessment, online first, DOI 10.1007/s11367-012-0476-x.

Baitz M, Gabriel R, Betz M, Deimling S (2007): Quality, reliability and trustworthiness of bio-fuel certificates, Econsense Workshop with Procedings, Berlin.

GaBi (2013): GaBi Software and Databases, PE International AG, http://www.pe-international.com

Klöpffer W, Heinrich AB (2001) Two planets and one journal. Editorial. Int J Life Cycle Assess 6(1):1–3

Rebitzer G (2001) Increasing credibility of LCA. 8th Case Studies Symposium, Brussels November 30, 2000. Int J Life Cycle Assess 6(1):53–54

INTEGRATING LCA-BASED MODELS INTO DESIGN PROCESS FOR BUILDINGS: A STUDY OF THE EXISTING PRACTICES IN FRANCE

Yann Leroy[1], François Cluzel[1], Toufic Zaraket[1], Sébastien Lasvaux[2], Maia Bentos[1]*

*[*1]Ecole Centrale Paris – Laboratoire Genie Industriel – Grande Voie des Vignes, F95295 Châtenay-Malabry Cedex – France – Yann.leroy@ecp.fr*

[2]Université Paris-Est, Centre Scientifique et Technique du Bâtiment (CSTB)

Keywords: Ecodesign, Life Cycle Assessment (LCA), Building, Design process

ABSTRACT

Buildings have a significant impact on the environment throughout their life cycle. They are a major responsible for exhausting valuable natural resources and polluting the atmosphere through the emission of greenhouse gases. Nowadays, a high interest is manifested worldwide in constructing green buildings so that to limit the harm caused by human habitations on the ecosystem. In this scope, sustainable design is thus a primary thrust area. However, the development of eco-design tools as well as their implementation by building experts is still limited. In this paper, we investigate the eco-design practices as adopted nowadays by building designers and constructors in France. By using the results of a qualitative survey, we analyze how the environmental issue is considered in the decision-making process. Later on, a proposition of how and which stage eco-design tools could be implemented is discussed.

INTRODUCTION

The building sector is considered as a major responsible for the environmental impacts. In France this sector accounts for about 25 percent of the total CO2 emissions(ADEME, 2013). Consequently, environmental regulations, standardizations and building certifications are implemented so that building sector is forced to meet national commitments towards sustainable environment. Eco-design is being widely used in the development of new environmentally-friendly products. A number of tools, such as Life cycle assessment (LCA), are developed and being deployed since a decade (Haapio & Viitaniemi, 2008).. LCA assesses the environmental performances of a system over its entire life cycle (Bribia, Uson, & Scarpellini, 2009) (Ortiz, Castells, & Sonnemann, 2009) (Sharma, Saxena, Sethi, & Shree, 2011). There is no question about the great interest and the favorable deployment context of LCA in the design process. Some recent works promote LCA as a consistent tool for building's ecodesign (Malmqvist et al., 2010). However, in the French building sector, the use of LCA to support decision-making processes throughout design stages is still limited.

In the scope of capturing actual ecodesign practices and more specifically LCA implementation in building design in France, two studies are performed simultaneously: (i) an exhaustive analysis of the building design process in France (ii) an investigation about the mechanisms used to integrate the environmental issue in the design process.

METHODOLOGY

The methodology adopted comprises two main steps undertaken through a research-action approach.
First, a comprehensive framework about the design process of buildings in France is established using a systemic approach. The objective is to identify actors involved, their actual needs and the promising stages where the introduction of environmental data can be useful. Design stages, respective inputs and outputs, design choices and engineering estimations and finally decision-makers are identified and characterized along the building project. Needs and constraints are also investigated. Preliminary based on literature review, the process framework was later on validated and refined by building experts.

In a second time, a survey on environmental practices in building's design process is carried out. Twelve semi-directed interviews are conducted on academics in building design, architects, engineers, eco-design experts, and Project Managers. Issues covered are clustered according 3 main topics: environmental approaches and certifications, assumptions usually defined while performing LCA and LCA integration into the design process.

RESULTS

The building's design process – a systemic approach

As depicted in figure 1, the common building's design process starts with client's needs and follows a sequential process: feasibility study, program, design, construction, exploitation, rehabilitation and/or deconstruction. Until design phase, main lines of the building's design, consisting in defining global solutions and performing estimations, are specified.

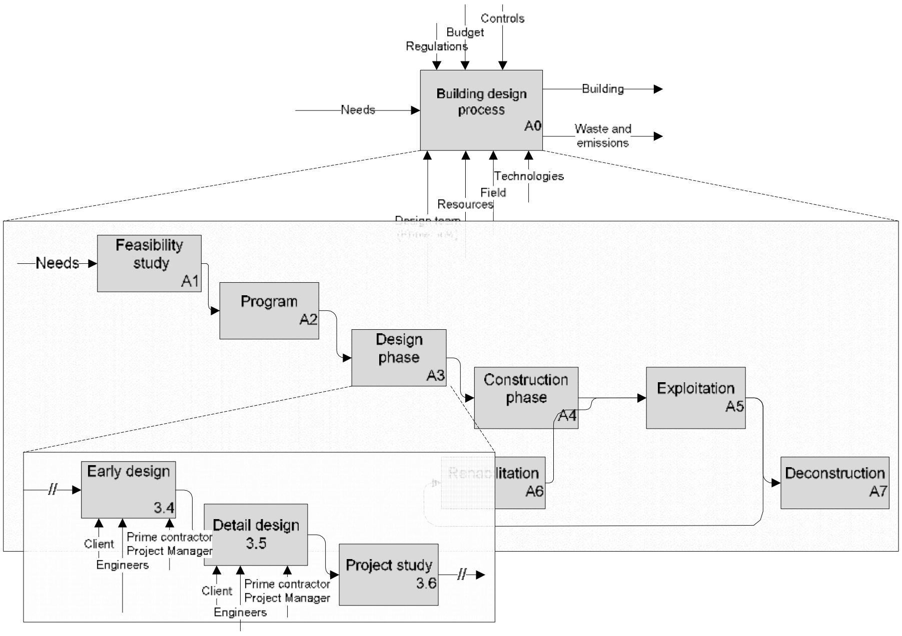


Figure 1: A systemic representation of the building's design process

The decision-maker is the project owner. Once design phase starts, estimations and design choices are progressively formalized. First technical solutions are evaluated and defined at early design stage. From this point, the project manager assisted by economists and engineers is in charge of design choices.

Ecodesign approach requires integrating environmental issues and life cycle thinking as soon as possible. In this context, early design phase appears as a promising step to introduce environmental concerns in design process until first technical solutions require evaluation and comparison. Moreover, even if the building's design process involved a lot of actors, the project manager is still the main decision-maker and has a holistic overview.

Survey on environmental approach and LCA deployment in building's design process

Major highlights from the survey are summarized as follow:

✓ Environmental approaches and certification

- Normative approaches and certifications as Breeam, HQE, LEED and labels for buildings materials are widely used but not systematic. Several limitations are pointed out:
- Certification is essentially performed to obtain competing advantages (not to increase building performances)
- Conflicting situations between environmental, cost and customer's satisfaction are revealed
- Cost is the main parameter the client considers in decision-making, thus trade-off are difficult to define

✓ Assumptions in LCA

- Lifespan is of high interest since it helps defining functional unit of the system under study (material and building). Nevertheless, it is now weakly integrated and theoretical lifespan is commonly used (50 years for building)
- Usage and consumer's behaviors are traditionally averaged when integrated

✓ LCA deployment and integration in decision-making

- LCA is rarely performed and essentially at the end of the design process
- LCA is often performed to feed environmental communication (EPD)
- Main limitations pointed out are: data unavailability, imprecision, the difficulty to deals with big systems as building and complexity
- At present LCA contributes to material choices (costs and user's behaviors are excluded) LCA contribution to decision-making is still limited until cost is a dominant criterion.

At present, environmental design is essentially driven by norms and client's requirements. Normative approaches are widely used while LCA is not commonly performed during the design process. Major applications are turned to communication and competing advantages.

DISCUSSION

The first results of this preliminary research suggest an increasing need to integrate environmental dimension in decision-making as soon as technical solutions are selected. Early design stage appears to be a promising step to initiate the dissemination of environmental data. For this sake, actual needs in terms of information have to be refined and the implementation of simplified approaches of life cycle instead of traditional LCA is suggested. By this, overcoming the difficulty of large amount of data required is possible. In addition considering the importance of investment cost in decision-making process, the definition of the system's boundaries is of high interest. Indeed, building owners and users are often different persons with conflicting expectations. Thus, maximizing cost performance during design phase can lead to high maintenance costs and environmental impact during the use phase. For example, an ongoing study on three competing floor covering solutions highlights that choosing the cheapest solution engages 2 to 7 times more environmental impact and 0.5 to 0.7 more maintenance (preventive and corrective) costs during the use phase. The results reveal that environmental and economic performances are highly sensitive to material lifespan and maintenance cycles. In this context, developing LCA-models which combine environmental issue, life cycle cost and contextual users' behaviors is of high interest. The latter issue is confirmed in the work of (Zaraket, Yannou, Leroy, Minel, & Chapotot, 2013).

CONCLUSIONS AND PERSPECTIVES

In this paper, building's design process is investigated through a systemic approach. Twelve semi-directed interviews were conducted to survey ecodesign practices and LCA's level of deployment. This study reveals that the early phase of an ecodesign process is a promising stage where the environmental dimension can be integrated. At present, the environment issue is traditionally integrated in the decision-making through normative approaches. However, and despite its growing interest, LCA is not commonly used. Once applied, LCA results are used essentially as a mean of communication and competing advantage. Building experts explain this by the limitations of LCA (complexity, data availability), the exclusion of costs and the dominant position of cost in decision-making. Future works will focus on a better employment of LCA as a function of the needs specific to each design stage, as well as on the enrichment of LCA-based models by integrating cost evaluations and user's behaviors.

REFERENCES

ADEME. (2013). Bilan 2012 & perspectives 2013. Retrieved May 10, 2013, from http://ademe.typepad.fr/files/dp-ademe_bilan-2012-perspectives-2013_31012013_vdef.pdf

Bribia, I. Z., Uson, A. A., & Scarpellini, S. (2009). Life cycle assessment in buildings : State-of-the-art and simplified LCA methodology as a complement for building certification. *Building and Environment*, *44*, 2510–2520. doi:10.1016/j.buildenv.2009.05.001

Haapio, a, & Viitaniemi, P. (2008). A critical review of building environmental assessment tools. *Environmental Impact Assessment Review*, *28*(7), 469–482. doi:10.1016/j.eiar.2008.01.002

Malmqvist, T., Glaumann, M., Scarpellini, S., Zabalza, I., Aranda, A., Llera, E., & Díaz, S. (2010). Life cycle assessment in buildings : The ENSLIC simplified method and guidelines. *Construction*, 1–8. doi:10.1016/j.energy.2010.03.026

Ortiz, O., Castells, F., & Sonnemann, G. (2009). Sustainability in the construction industry : A review of recent developments based on LCA. *Construction and Building Materials*, *23*(1), 28–39. doi:10.1016/j.conbuildmat.2007.11.012

Sharma, A., Saxena, A., Sethi, M., & Shree, V. (2011). Life cycle assessment of buildings : A review. *Renewable and Sustainable Energy Reviews*, *15*(1), 871–875. doi:10.1016/j.rser.2010.09.008

Zaraket, T., Yannou, B., Leroy, Y., Minel, S., & Chapotot, E. (2013). A usage model-driven approach for forecasting occupant-related energy consumption in residential buildings. *CONFERE*. Biarritz.

LESSONS LEARNT FROM DEVELOPING A ROADMAP FOR THE COAL INDUSTRY IN SOUTH AFRICA: A MULTI-STAKEHOLDER PROCESS

Brett Cohen, Yvonne Lewis, Philippa Notten and Lauren Basson. The Green House. 70 Rosmead Ave, Kenilworth, 7708, South Africa, email: brett@tgh.co.za*

Keywords: scenario planning; stakeholder engagement; communication

ABSTRACT (120 WORDS)

The South African coal roadmap process was initiated by the coal industry, including business and government, to provide an evidence base to support decision-making and inform policy as it relates to the coal value chain. This paper briefly describes the process and provides an overview of the quantitative model that was developed. A reflection is presented on insights gained from the multi-stakeholder process in which there were conflicting interests and viewpoints, as well as differing expectations of what such a process is able to deliver. Finally, consideration is given to how results are best presented to a wider audience who may not be familiar with the model structure and inputs, to help support decision-making and planning.

INTRODUCTION

South Africa is heavily dependent on coal for its primary energy supply, with over 90 percent of electricity being supplied from coal. Coal mining also provides a significant source of foreign revenue through exports, and provides much-needed employment. At the same time, the dependence on coal results in a greenhouse gas intensive economy, and negative impacts on the natural environment. The coal industry in South Africa faces an uncertain future due to South Africa's stated commitment to a low carbon trajectory on the one hand, and its need for continued economic growth and energy security on the other.

The South African coal roadmap (SACRM) process was a three-year research and quantitative modelling study initiated by the South African coal industry to provide a fact base to support decision-making and policy engagement as it relates to the coal value chain.

APPROACH TO DEVELOPMENT OF THE ROADMAP

Scenario analysis provided a framework to describe four future worlds, each of which would have different implications for how the value chain may evolve to 2040, from a coal intensive "more of the same" future to a "low carbon world" (Figure 1). These futures were defined in terms of the role of coal in supplying both electricity and liquid fuels and quantitatively modelled to determine the wider implications for the coal value chain, the economy and South Africa as a whole. To develop the roadmap, the results from the scenario analysis were interrogated, and used to identify actions that are required regardless of which future evolves.

The roadmap also presented industry-agreed standpoints on contentious issues that reflected the consensus that the process helped to achieve.

LAGS BEHIND The world decarbonises, but coal remains a significant energy source in South Africa and other developing countries. Coal-based power dominates local electricity supply, but with clean coal technologies such as ultra-supercritical power stations, carbon capture and storage and underground coal gasification. A new coal-to-liquids plant is built in 2027 to meet local liquid fuels demand.	**LOW CARBON WORLD** The world decarbonises and moves towards use of nuclear and renewables for electricity supply. Funding is available for South Africa to follow suit, with no new coal-fired power stations built beyond those under construction. Carbon capture and storage is pursued and no more coal-to-liquids plants are built in South Africa.
MORE OF THE SAME Coal use continues globally and locally. Coal-based power generation using existing supercritical technologies dominates the electricity mix, and the life of existing power stations is extended. Two new coal-to-liquids plants are built between 2027 and 2040 to meet local liquid fuels demand.	**AT THE FOREFRONT** Coal use continues globally, but South Africa aims to diversify its energy mix to include renewables and more nuclear generation. New coal fired power plants after Medupi and Kusile use ultra-supercritical technologies, with smaller power stations (including FBC stations) being built. No more coal-to-liquids plants are built.

Figure 1. Scenarios considered in the coal roadmap development

DESCRIPTION OF THE QUANTITATIVE MODEL

The quantitative model for this study was developed in the Analytica modelling software (Lumina Decision Systems, 2013). Input data was obtained from publically available literature and from input from industry experts.

The coal demand module summed coal demand from electricity generation, coal-to-liquids and industrial users. The electricity generation module considered different power station build plans reflecting the degree of diversification per scenario, including coal-fired power stations as well as generation by nuclear and renewable infrastructure. The coal supply module matched as far as possible predicted coal demand by power stations and industrial users to existing mines and planned mining projects in the country, with the remainder of planned coal projects going to export markets. The cost module determined the cost of supply of coal to power stations, where power stations would preferentially source their coal and export revenues. Finally, various impact modules were used to determine the implications of following the different scenarios for considerations including investment in power generation infrastructure cost, electricity generation cost, export volumes, rail infrastructure requirements and environmental performance including coal resource consumption, greenhouse gas emissions, water demand, non-GHG emissions and solid waste generation.

LEARNING FROM THE PROCESS

The detailed quantitative analysis, including a detailed modelling report (The Green House, 2013a), a scenarios report (The Green House, 2013b), the Roadmap (The Green House and

SACRM Expert Group, 2013c) and a short "glossy" which highlights the key findings are due to be released into the public domain shortly. As such, the results are not repeated here. The aim of this paper is to rather highlight the process and learning from conducting such a large-scale, multi-stakeholder process, with many stakeholders who have competing interests and are custodians of commercially sensitive information.

Managing stakeholder expectations

Stakeholders in the SACRM started off including officials across government departments, representatives of the electricity supply utility company (Eskom), decision makers within large mining companies, technical experts with an interest in the coal value chain, academics, labour and NGOs. Even within organisations, individuals had vastly differing views on the purpose of the analysis. Many parties suggested that the aim was to advise government on the policy direction that it should take. Government was very clear that the study would help them to inform policy making, but not dictate what direction policy should take. Academics suggested that the role was to support identification of a research agenda for the coal industry, while NGOs were strongly in favour of the Roadmap helping to highlight the environmental challenges that need to be addressed by the coal and electricity supply sectors.

As the study proceeded, many stakeholders' interest in the process dwindled, leaving mostly representatives of large mining companies and the power utility involved. As such, it was these stakeholders' needs and views that were ultimately represented in the Roadmap.

Communicating the purpose of scenario analysis and Roadmap development

The initial brief on the project identified explicitly a need for scenario analysis in developing the Roadmap. An interesting observation is the vastly different understandings of what exactly scenario analysis is, and its role in decision-making. In particular, for much of the three-year process, stakeholders were under the impression that four scenarios were to be analysed, and then they would choose one of the scenarios that they wanted the country to follow, and see how they could make that scenario happen. It took a lot of repeated discussion to reach the point of collective understanding that scenarios are a set of plausible, internally consistent futures, and the purpose of scenario analysis is to explore how decision makers can plan in the face of uncertainty about the future. The Roadmap then provides guidance on what actions could be undertaken to allow for robust planning for the future.

Data and assumptions

As can be expected in such a large project, covering the entire coal value chain, and with multiple stakeholders all protecting their vested interests, accessing certain data was a challenge. Despite the project team signing non-disclosure agreements and being required to aggregate data, many parties remained reticent to provide proprietary information to support the modelling. As such, the model was largely populated with information from the public domain. This provided a good starting point from which to engage discussions and elicit better data from the stakeholders.

In making projections into the future, a number of assumptions need to be made. Some of the notable variables for which assumptions were required are demand for electricity (which determines both coal demand and investment in new power stations), mine and power station costs, product yields for certain mines and investment appetites of mining houses. Once again, it was interesting to see how experts in the process were obligated to engage in a much deeper level on the assumptions fed into the model, once they had seen the model results. After further analysis, many of the assumptions were revised with some variables reduced by a factor of two to five, once the results were presented. The results thus provided an important platform for experts to discuss and reconsider commonly held beliefs. Critically, the model results and extensive checking of assumptions by the experts highlighted the tipping points in the system. So it was not a case of proving one party right over another, but rather showing that both parties are right in their understanding of the system under particular conditions.

Communication of results
Information to support engagement of a wide range of stakeholders needs to be concise, understandable and visual. Technical analysts and modellers are accustomed to presenting lengthy technical reports, detailing all of the input data, assumptions, approaches, sensitivities and uncertainties. Furthermore, graphs that are not always easily accessible to non-technical audiences are relied on to present results, with the assumption that the reader will engage with assumptions and interpretation in the accompanying text.

In the SACRM process, it quickly became clear that audiences generally do not have the time to engage with such reports, and often do not have the technical ability to understand the subtleties, and are thus quickly lost and critical outcomes are often missed.

Exploring the trade offs inherent in the results
A final question that is not easily resolvable relates to how results are ultimately used to support decision making. Ideally some type of MCDA approach would be used to explore the trade-offs between results, given the large number of indicators that were explored. However, in reality different stakeholders only explored the areas of direct interest to themselves, and placed secondary value on the results not directly relevant to them. A recommendation from this work would be to explicitly explore these tradeoffs using structured decision approaches.

CONCLUSIONS

The SACRM provided a platform from which to engage in a real life complex multi-stakeholder process, supported by extensive value chain modelling. This approach allowed stakeholders to see the impacts of decisions made by mining houses and the utility on the value chain, how this relates to the policy context, and the tipping points of the system.

REFERENCES

Lumina Decision Systems. (2013). Business Intelligence Tools, Enterprise Risk Management and Decision Support Software – Analytica. Retrieved June, 14, 2013, from http://www.lumina.com/.

The Green House. (2013a). Outlook for the coal value chain: Scenarios to 2040 technical report. *In press.*

The Green House. (2013b). Outlook for the coal value chain: Scenarios to 2040. *In press.*

The Green House and SACRM Expert Group. (2013c). The South African Coal Roadmap. *In press*.

SPREAD IN LCA RESULTS FROM USING MULTIPLE DATA SETS AND MODELLING CHOICES: A CASE STUDY OF DISPOSABLE PS CUPS

Eugenie van der Harst[1] and José Potting[1,2]*

[1]*Environmental Systems Analysis Group, Wageningen University,*

[2]*Environmental Strategies Research (fms), KTH Royal Institute of Technology*

** NL-6700 AA Wageningen, the Netherlands, eugenie.vanderharst@wur.nl*

Keywords: LCA; disposable cups; multiple data sets; methodological choice; uncertainty.

ABSTRACT

Life cycle assessment (LCA) is a standardized methodology, but LCAs of the same product often still lead to divers outcomes. This study purposely used multiple data sets and methodological choices in an LCA of a disposable PS cup to quantify how these variations propagate and lead to a spread in LCA-results. The results for the PS cup consistently show major contributions from PS production, cup manufacturing, incineration and recycling (and minor contributions from other processes). Notably differences in amounts and types of energy used and reported emissions caused variation in results. Energy related impact categories contain smaller spread than the toxicity categories. The spread in results might give less clear, but more certain results to decision makers.

INTRODUCTION

Life cycle assessment (LCA) draws the potential environmental impact of product or service systems. Although LCA procedures are standardized (ISO, 2006), LCAs of the same product in practice often result in different and sometimes even lead to contradictory outcomes. This variation in outcomes is confusing and undermines the use of LCA as a decision support tool.

Van der Harst and Potting (2013) reviewed ten (comparative) LCAs on disposable beverage cups made from petro-plastic, bioplastic and paper. The ten studies shared climate change as the only common impact category. No cup material demonstrated the best or worst climate change impact across all comparative LCAs. The quantitative climate change impact results varied among the different studies. The ratio between the highest and lowest results was 1.7 for bioplastic cups, 3.4 for petro-plastic cups, and 20 for paper cups. Reasons for discrepancy in results might arise from differences in properties of the cups, production processes, energy sources used, and waste processing options. It was not possible to trace back, however, how different data sets or modeling choices quantitatively propagated into impact results.

This paper shows for a polystyrene (PS) disposable cup how variation in data sets and choices in waste options propagated and can led to a spread in LCA outcomes.

METHODS

Life cycle of PS cups

The functional unit here is cradle-to-grave provision of one disposable white PS cup fit for the serving of hot beverages from a presently typical vending machine in the Netherlands.

The life cycle of the disposable PS cup starts with the extraction of fossil resources (oil and natural gas) for the production of PS granulates. The cup is manufactured via an extrusion and thermoforming process of the PS granulates. Next, the cups are packed in foil and in a carton box and shipped via a distributor to the customer, where the vending machines are replenished with the cups. The beverage drinker deposits the used disposable cup in a waste bin. The waste can be sent to a municipal solid waste incinerator (MSWI) where the energy from the incineration can be recovered as electricity and/or heat. An alternative option is to collect the PS cups separately and sent them to a recycler where the cups are processed into recycled PS. This study included both incineration and recycling as waste options. We used system expansion to credit the recovered energy and the recycled PS. Landfilling was not included since it is forbidden in the Netherlands.

Research approach

First we made an initial LCA of the PS cup using only one data set per process. Contribution analysis identified the relative share of the separate processes in the overall environmental impact. Sensitivity analysis of processes with minor contribution determined if these processes continued to be of little importance. We acquired additional data sets only for the processes that in the initial LCA or sensitivity analysis showed to have a substantial contribution to overall LCA results.

We collected most data sets from publicly and commercially available reports and databases. We used company specific information for the cup manufacturing process and the recycling process. For each process, the impact results for each separate data set were assessed. Next, we calculated for each process the average impact results from the multiple data sets, and the spread in these results (highest and lowest value). Then, to evaluate the overall life cycle performance of the PS cup, we combined the results from the separate processes into the total average results and the spread in these results. This approach showed, similar to the earlier contribution analysis, which processes contributed most to the LCA results. Additional to the earlier sensitivity analysis, this approach showed which processes caused the most variation in the results, and the spread in the LCA results due to the use of multiple data sets and methodological choices.

We included the cumulated energy demand (CED) (Frischknecht et al., 2003) and all ten impact categories from the CML Baseline 2001 methodology (Guinée et al., 2002).

RESULTS

Results of initial LCA

The initial LCA with only one data set per process and incineration as waste option identified PS production, cup manufacturing, and PS incineration as highest contributors to all impact categories. Sensitivity analysis confirmed the minor impact of transport and of the production and waste treatment of the packaging material (foil and carton box). Replacing incineration by recycling as waste option in the initial LCA showed to have an important influence. This influence originated from the recycling process itself (i.e. actual conversion of PS waste into recycled PS) and the applied credits for recycled PS.

Spread in processes
Additional data sets were collected for PS production, cup manufacturing, PS incineration, PS recycling process and credits for recycled PS. We calculated the average impact results for each of these processes and determined the spread in these results (highest and lowest values). The average impact results confirmed the importance of the selected processes.

The spread in PS production results was relatively small in the energy-related categories, notably cumulative energy demand and abiotic depletion potential, but large in the toxicity impact categories. We traced the origin of the spread back to geographical differences between PS production in Europe versus the USA. Variation in the cup manufacturing and recycling process results stemmed from the use of different energy amounts and types of energy (electricity and/or heat). Incineration results also showed a small spread in the energy categories, but a large spread in the toxicity categories. Different amounts and types of credited energy and different amounts of reported metal emissions are the main reasons for the spread in these incineration results. We credited recycled PS according to various crediting approaches. The different crediting choices created a spread in the credited PS results in most impact categories and specifically in the energy related categories.

Total LCA results and its spread
We combined the impact results from the separate processes into the average overall LCA results and calculated the spread in the LCA results. The spread in the separate processes propagated into a large spread in the LCA results. The spread in the energy related impact categories were smaller compared to the spread in the toxicity categories.

Average LCA results showed in most impact categories, based on the data sets used in this study, a slight preference for recycling compared to incineration of PS cups. For all impact categories, the spread in the LCA results of the incineration and recycling LCA overlapped.

DISCUSSION

Incineration and recycling were both included as waste treatment option for the disposed cups. The average LCA results showed a slight preference for recycling compared to incineration. This is not confirmed, however, by the overlapping spread in results between the incineration and recycling LCA.

The way of crediting recycled PS turned out to be an influential factor in the LCA results. We used system expansion and avoided allocation to credit recycled PS. Other allocation approaches such as the cut-off principle, cascading or transferring credits to a consecutive product, could have produced different outcomes (Ekvall & Tillman, 1997; Frischknecht, 2010).

The energy related impact categories showed a smaller spread compared to the toxicity categories. The environmental impact calculation is based on the inventory data. The number of included items and the precision of the measurements can differ between the various data sets. Inventory data on used amounts of energy and material often show smaller differences than data on emissions (Weidema, Fress, Holleris Petersen, & Ølgaard, 2003). This could explain the difference in spread between the impact categories.

LCA results showed strong influence from inventory data with different geographical origin (Europe versus USA), and temporal origin (earlier versus newest PlasticsEurope PS dataset).

Spread in results caused by the use of multiple data sets basically represents the uncertainty due to variability in inventory data, while the spread due to different allocation procedures represents modeling choices. The spread from using multiple data sets and modeling choices might make the outcome of an LCA less clear, but it also generates a more certain outcome.

CONCLUSIONS

Polystyrene (PS) production, cup manufacturing, and incineration and recycling of the PS cup all played an influential role in the disposable PS cup LCA. The use of multiple data sets and modeling choices for these processes led to a spread in the results. This spread was caused by differences in used amounts and types of energy and reported emissions. The variation in the processes propagated into the uncertainty of the total LCA. Average LCA results showed a slight preference for recycling above incineration of PS cups. The spread in the incineration and recycling LCA results overlapped. This spread might provide a less clear-cut outcome, but the outcome was more certain. The use of multiple data sets and modeling choices thus provides decision makers with more robust LCA information.

Acknowledgement

The authors thank the Province of Gelderland in the Netherlands for their funding.

REFERENCES

Ekvall, T., & Tillman, A.-M. (1997). Open-loop recycling: Criteria for allocation procedures. *The international Journal of life cycle assessment, 2*(3), 155-162. doi: 10.1007/bf02978810

Frischknecht, R. (2010). LCI modelling approaches applied on recycling of materials in view of environmental sustainability, risk perception and eco-efficiency. *The international Journal of life cycle assessment, 15*(7), 666-671. doi: 10.1007/s11367-010-0201-6

Frischknecht, R., Jungbluth, N., Althaus, H.-J., Doka, G., Dones, R., Hellweg, S., . . . Spielmann, M. (2003). Implementation of Life Cycle Impact Assessment Methods. Final Reports Ecoinvent 2000 No. 3. Dübendorf: Swiss centre for Life Cycle Inventories.

Guinée, J. B., Gorrée, M., Heijungs, R., Huppes, G., Kleijn, R., Koning, A. d., . . . Huijbregts, M. A. J. (2002). *Handbook on life cycle assessment. Operational Guide to the ISO Standards*. Dordrecht: Kluwer Academic Publishers.

ISO. (2006). *ISO 14040 International Standard. In: Environmental management -- Life Cycle Assessment -- Priciples and framework*. Geneva, Switzerland: International Organization for Standardization (ISO).

Van der Harst, E., & Potting, J. (2013). A critical comparison of ten disposable cups LCAs. *Environmental Impact Assessment Review, accepted*.

Weidema, B. P., Fress, N., Holleris Petersen, E., & Ølgaard, H. (2003). Reducing Uncertainty in LCI. Developing a Data Collection Strategy. Copenhagen: Danish Environmental Protection Agency.

STREAMLINED CARBON FOOTPRINT COMPUTATION — A CASE STUDY IN THE FOOD INDUSTRY

Yin Jin Lee and Edgar Blanco.*

** Massachusetts Institute of Technology, 77 Massachusetts Avenue, Building E40-261, Cambridge, MA 02139-4307. Email: yinjin@mit.edu.*

Keywords: carbon footprint calculation; uncertainty analysis; data gap; cut-off error

ABSTRACT

Using streamlined iterative carbon footprint calculation with uncertainty analysis, we developed a methodology to quickly estimate the carbon footprint of prepared meals. We used the methodology to calculate the carbon footprint of a dish that included 105 inputs from cradle to grave. We were able to quantify the uncertainty of data quality, data gap and cut-off error. We also used hypothetically true carbon footprints to validate the accuracy of the result. It was observed that the total carbon footprint estimate and its uncertainty converged when only the top 33 out of 105 inputs were updated. The method affirms that using cut-off strategies is a legitimate approach to reduce data collection effort while maintaining the integrity of carbon footprint estimates.

INTRODUCTION

Although the food service sector controls the types and the compositions of food made available to consumers, it has limited control and knowledge of the true carbon footprint of the various ingredients and processes. A methodology developed with a focus on calculating the carbon footprint of prepared food with minimal information can help food service providers design their dishes to minimize their carbon footprint and ideally make carbon labeling easier. For simplicity, we refer to all processes and materials that contribute to the total carbon footprint as *inputs*. In general, carbon footprint analyses can be greatly streamlined if we can focus our data collection effort on only a subset of all the inputs, with an understanding that these inputs are the ones that largely determine the final value of the carbon footprint.

In a previous case study (Lee, Yang, & Blanco, 2012), we noted several limitations in using existing data to compute food carbon footprint. These limitations are applicable to carbon footprint calculations in general too. Firstly, we cannot justify the subset size, commonly referred to as the *cut-off*. The British Standards Institute PAS2050:2011 recommends to cut off the inputs and outputs that contribute to the last 1% of the total carbon footprint (BSI British Standards, 2011) while the GHG Protocol recommends that the companies use screening calculations to prioritize the data collection effort (Bhatia et al., 2011). In this work, we will show that by performing CF and uncertainty calculation as the emission factor as the emission factors of the high impact inputs are corrected, one at a time, we can eventually witness convergence of the carbon footprint estimate, as postulated by Williams (2009).

Secondly, we do not have a way to support the accuracy of the estimated carbon footprint when we use proxies to replace unknown emission factors. The lack of true emission factors is also called data gaps. This problem are generally addressed in two ways (Bhatia et al., 2011; Canals et al., 2011): first is by extrapolating from existing databases and second is by using existing emission factors as proxies in the calculation. Neither approach has been proved to be accurate while accounting for the differences between the known proxies and the unknown true emission factors. In this work, we would borrow the concept of *test sets* from data mining (Hastie, Tibshirani, & Friedman, 2009) to support the use of proxies for screening calculations, and as substitutes for the emission factors of the lower impact inputs.

Lastly, we introduce an analytical solution to find proxy variance when the proxy is the average of several standard emission factors. Weber (2012) calculated the variance of the *average proxy* assuming that the proxies have the same true mean. Yet in most applications, the emission factors do not share the same true mean. Assuming that the emission factors share the same true mean can underestimate the uncertainty of the average proxy. Patanavanich (2009) proposed using Monte Carlo simulation to obtain the correct variance for average proxy when the sources of emission factors are distinctly different. In this work, we found that the *Law of Total Variance* (Bertsekas & Tsitsiklis, 2002) is the analytical solution to the Monte Carlo simulations, and we applied it to simplify the uncertainty analysis.

METHODS

Primary data collection and emission factor database

The food production phases were divided into five distinct stages, namely, Agriculture, Transportation, Packaging, Preparation and Disposal. Primary data of the inputs to a chicken entrée was collected directly from a restaurant and its suppliers. There were 105 inputs to the dish. Separately, we consolidated a database of emission factors sourced from multiple sources. These data are available in the Lee (2013).

Test set

The proxy emission factors in the database were split into two sets, the first set was used for estimating the total carbon footprint and the second set was used as hypothetically true emission factors to test the accuracy of the estimate.

Analytical solution to proxy uncertainty

Here we describe how the *Law of Total Variance* is applied to find the variance of the average of multiple proxies. If the i^{th} input to the product has N available standard emission factors, each emission factor (EF_n) is assigned an uncertainty based on the analyst's judgment (Meinrenken et al., 2012). The total variance $var(\overline{EF_t})$ for the i^{th} input to the product is calculated in two parts, one part is the average of the N variances (represented by $\boldsymbol{E}[var(EF_n|N)]$, and the second part is the variance between the N averages (represented by $var(\boldsymbol{E}[EF_n|N])$). The complete representation of the equation is

$$var(\overline{EF_t}) = \boldsymbol{E}[var(EF_n|N)] + var(\boldsymbol{E}[EF_n|N]), for\ n = 1, \dots, N$$

where

$\overline{EF_t}$ is the average proxy for the i^{th} input obtained from all N emission factors EF_n
EF_n is the n^{th} proxy emission factor

Iterative approach
The iterative approach is as follows: a screening calculation is first done to compute the total carbon footprint of the product. The individual carbon footprint contribution from each input is ranked and the input with the greatest contribution to the total carbon footprint (also the input with the highest impact) is replaced by the hypothetically true emission factor in the test set. The total carbon footprint is recalculated with other inputs using the same proxies as in the previous step. We revise the total carbon footprint until all inputs are updated.

RESULTS AND DISCUSSION

Proxy uncertainty
The expected total carbon footprint and standard deviation of the *screening calculation* based on the analytical solution and the Monte Carlo simulation were 2.051±0.392 $kgCO_{2eq}$ and 2.043±0.383 $kgCO_{2eq}$ respectively. The results from the analytical solution and the results from the analytical solutions matched even though they calculated the variance with different approaches. While the simulation results give the distribution of the carbon footprint estimate, the analytical solutions can substantially cut down the computing time and the amount of data generated in the intermediate steps.

Using iterative approach to justify the cut-off
Based on the blue curve in Figure 1, the carbon footprint estimate was 2.34±0.06 $kgCO_{2eq}$ when the top 33 inputs (99th percentile) were updated. The final estimate when all 105 APs were updated with the test set emission factors was also 2.34±0.06 $kgCO_{2eq}$. We can use this graph to choose other cut-offs depending on our need for accuracy and precision. By updating the total carbon footprint step-wise with test set(s), analysts can now justify the way they choose cut-off. This approach can be applied to carbon footprint calculations in other industries too.

Test set
The significance of using hypothetically true emission factors in a test set showed that the carbon footprint estimate would converge quickly even when only a subset of the inputs have the hypothetically true emission factors, while the remaining inputs are represented by proxies (Figure 1). This is possible because the inputs were updated in descending order of their carbon footprint impact, and because a small subset of the inputs contributed to a large fraction of the total carbon footprint. This trend supports that appropriate cut-offs can save substantial data collection effort without sacrificing the accuracy of the estimate.

CONCLUSIONS

Using food carbon footprint calculation as a case study, we found several ways to make carbon footprint calculations easier and more accurate. First is to use multiple proxies, and to calculate their uncertainty using the Law of Total Variance. We agree with Meinrenken et al. that analytical methods for error propagation can make calculation and analysis easier and that analytical methods for error propagation can make calculations faster (Meinrenken et al., 2012). Next we showed that by recalculating the total carbon footprint and its uncertainty as we updated the high impact inputs one at a time with hypothetically true emission factors, we could quantitatively justify cut-off, which at this point, is still an arbitrary assigned standard.

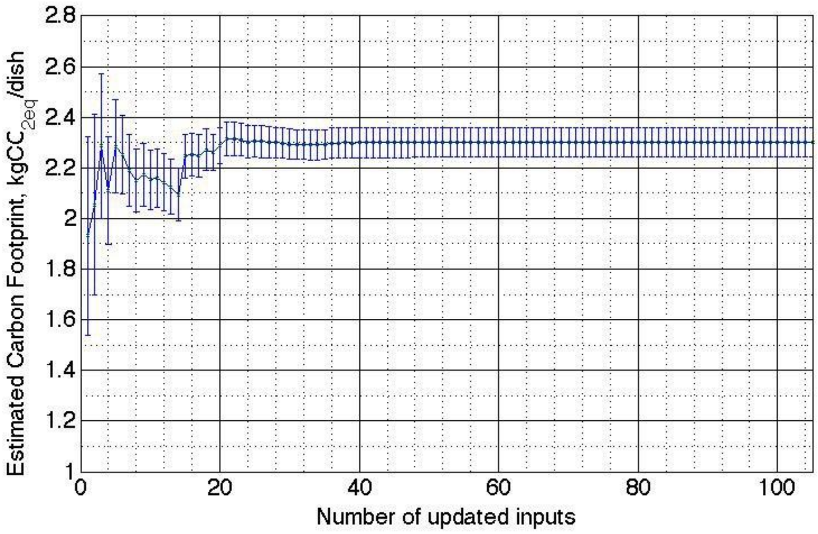


Figure 1. The estimated carbon footprint estimate converges quickly as the inputs are updated with the hypothetically true values from the test set.

REFERENCES

Bertsekas, D., & Tsitsiklis, J. (2002). General Random Variable. *Introduction to Probability* (2nd ed., p. 192). Belmont, MA: Athena Scientific.

Bhatia, P., Cummis, C., Brown, A., Draucker, L., Rich, D., & Holly Lahd. (2011). *GHG Protocol: Product Life Cycle Accounting and Reporting Standard*. USA: World Resources Institute. Retrieved from http://www.ghgprotocol.org/standards/product-standard

BSI British Standards. (2011). *PAS 2050:2011 Specification for the Assessment of the Life Cycle Greenhouse Gas Emissions of Goods and Services*.

Canals, L. M. I., Azapagic, A., Doka, G., Jefferies, D., King, H., Mutel, C., Nemecek, T., et al. (2011). Approaches for Addressing Life Cycle Assessment Data Gaps for Bio-based Products. *Journal of Industrial Ecology*, *15*(5), 707–725. doi:10.1111/j.1530-9290.2011.00369.x

Hastie, T., Tibshirani, R., & Friedman, J. (2009). *The Elements of Statistical Learning* (2nd Editio.). New York, NY: Springer.

Lee, Y. J., Yang, X., & Blanco, E. (2012). Streamlined life cycle assessment of carbon footprint of a tourist food menu using probabilistic underspecification methodology. *Sustainable Systems and Technology (ISSST)*. Boston, MA: IEEE International Symposium. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6227980

Meinrenken, C., Kaufman, S., Ramesh, S., & Lackner, K. (2012). Fast Carbon Footprinting for Large Product Portfolios. *Journal of Industrial Ecology*, *00*(00), 1– 11. doi:10.1111/j.1530-9290.2012.00463.x

Weber, C. L. (2012). Uncertainty and Variability in Product Carbon Footprinting. *Journal of Industrial Ecology*, *16*(2), 203–211. doi:10.1111/j.1530-9290.2011.00407.x

THE IMPORTANCE OF DATA SPECIFICITY IN CLIMATE ACCOUNTING OF WASTE MANAGEMENT SYSTEMS

Ingunn Saur Modahl, John Baxter, Kari-Anne Lyng, Silje Arnøy, Hanne Lerche Raadal*
(all Ostfold Research)

** Gamle Beddingvei 2b, 1671 Kråkerøy, Norway. E-mail: ism@ostfoldforskning.no, phone: +47 4112 3551*

Keywords: global warming; waste management; plastic packaging; data specificity

ABSTRACT

Documenting and optimising municipal waste handling and management activities in the environmental impact perspective requires reliable input data in which stakeholders can have confidence. LCA methodology for such analyses is well established, however the parameterization of LCA models often requires time-consuming and costly data-gathering. This partly depends on the perceived need for locally gathered data, specific to the system in question. This paper examines ways in which parts of this onerous exercise might be avoided for plastic packaging, and the implications of doing so.

The study has shown that, for GWP, material recycling is better than energy recovery for all the investigated plastic packaging treatment cases. It seems unlikely that local conditions can alter this conclusion.

INTRODUCTION

The aim of this paper is to show that to environmentally optimize the strategic decisions in Norwegian municipalities' waste management, it is not always important to use specific instead of generic data for climate accounting of the waste management options.

On behalf of Waste Management Norway (Avfall Norge) and 18 municipalities/waste management companies in Norway, Ostfold Research has developed a model for calculating the Global Warming Potential (GWP) for several waste types and different treatments. The model is based on Life Cycle Assessment methodology (LCA) and has been employed to calculate the GWP per kilogram waste for the different treatment options landfill, combustion with energy recovery and recycling, including the biological treatment processes biogas production and composting of food waste. The model has been used for comparison of total GWP for different waste treatment options in general (Raadal, Modahl and Lyng 2009; Lyng and Modahl 2011), and it has also been used for development of climate accounts for waste handling in specific cities, municipalities and regions (specific data used for Fredrikstad, SHMIL, Oslo, IRIS, MNA, Porsgrunn, IR, ENVINA, FIAS, HAF, Fosen, Hamos and RIR). These studies have also been used as input to strategic decisions on waste management options.

In most cases use of specific data are preferable to generic data in LCA's (Modahl et al. 2012). This is especially the case for product optimization and comparison of specific products. There are, however, some problems associated with the use of specific data, mostly relating to cost, availability and time frame (snapshot vs. long-term). Hence, the general view/natural assumption is that it is better to use specific data than generic data when a choice is to be made between two or more competing solutions.

METHODS

This paper presents GWP results of different waste management options of plastic packaging in specific municipalities in Norway, performed by Ostfold Research in the period 2009-2012. The specific results are compared to the generic results based on average Norwegian values. This comparison is used to investigate and discuss to what extent local conditions affect the results, for defining the factors that are most likely to influence the results, and to see if local conditions can alter the conclusions regarding which treatment option should be chosen for each waste type.

The net environmental impact of a waste treatment value chain is the sum of specific environmental burdens (costs) and benefits along the value chain. Burdens arise from transporting and treating waste, with benefits arising from replaced energy and/or material from energy recovery and/or material recycling. In principle, specific data is required for a number of steps along the value chain, as shown in the following table for plastic waste treatment.

Table 1 Data parameters for the value chain stages.

Value chain stage	Nature of burdens / benefits	Potential specific data parameters / factors
Transport	Emissions from transport vehicles.	Types of vehicle used, distances travelled, vehicle filling regime/degree of utilisation.
Treatment	Emissions from incineration plants or plants for sorting and material recycling.	Data on plant performance and feedstock (composition), internal transport, use of energy and water.
Replaced materials and energy	Avoided emissions from materials production or heat/electricity generation.	Performance of incinerator and of downstream equipment/transmission infrastructure (e.g. efficiency); what the recovered energy is used for (energy mix replaced), quality of materials produced and what products they replace etc.

RESULTS

The net results are shown in figure 1, and the results for each life cycle phase are shown in figure 2. Both specific and generic results are shown. The scales are those of environmental burden (that is, burdens are taken as positive and benefits as negative).

The results in figure 1 show that there is a distinct difference between the recycling cases and the energy recovery cases. Even the worst recycling case (Fosen) is 1.23 kg CO_2-eqv. better than the best energy recovery case (Fredrikstad) per kilo plastic packaging waste treated. Only one case is given for landfill (the generic case), and this result lies between energy recovery and material recycling. For material recycling, the specific cases lies between +3% (Oslo) to -

50% (Fosen) of the result of the generic case. For energy recovery, the specific cases are from 63% better (Fredrikstad) to 25% worse (MNA 2010).

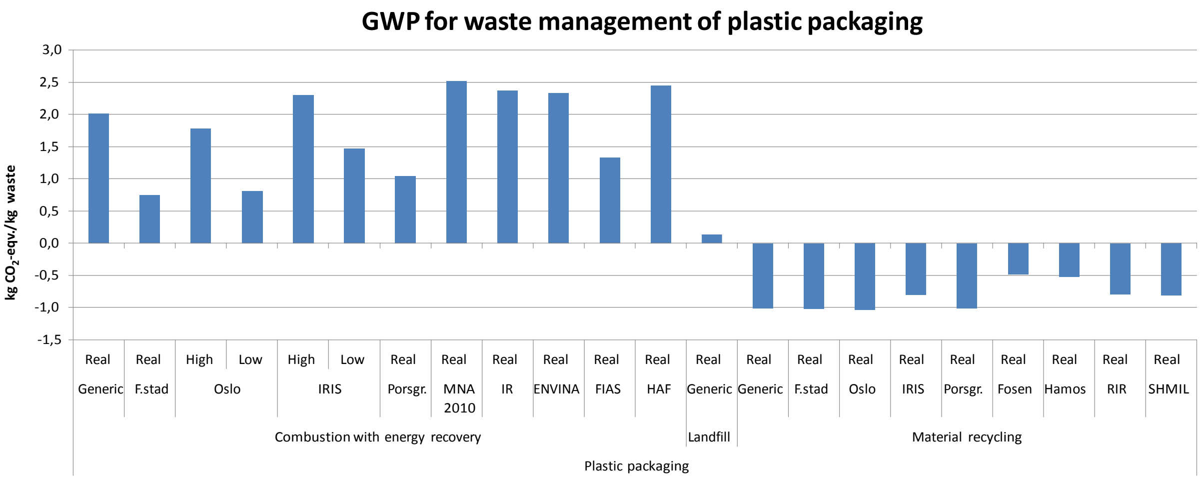


Figure 1 Net GWP for waste management of plastic packaging in Norwegian municipalities.

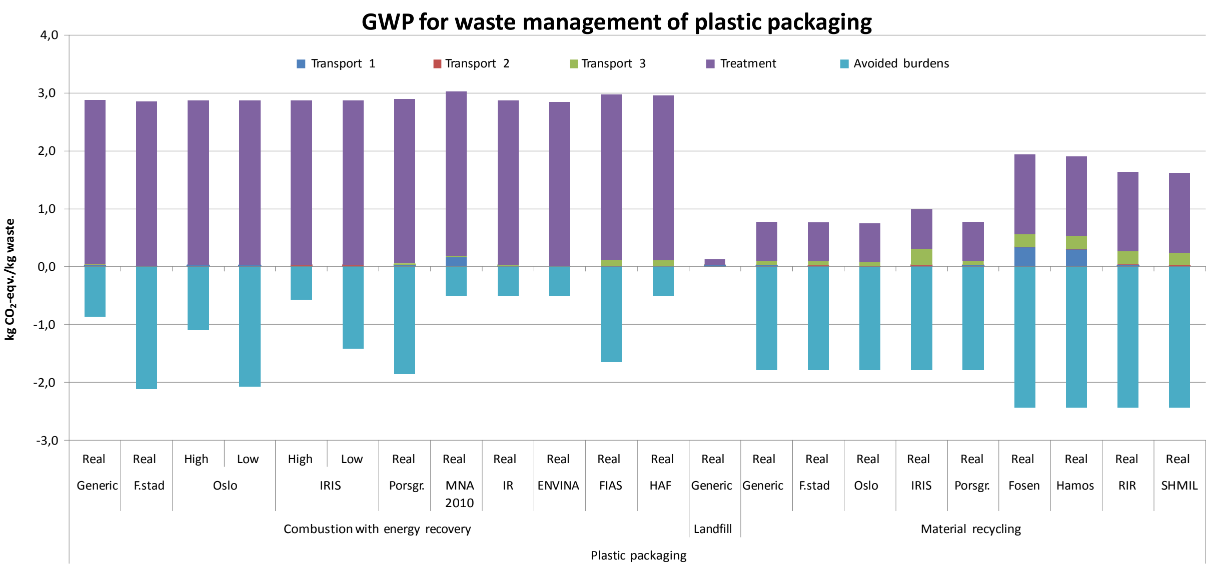


Figure 2 GWP, shown for each life cycle phase, for waste management of plastic packaging in Norwegian municipalities. For each data set, the burdens from different life cycle stages are stacked above the origin with the benefits appearing below it.

In figure 2 one can see that for the energy recovery cases, the burdens from the treatment phase (combustion) are almost the same for all cases, while the avoided burdens vary considerably. In the case of material recycling, the treatment burdens vary the most, while the avoided burdens are more similar. For both energy recovery and material recycling, transport is, in most cases, of minor significance.

DISCUSSION

A distinction should be made between climate documentation of existing waste treatment options and climate information used as input to strategic decisions regarding waste management of plastic packaging waste. The conclusions regarding GWP used for strategic decision-making are not very sensitive to data specificity; material recycling of plastic packaging is in all cases better than energy recovery. For climate accounting, the results vary to a degree that specific data is needed.

CONCLUSIONS

The study has shown that, for GWP, material recycling is better than energy recovery for all the investigated plastic packaging cases. Local conditions affect the results with regard to avoided burdens in the energy recovery cases and with regard to treatment burdens in the material recycling cases. Hence, in existing plants, efforts should be made to enhance the incinerator efficiency, and to reduce the energy use and increase the material quality in the recycling plants. Transport is, in most cases, not a very significant factor.

It seems unlikely that local conditions can alter the conclusion regarding which treatment option is the best with regard to GWP for plastic packaging waste. Specific data are hence not needed for strategic decision-making. However, for climate accounting of plastic packaging waste treatment, specific data should be used.

REFERENCES

Lyng, K.-A. og Modahl, I.S. (2011): *Livsløpsanalyse for gjenvinning av plastemballasje fra norske husholdninger (LCA of recycling of plastic waste from Norwegian households).* Østfoldforskning AS. In Norwegian. OR 10.11, September 2011.

Modahl, I.S., Askham, C., Lyng, K.-A., Skjerve-Nielssen, C. and Nereng, G. (2012): *Comparison of two versions of an EPD, using generic and specific data for the foreground system, and some methodological implications.* Int. J. Life Cycle Assessment, Springer-Verlag, online 17.May 2012. Volume 18, Issue 1 (2013), Page 241-251. DOI: http://www.springerlink.com/openurl.asp?genre=article&id=doi:10.1007/s11367-012-0449-0

Raadal, H.L., Modahl, I.S. and Lyng, K.-A.: (2009): *Klimaregnskap for avfallshåndtering (fase I og II) (Climate footprint of waste handling, phase I and II).* In Norwegian. Østfoldforskning AS, OR 18.09, June 2009.

THE USE OF MULTICRITERIA ANALYSIS – LESSONS FROM SUSTAINABILITY ASSESSMENT OF HYGIENE PRODUCTS CONTAINING NEW WOOD-BASED MATERIALS

Magdalena Svanström and Greg Peters, Chemical Environmental Science, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden, magdalena.svanstrom@chalmers.se*

Keywords: MCA; MCDA; product development; weighting; aggregation

ABSTRACT

This paper discusses the process of using multicriteria analysis (MCA) in sustainability assessment of absorbent hygiene products, comparing a reference product representing current technology, to product concepts containing new wood-based materials. The MCA required aggregation of qualitative and quantitative product performance indicators using different stakeholder value sets. The decision-makers in the MCA were drawn from different companies and from academia. The intent of the paper is to draw out some of the potential issues that may be encountered in similar assessments. The presentation also discusses different aggregation methods and provides results from the assessment and the aggregation.

INTRODUCTION

In sustainability assessments, an ever-present issue is how to compare seemingly incomparable aspects and how to manage trade-offs. Sometimes, weighting by the use of multicriteria analysis (MCA), sometimes called multicriteria decision analysis (MCDA), is applied (Mendoza and Martins, 2006). Weighting is based on the opinions of participants in the MCA, allowing integration of different aspects and providing structure and transparency to decision-making. MCA can thus be used in multi-stakeholder discussions within a company or project to derive weighting sets and also to illustrate the effects of applying different weighting sets.

The MCA work described here was performed as part of a larger four-year technical research and development project. It aimed to replace at least 50% of the absorbent porous structure in an incontinence product with new wood-based materials while maintaining performance and improving product sustainability. Sustainability assessment activities were performed throughout the research to guide material development towards sustainability. A final MCA was done in the last 6 months of the project to determine whether the project had fulfilled its goals. This paper describes the MCA procedure, and also reflects on the process.

MATERIALS AND METHODS

There are many ways to perform an MCA. We used our earlier experience and Rowley *et al*. (2012), which provided a practical methodological basis for this work. Additional methodological support was obtained from Brans and Mareschal (2005), Lundie *et al*. (2006), Olson (2001) and Guitouni and Martel (1998). Briefly, the key elements of most MCA processes include: identification of the goals of the process, definition of decision criteria, definition of alternative choices, population of a performance matrix, weighting, and aggregation.

A project consortium workshop was held to bring together different stakeholders for the MCA. The reference product was based on a current market product and two hypothetical products with similar function were based on the new wood-based materials developed within the project. A list of 37 indicators was reduced to 31 when participants were asked to think critically about experiences with them and principles for the selection of indicators (see Rowley *et al*. 2012). Data for the different indicators had mainly been generated in different other activities earlier on in the project. Participants also provided some product evaluations at the workshop, adding to the life cycle assessment, materials testing and financial data.

The aggregation process had to cope with quantitative and non-quantitative data (not all schemes allow mixed data), avoidance of the requirement for stakeholders to generate trade-off weights using quantitative scales (necessary for single synthesising criterion schemes – see Rowley *et al*. 2012), and the expectations of the level of stakeholder interaction (interactive schemes were ruled out). Therefore, we chose PROMETHEE ("preference ranking organization method for enrichment of evaluations"), a European pairwise comparison method that has been in use since the 1980s. Details are available in Brans and Mareschal (2005). Briefly, the performance of two alternatives is compared and the differences are converted using a preference function chosen to reflect the information available to the decision-maker. The simplest "usual" function is sometimes called "strict preference", in which even a small difference in performance results in complete preference for the better alternative.

Workshop participants provided personal weighting factors by distributing a total of 100 points among the indicators. Demographics and previous practical experience with diapers were also noted to make it possible to check for potential biases. Additional weighting sets were collected in group evaluations of future scenarios, and individual company preferences. These did not change the MCA outcomes and are not discussed further here.

RESULTS AND DISCUSSION

Some results from the MCA exercises are reported in Table 1. The performances of the compared alternatives are here given only as a ranking with 1 being the one that performed the best in the assessment. Also for negative indicators, such as cost, 1 represents here the best performing alternative (e.g. lowest cost).

Considering the average individual weights (n=16), reported in Table 1, product price and global warming were priorities. If weights are grouped for aspects, product function achieved the highest weight. Using the average weights, the reference scenario outperformed the other two. The variation due to demographic parameters was generally not large and unlikely to exhibit statistically significant variation if subjected to formal tests. It is interesting, though, to note that having had practical experience with diapers had almost no bearing on how important the financial or product performance characteristics were weighted. The most distinct differences are the relative weighting of environmental plus resource issues versus product performance plus cost issues across the gender divide – the women slightly favoured these particular “externalities” over the consumer and cost issues (43:39) compared with the men’s strong opposite weighting (31:51). This ratio distinguished university panellists (43:36) from industrial panellists (34:49) even more strongly. There was also a continuous trend in increasing weight for product performance with age. However, neither of these differences influenced the preference of the reference product over the new concepts.

Table 1. Aspects and indicators applied in the MCA, performance ranking for the compared alternatives (1 contributes in the best way to sustainability, followed by 2 and 3) and the average weighting factor (WF) given to each indicator in a workshop with 16 participants.

Aspect	Indicator	Ref	New 1	New 2	WF
Environment	Acidification	2	1	3	2.0
	Eutrophication	1	2	3	2.4
	Smog formation	1	2	3	1.6
	Global warming	1	2	3	6.2
	Ecotoxicity; freshwater ecosystems	1	3	2	3.1
	Ecotoxicity; terrestrial ecosystems	3	1	1	3.0
Resources	Fossil primary energy	1	2	3	4.6
	Total primary energy	1	2	3	3.0
	Total secondary energy	1	2	3	3.6
	Water	1	2	3	1.4
	Process water	1	3	2	1.2
	Wood	2	1	3	2.4
	Oil	3	1	1	3.2
Health	Human toxicity	3	2	1	3.6
	Product safety	1	2	3	4.4
	Occupational safety	1	2	3	3.5
Product function	Preventing urine leakage	2	1	3	4.9
	Keeping the skin dry	1	2	2	3.2
	Dryness of surface material	1	1	1	1.9
	Absorption capacity	1	1	1	3.4
	Retention of urine	1	2	2	3.7
	Preventing faeces leakage	1	1	1	2.4
	Keeping the shape of the absorption area	1	1	1	1.5
	Thickness of the core	1	2	2	2.0
	Being comfortable to wear	1	1	3	4.0
	Looking clean	1	1	1	1.2
Social	Social equity in value chain	1	1	1	4.0
	Risks to brand	1	1	1	2.9
Economy	Product price	1	2	3	6.9
	Investments	1	2	2	4.7
	Avoidance of technical lock-in	2	1	1	4.1

We also examined two systemic variations in the input data: biasing the weights and introducing an indifference threshold. In the bias test, the weights were adjusted until a rank reversal of the first two options occurred; for criteria that favoured the New 1 over the reference product, the weights were increased and for those that favoured the reference product over the New 1, the weights were decreased by the same amount. In order for the New 1 product to be preferred, the model required that the weights be biased by 30%, i.e., the weights for indicators favouring the New 1 had to be multiplied by 1.3 and the others by 0.7. Another possible way in which the New 1 product could outperform the reference product was if the criteria favouring the reference product were considered to only exhibit a small, insignificant outperformance, which can be referred to as an "indifference threshold". However, introducing a threshold could not alter the rank order due to the fact that only 7of the 20 indicators favour the New 1 over the reference product.

Although we hoped one of the new products would succeed, as analysts we were happy to arrive at a robust result - preference for the reference product over both new alternatives. The goal of the research project was not fulfilled but a satisfying level of certainty was. However, the project started to develop highly interesting materials that will likely prove more sustainable after further development efforts.

One of the key challenges faced by the research team was our conflicting roles as MCA workshop facilitators and environmental experts in the research project. Ideally, the workshop facilitators would be concerned only with the impartial fulfilment of the workshop aims, ensuring everyone understood the methodology and process. In practice, this requires elucidating the connections between the MCA process, the indicators and the products. For example, choosing an indicator involves an assessment of whether an indicator plays an important role – a value judgment the panellists should make but which they were at times more comfortable relying on our expert judgment. In retrospect, several hours might have usefully been directed earlier to general education of panellists about environmental and social performance indicators, had this time been available.

CONCLUSIONS

This MCA was performed to compare the sustainability of a reference and two conceptual absorbent hygiene products containing newly developed wood-based materials. The results robustly favour the reference product. Changing the rank order would require improved performance of the new products against several criteria. Key challenges experienced in this project were the need to educate decision-makers during an efficient evaluation process, and the conflict between the assessor roles of facilitator and expert.

REFERENCES

Brans J-P, Mareschal B (2005). PROMETHEE Methods. pp163-196, Chapter 5 Figueira J, Greco S, Ehrgott M. *Multiple Criteria Decision Analysis: State of the Art Surveys*. ISBN: 978-0387-23067-2, Springer, New York, USA.

Guitouni A, Martel J-M (1998) Tentative guidelines to help choosing an appropriate MCDA method. *European Journal of Operational Research 109:501-521.*

Lundie S, Peters G, Ashbolt N, Lai E, Livingston, D (2006) A sustainability framework for the Australian water industry. *Water, 33(7):83-88*. ISSN 0310-0367.

Mendoza, GA, Martins, H (2006). Multi-criteria decision analysis in natural resource management: A critical review of methods and new modelling paradigms. *Forest Ecology and Management 230:1-22.*

Olson DL (2001). Comparison of three multicriteria methods to predict known outcomes. *European Journal of Operational Research 130:576-587.*

Rowley HV, Peters GM, Lundie S, Moore SJ (2012). Aggregating sustainability indicators: Beyond the weighted sum. *Journal of Environmental Management, 111:24-33.*

MANAGEMENT OF NATURAL RESOURCES - BIOTIC

Wednesday, Aug 28: 8:30 am - 10:00 am

Session chairs: George Afrane, University of Ghana, Ghana
Sarah Jane McLaren, Massey University, New Zealand

AGRICULTURAL LIFE CYCLE ASSESSMENT (LCA) AS A ROUTINE EXERCISE IN IRAN: OPPORTUNITIES AND CHALLENGES

Ali Daneshi[1],Abbas Esmaili-sari[1], Mohamad Daneshi[2], Henrikke Baumann[3]*

[1] Department of Environmental Sciences, Faculty of Natural Resources and Marine Sciences, Tarbiat Modares University, Noor, Mazandaran, P.O. Box 46417-76489, Iran, email:mscdaneshi@gmail.com*

[2] Research and Development unit, Tehran Pegah Factory, Iranian Dairy Industries Co, Tehran, Iran

[3] Department of Environmental System Analysis, Chalmers University, Sweden

Keywords: Dairy; LCA; Water; Feed; Data management.

ABSTRACT

To direct sustainability in agricultural sector via Life Cycle Management (LCM), an easy access to high quality environmental, social and economical data is important. In this study, we explored the possibility of performing environmental life cycle assessment in Iranian dairy sector. Main life cycle stages were examined for availability and quality of needed data. At each stage, applicable databases are introduced. To spur life cycle studies, we need legislation to encourage all parties by incentives for more sustainable products. Next step may be to review & restructure already existed databases, articles and grey publications to extract suitable data for LCI stage. However, it is now possible to assess some impact categories in dairy industry.

INTRODUCTION

Agricultural productivity in world has increased 150-200% between 1960 and 2010 by only 12% expansion in the cultivated land area (FAO, 2011). However, industrialization, population growth and intensification of land use causing this increased agricultural yield over the past several decades has not already come without several costs (Gliessman, 2004).

Agriculture is an important economic sector in Iran and provides 23.0% of Iran's gross domestic product (GDP), of which 30% is attributed to livestock sector (FAO, 2005). Iranian livestock sector, in 2007 produced 2323 and 7596 thousand tones of Meat and Milk respectively and per capita consumption of Meat and Milk were 30.4 and 70.5 kg/year (FAO, 2009). Nearly 18.1 percent of Iran active labor forces are also in the agricultural sector, which illustrates the great impacts of sector on social and economical issues in the country.

Depletion of natural resources occurs because of the aggregate of human activities, in fact one agricultural product may not be a problem but a million becomes one. In Iran, soil is lost due to erosion approximately 19 times faster than it forms (Emadodin et al, 2012). This way, in a long run, natural world will not be able to support our increasing needs anymore and to keep higher or at least present level of productivity we need to apply sustainability measures.

Iran is ranked the fifth country in the irrigated farming area, however, in the 20th rank, according to the total arable land. In addition, Iran also listed between 7th to 18th countries with the most GHG emission in world according to different reports. Soil erosion is a major environmental threat to the sustainability and productive capacity of agriculture by reduction of soil fertility and loss of nutrients and thus, declines of crop yields in farmlands. Mean annual soil erosion rate in Iran is about 25 tons/ha/year, 4.3 times more than the mean annual soil erosion rate in the world (Rostamian et al, 2008) In a recent report by FAO, water scarcity and soil degradation are considered as major risks for Iranian agricultural production (FAO, 2011). Iran is situated in one of the most arid and semi arid regions of the world. The average annual precipitation is 252 mm (one-third of the world's average precipitation). Agriculture is responsible for 92% of yearly water withdrawal. Approximately 45 % of water is supplied through surface water and 55 % with groundwater. The average decrease in the groundwater table is 0.51 meter. Water average efficiency in agriculture is estimated to be approximately 35 % (Emadodin et al, 2012).

Life cycle management (LCM) is a powerful tool to assess sustainability in this sector and to make it operational, an easy access to high quality environmental, social and economical data through the overall life cycle of products is of great importance. To manage and efficiently steer the work in the different parts of the life cycle, different tools has to be applied such as environmental management systems, procedures for approval of chemicals, product safety, supplier evaluations, energy or water saving programs, etc (Riise and Palsson, 2011). Besides, we need mainly technical data and indicators for each product system for progress measurement, setting benchmarks and impact assessment. Because of data intensive nature of LCM, data management and availability is crucial to dissemination of method especially in developing countries. In this study, we explored the possibility of performing routine environmental life cycle assessment in Iranian dairy sector.

RESEARCH METHODS

The product system is comprised of three sub-systems of feed production, animal husbandry and dairy processing. For feed inventory, different national databases of crop & feed production developed by governmental organizations plus other reports and articles written by research institutes or Universities were reviewed. Moreover, seven animal husbandries providing raw milk were also studied by face-to-face questionnaire. Tehran Pegah company with a 600 tons of milk/day capacity was selected as a milk processing plant unit. Overally the gathered data are for 2011 and in Tehran Province. All these main life cycle stages were examined for availability and quality of essential data.

RESULTS

In general there are large amount of studies available in libraries of government and research institutes but most of them are neither in English language nor online. Studies on background inputs like pesticides and fertilizers are rare. In case of country's electricity mix production, yearly report of electricity production and fossil fuels burned in power plants are available (Tavanir, 2011), however, for fuels' life cycle we have to rely on International databases.

At feed cultivation stage, provincial agricultural input-output tables for each crop including fertilizers use, labor hour, machinery, water use, pesticides and transportation are at hand and are updated each 5 years by Ministry of Agriculture. These tables are historically used to estimate production costs of crops but there are possibilities to convert this vast amount of information to useful forms for application in Life Cycle Inventory. In addition, most of protein feeds consumed for livestock products like Soy cake are imported from countries like Brazil, India and USA (TCCIM, 2012). Thus, we must consider environmental burdens of this transportations.

For smaller animal husbandries, the main challenges are lack of documentation and clearly environmental consideration. Besides, they obtain needed feed from different sources and this makes life cycle study uncertain. However, they cooperate nicely. On the other hand, documentation and organization are the necessary parts in industrialized and bigger animal husbandries. Moreover, the source of feeds are usually known which helps in tracking regional environmental burdens. Moreover, constituents of the ration is completely planned which allows for clarity and order in data collection. Data collection and management is a routine work in the dairy processing plant, and being more industrialized and regulated by government and ISO standards, it is expected that dairy processing plants to comply with life cycle studies easily.

As a result of real concern over the issue of water consumption in agriculture, there are some databases for estimation of blue & green water needs of crops in different regions. In 1997, Farshi and coworkers (1997) published their water requirement database of main field crops in Iran, which included blue and Green water requirement of major crops per hectare. Modeling approach was applied together with extensive pilot studies. Model inputs were climate data, FAO equations in CROPWAT and pilot studies including crop yields and water consumption. Another example is Netwat, which is software database giving net blue water need of crops in each province based on previous studies.

DISCUSSION

As Wernet et al. (2011) suggested, it is better to first base our national Inventory on already existed databases like ecoinvent, and then try to revise and complete it with foreground data in time and it is acceptable as long as the sources of data are stated. However, without a major contribution from the government it seems impossible to do life cycle inventory studies on important background life cycle stages like fertilizers production and fossil fuel extraction & refinery.

Because of great reliance of country in dairy sector to import from other part of the world for example protein feeds and fertilizers, pesticides in feed production stage, medicine or Vitamin supplements in livestock’s ration and some food additives and stabilizers in dairy processing, it is necessary to note that, for producing a product considering environmental life cycle analysis, producers have to cooperate in global scale to form a network for collection and distribution of data.

In the case of water consumption in agriculture and animal husbandries, there should be sort of control over the consumption of water maybe by installing contour, because low or no price for water caused them to not account for water seriously. Over the last few years, by partly removing subsidies of water, electricity and fossil fuels, there is clear tendency in different sectors for innovation and efficiency in inputs consumption for cost reduction.

Although we should avoid putting too much pressure on producers and always bear in mind that to make a product sustainable means to keep it competent through the environmental, social and economical bottom lines from cradle to grave; in the whole life cycle (Hermann et al. 2011).

CONCLUSIONS

In conclusion, we need legislation to encourage all parties by incentives for more sustainable products. Moreover, probable financial benefits from applying life cycle thinking on overall long-term productivity must be stated clearly. Next step is to restructure already existed databases according to crop type, scope and time to extract suitable data for LCI part of agricultural products with unit process and appropriate functional units in mind. We concluded that, though with some improvements in data collection and management especially by government organizations, it is possible to study some environmental impact categories like global warming, eutrophication or acidification to support optimization in this sector.

REFERENCES

Emadodin I, Narita D, Bork H R (2012). Soil degradation and agricultural sustainability: an overview from Iran. *Environment, Development and Sustainability. 14:611–625.*

FAO (2005). Iran: Livestock sector brief. Livestock Information, Sector Analysis and Policy Branch AGAL. Rome.

FAO (2009). Livestock in the balance. The state of food and agriculture. Rome.

FAO (2011). The state of the world’s land and water resources for food and agriculture. Rome.

Farshi A A, Shariati M R, Jaroallahi R, Ghaemi M R, Shahabifar M, Tavallaei M M. (1997). An estimate of water requirement of main field crops and orchards in Iran, Vol: Field crops. Agricultural Education, Agricultural Research, Education and Extention organization of Iran. Karaj, Iran. (In Persian).

Gliessman S R (2004). Integrating agroecological processes into cropping systems research. *Journal of Crop Improvement. 11:61–80.*

Herrmann C, Bergmann L, Thiede, S, Halubek, P (2007). Total Life Cycle Management - An Integrated Approach Towards Sustainability. *In: 3rd International Conference on Life Cycle Management. University of Zurich at Irchel.*

Riise E, Palsson A C (2011). Life cycle management - managing the sustainability of supply chains in the TOSCA project. *LCM 2011conference proceeding. Berlin.*

Rostamian R, Jaleh A, Afyuni M, Mousavi S, Heidarpour M, Jalalian A, Abbaspour K C (2008). Application of a SWAT model for estimating runoff and sediment in two mountainous basins in central Iran. *Hydrology Science Journal (5): 977-988.*

Tavanir (2012). Iran Power Generation transmission & Distribution Management Co. *Ministry Of Energy*. Accessible at: http://amar.tavanir.org.ir/en/pages/epii/10.php

TCCIM (2012). Import-Export statistics. *Tehran Chamber of Commerce and Industries and Mines (TCCIM).* Accessible at: http://www.tccim.ir/ImpExpStats.aspx

Wernet G, Stucki M, Shenoy M, Muthusezhiyan N (2011). Establishing a data framework for Life Cycle Management in India. *LCM 2011conference proceeding.Berlin.*

CLOTHES MADE FROM EUCALYPTUS – OUR FUTURE?

Sandra Roos and Greg Peters*

**Swerea IVF AB, PO Box 104, SE-431 22 Mölndal, Sweden, Department of Chemical and Biological Engineering, Chalmers University of Technology, SE-412 96 Göteborg, Sweden,* sandra.roos@swerea.se

Keywords: life cycle assessment; textiles; decision making; biotic resources; public procurement.

ABSTRACT

This paper is an illustration of how life cycle assessment (LCA) was successfully applied to provide a scientific background for decision making in the textile sector. The life cycle environmental performance of a new eucalyptus based textile was compared to the current cotton based textile in the application of a women's hospital uniform. The results from the life cycle impact assessment showed clear benefits with replacing the cotton based textile, mainly through avoiding water depletion and pollution from pesticides caused by the cotton cultivation. The raw material production and the laundry during the use phase are the two main aspects of the uniform. Further, the knowledge gained during the LCA was used to formulate environmental requirements for the suppliers.

INTRODUCTION

The Swedish textile sector is characterised by long distribution chains and products imported mainly from south-eastern Asia. Among Swedish textile companies, the awareness is growing of the downsides of cotton in the early life cycle stages. Cotton cultivation today is infamous for environmental impacts from its heavy use of pesticides and water (Pfister, Koehler, & Hellweg, 2009), and social responsibility issues including both forced labour and child labour (Bärlocher, Holland, & Gujja, 1999). Many companies are asking the same question - are there better alternatives to cotton? At the same time the demand for textile fibres is growing with the increase of the global population. Today, fossil based fibres such as polyester and polyamide stands for around 57 percent of the world market for textile fibres, cotton stands for 37 percent and cellulose fibres such as viscose and modal stands for 4 percent, wool 2 percent (Humphries, 2009). What will our clothes be made of in the future?

TvNo Textilservice AB is a Swedish laundry service providing textiles for rent to hospitals, medical clinics and aged care facilities. TvNo investigated a eucalyptus/polyester based textile as an alternative to their cotton/polyester textile used in women's uniforms. In addition to comfort testing and validation of technical parameters such as tear resistance, pilling and service life, TvNo also wanted to make an informed decision of the environmental performance of the two alternatives.

METHOD

A cradle-to-grave LCA was performed where a women's hospital uniform made from fifty percent cotton and fifty percent polyester provided the base case. As the alternative product, a uniform was chosen where the cotton was substituted with Tencel^{TM} (lyocell fibres made from eucalyptus).

The study focused on the difference between the cotton and the eucalyptus fibres, which means that the same data were used for all life cycle stages of the uniform that do not differ between the two fibres. The end-of-life scenario was set to incineration of both uniforms, as this is the most common waste management route for textiles in Sweden (Carlsson, Hemström, Edborg, Stenmarck, & Sörme, 2011). The specific data collected from the suppliers for this study concerned the manufacturing of the Tencel^{TM} fibres, the weaving, the wet treatment and the confectioning (cutting/sewing/printing) in the production phase, and the laundry and transports in the use phase, see Table 1. The dialogue with the suppliers around data collection was also used in order to understand the current environmental work in the supply chain and identify the possible knowledge gaps. The generic data was collected from Ecoinvent 2.2 and Swerea IVF's own database. The calculations were performed in SimaPro 7.3.3.2.

Table 1. Data sources for the life cycle inventory.

Life cycle stage	**Data source**	**Life cycle stage**	**Data source**
Cotton fibre production	Ecoinvent 2.2	Weaving	Swerea IVF data
Tencel^{TM} fibre production	Lenzing AG	Wet treatment	Lauffenmühle / Swerea IVF data
Polyester fibre production	Ecoinvent 2.2 / Swerea IVF data	Confectioning	Nybo Jensen Konfektion A/S
Yarn spinning	Swerea IVF data	Use	TvNo Textilservice AB

The functional unit is a single use, which for the hospital uniforms is the same as one laundry cycle. Both the cotton/polyester uniform and the eucalyptus/polyester uniform were assumed to be used for 75 laundry cycles.

Textiles are generally associated with environmental impacts such as pollution from chemicals, water depletion and climate change (Allwood, Laursen, Rodriguez, & Bocken, 2006). Therefore the chosen midpoint environmental impact categories were climate change, energy use, eutrophication, freshwater toxicity, human toxicity, water use and land use. For toxicity calculations UseTox^{TM} (Rosenbaum et al., 2011) was used and for primary energy the guidelines in Hischier & Weidema (2009) was used. For the other categories ReCiPe, Midpoint (H) V1.06/World ReCiPe H (Goedkoop et al., 2008) was used.

RESULTS AND DISCUSSION

Environmental performance of the two products
The eucalyptus alternative scored better than the cotton alternative for all parameters except energy use (see Figure 1 below). The life cycle contribution to climate change is for the Tencel/polyester uniform 8.5 kg carbon dioxide equivalents. This corresponds to around 500 grams of beef meat or a 70 kilometer drive with a green car. The LCA gave thus the background needed for TvNo to make an informed decision and choose the eucalyptus uniform. Further, the knowledge gained during the life cycle assessment was used to formulate environmental requirements for the suppliers.

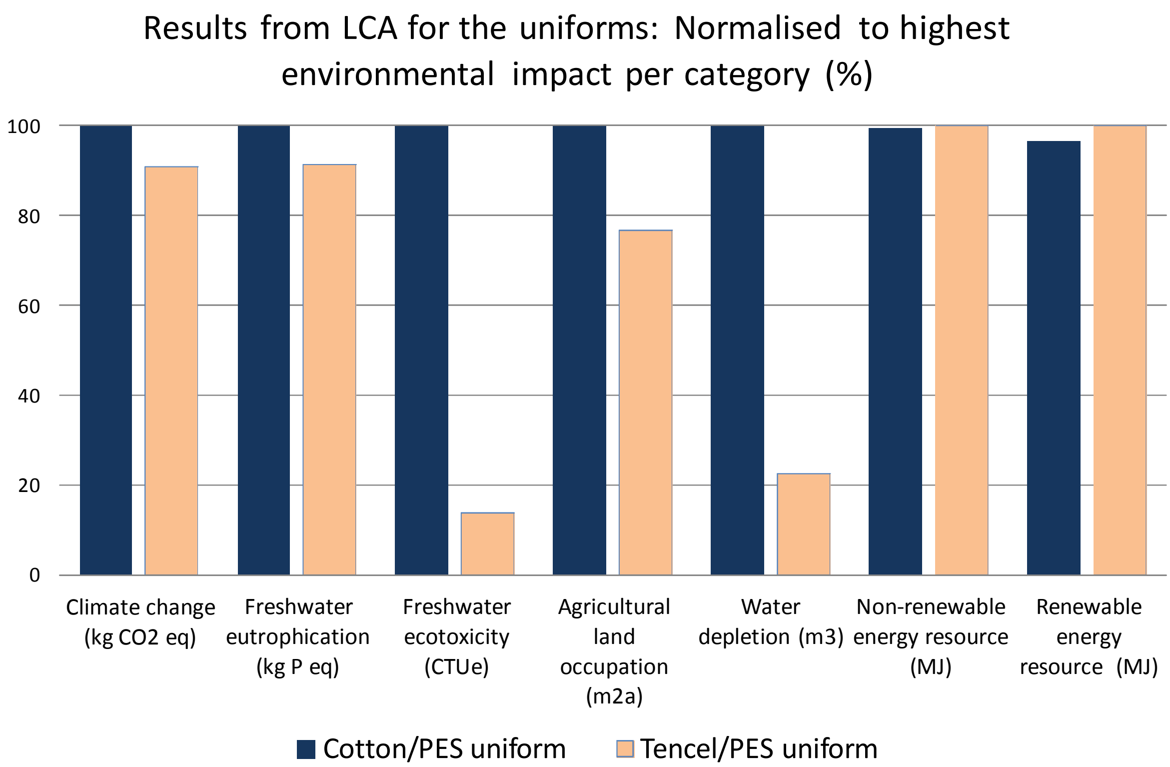


Figure 1. Results for the comparison between the cotton/polyester uniform (blue bars) and the Tencel/polyester uniform. Please note that the results are normalised within each impact category and do not describe any weighting between the different impact categories.

Formulation of environmental requirements on the suppliers
In a long textile distribution chain the transparency is easily lost, making the compliance with environmental requirements difficult. Different environmental labels imply different criteria. Environmental requirements can ideally be complemented by setting knowledge requirements on the suppliers.

Examples of environmental requirements include:

- Restricted substance lists (RSL).
- Certified raw material (FSC, GOTS, OEKO-TEX 100 etc.).
- Certified processes (ISO 14001, BlueSign, BCSI etc.).

Examples of knowledge requirements include:

- Be able to report how the compliance with the RSL is ensured.
- Be able to explain what applied environmental labels include.

The discussions in the supply chain with suppliers and sub-suppliers that were initiated by the LCA study also led to an increasing awareness of the importance of controlling the environmental performance in the early life cycle stages, e.g. the use of environmentally certified eucalyptus wood.

CONCLUSIONS

The eucalyptus alternative scored better than the cotton alternative for all the investigated parameters except energy use. The LCA gave thus the background needed for TvNo to make an informed decision and choose the eucalyptus uniform. Further, the knowledge gained during the life cycle assessment was used to formulate environmental requirements for the suppliers. The discussions in the supply chain with suppliers and sub-suppliers that were initiated by the LCA study also led to an increasing awareness of the importance of controlling the environmental performance in the early life cycle stages.

REFERENCES

Allwood, J. M., Laursen, S. E., Rodriguez, C. M., & Bocken, N. M. P. (2006). *Well dressed? The present and future sustainability of clothing and textiles in the United Kingdom*. *University of Cambridge Institute for Manufacturing*. Retrieved from http://www-mmd.eng.cam.ac.uk/sustainability/projects/mass/technical_annex_201106.pdf

Bärlocher, C., Holland, R., & Gujja, B. (1999). *The impact of cotton on fresh water resources and ecosystems*. Zurich, Switzerland.

Carlsson, A., Hemström, K., Edborg, P., Stenmarck, Å., & Sörme, L. (2011). *Kartläggning av mängder och flöden av textilavfall*. Norrköping, Sweden.

Goedkoop, M., Heijungs, R., Huijbregts, M., De Schryver, A., Struijs, J., & Van Zelm, R. (2008). *ReCiPe 2008, A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level* (1st ed.). Retrieved from http://www.lcia-recipe.net

Humphries, M. (2009). *Fabric Reference* (4th ed.). Upper Saddle River: Pearson Education, Inc.

Pfister, S., Koehler, A., & Hellweg, S. (2009). Assessing the environmental impacts of freshwater consumption in LCA. *Environmental science & technology*, *43*(11), 4098–104. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19569336

Rosenbaum, R. K., Huijbregts, M. a. J., Henderson, A. D., Margni, M., McKone, T. E., Meent, D., Hauschild, M. Z., et al. (2011). USEtox human exposure and toxicity factors for comparative assessment of toxic emissions in life cycle analysis: sensitivity to key chemical properties. *The International Journal of Life Cycle Assessment*, *16*(8), 710–727. doi:10.1007/s11367-011-0316-4

INCREASING THE SUSTAINABILITY OF DURUM WHEAT CULTIVATION THROUGH A LIFE CYCLE ASSESSMENT APPROACH

Luca Ruini[1], Filippo Sessa[2], Massimo Marino[2*], Pierluigi Meriggi[3], Matteo Ruggeri[4]*

[1] Barilla G. R. Fratelli S.p.A
[2] Life Cycle Engineering Srl
[3] Horta Srl
[4] Università Cattolica del Sacro Cuore

** Postal address: Life Cycle Engineering c/o Environment Park – 60,via Livorno, I–10144 Torino (TO). E–mail address: sessa@studiolce.it.*

Keywords: Durum wheat, Sustainable agriculture

ABSTRACT

Durum wheat cultivation is responsible for most of the environmental impact of pasta production. Due to this reason, Barilla put forth a specific project aimed to increase widespread use of sustainable cropping systems. Such analysis was based on a holistic approach, taking into consideration economic, agronomic, and environmental indicators. The project focused on identifying potential improvements in the most diffused cropping systems for the cultivation of durum wheat in Italy, while maintaining high levels of quality and food safety. The project has demonstrated that the durum wheat cultivated according to the guidelines of sustainability developed by Barilla has a global warming potential significantly lower than that cultivated with conventional agricultural practices.

INTRODUCTION

Barilla has released its study on the environmental impacts of pasta conducted with the life cycle assessment methodology through the publication of the Environmental Product Declaration (Barilla, 2010). Given that the home cooking phase does not fall under company dominion, and thus not factored into consideration, durum wheat cultivation is responsible for more than 80% of the ecological footprint, approximately 60% of the carbon footprint and for entirety of the water footprint. Due to this reason, Barilla put forth a specific project aimed to increase widespread use of sustainable cropping systems of durum wheat. Analysis was based on a holistic approach, taking into consideration economic, agronomic, food safety and environmental indicators. The project focused on identifying potential improvements of the most diffused cropping systems for the cultivation of durum wheat, while maintaining high levels of quality and health standards. Agricultural practices can in fact influence the environmental, economic and food safety performances of cultivation (Tilman et al, 2002). In particular, this study contemplates the main practices of crop rotation, use of fertilizers, tillage, seeding, and weed and pest management.

Italy was the first cultivation area considered because it is the country where Barilla purchases approximately 70% of the durum wheat necessary to its entire pasta production.

The project started in 2010 and it has been developed in different phases. In the first year the company put in place theoretical studies on durum wheat cultivation in Italy and the evaluation of environmental impacts and of overall agriculture efficiency through the use of economic, social and environmental sustainability indicators.

In 2010/2011 Barilla analyzed a sample of farm to compare real data from farms with optimal values to obtain sustainable productions. The results shows that rotation of durum wheat with dicotyledons is more sustainable than rotations only with cereals and monoculture, and a reduction in production costs is possible with a better efficiency in the use of inputs. The results of this study were published in the *Handbook for sustainable cultivation of quality durum wheat in Italy*, which serves as source of practical suggestions for farmers.

Finally, in 2011/2012 the project was extended to demonstrate that an accurate planning of crop rotations and the use of a decision support system could help in being more sustainable, both environmentally and economically. In this part of the project a decision support system was given to the farmers to help them following the suggestions of the *Handbook for the sustainable cultivation of quality durum wheat in Italy*.

MATERIALS AND METHODS

Two different durum wheat crop management were compared. The first one consists in farmer's usual crop management with only farmer crop choices and strategies, while in the second one the farmers were supported by the decision support system (DSS) *granoduro.net* ™, a web service that integrates information on weather patterns, soil conditions and varietal characteristics in order to give to the farmer the opportunity to optimize seeding, fertilization, weed control and disease management. The DSS provides also information on nowcasting and forecast weather conditions and crop growth and development.

The test was conducted in 13 farms, located in the most important areal for durum wheat cultivation in Italy (4 in Emilia-Romagna, 6 in Marche, 1 in Tuscany and 2 in Apulia). In order to verify the effectiveness and feasibility of the suggested practices, farmers have agreed to cultivate part of their land following the *Handbook* and *granoduro.net*™ and part following their routine practices.

The cultivation of durum wheat after several crops was tested to determine whether different crop rotations could aid in increasing sustainability of the whole process (Caporali et al., 1992). Such previous crops were divided into four groups: cereals (maize, sorghum, soft wheat, durum wheat), industrial crops (sunflower, rape seed, sugar beet), leguminous (faba bean, chickpea, proteic pea), vegetables (tomato). Previous crops were also divided into three groups according to their influence on durum wheat cultivation: favorable (faba bean, chickpea, rape seed, proteic pea, sugar beet), neutral (sunflower) and unfavorable (maize, sorghum, wheat). A comparison was made, for each type of previous crop, between the cultivation of durum wheat with and without the use of the decision support system granoduro.net™.

RESULTS

The cultivation f durum wheat after a vegetable or a leguminous contributes in reducing significantly the greenhouse gas emissions compared to the cultivation after a cereal (Figure 1).

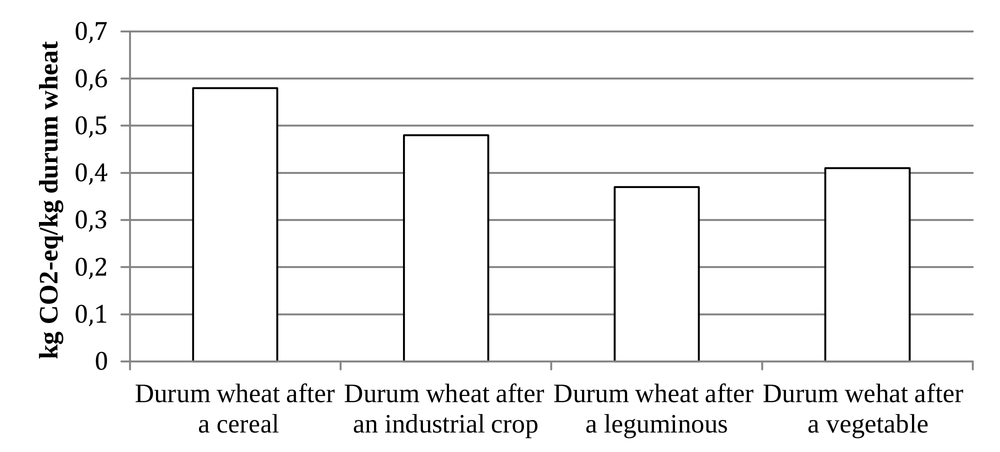


Figure 1. Carbon footprint of durum wheat cultivated after different crops

Concerning the expenses the cultivation of durum wheat after a leguminous or a vegetable contributes in reducing significantly production costs (Figure 2) compared for example to the cultivation after a cereal. To finish, a favorable previous crop contributes in obtaining a significantly higher yield (+20% equivalent to +1,3 t/ha) compared to an unfavorable one.

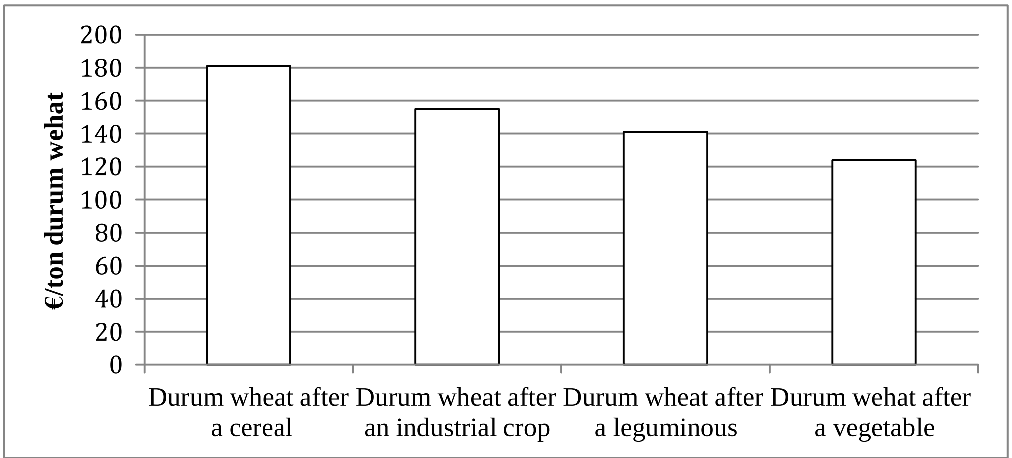


Figura 2. Production costs of durum wheat cultivated after different crops

Results show that the use of *granoduro.net*™ contribute in further reducing carbon footprint (Figure 32), supply to the reduction of production costs especially in case of favorable or neutral previous crop and contributes in reducing the costs of pesticides and fertilizers management.

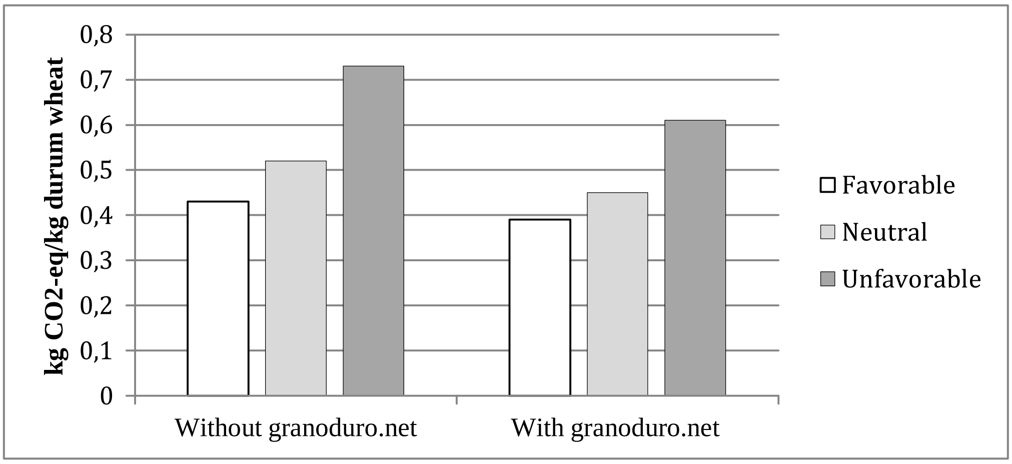


Figure 3. Carbon footprint of durum wheat cultivated with and without the DSS granoduro.net™.

To sum up the use of the DSS contribute to a reduction in direct costs of production, a reduction in carbon footprint, an increasing in nitrogen use efficiency and to maintain high yields.

DISCUSSION

The project has demonstrated the importance of an integrated approach to study the sustainability of a cropping system. It's important to bear in mind that agriculture is primarily an economic activity and there's the risk walking the line of counter-productivity when merely focusing on environmental and food safety issues. However, the study shows that environmentally friendly practices are also often economically advantageous because they greatly increase the efficiency of technical tool usage and the yield.

CONCLUSIONS

The project has highlighted the importance of technical instruments such as the DSS granuduro.net to help the farmers in their decisions. With this kind of support the agriculture would be less costly and at the same time the environmental impacts linked to its activities could be reduced. The project's ultimate goal is to take "sustainable agriculture" to a large scale by signing contracts with farmers that encompass sustainable practices.

REFERENCES

Barilla, 2010. Environmental Product Declaration of Dry semolina pasta from durum wheat. www.environdec.com/en/Detail/?Epd=7699.

Caporali, F., Onnis, A., 1992. Validity of rotation as an effective agroecological principle for a sustainable agriculture. Agriculture, Ecosystems & Environment, Volume 41, Issue 2, July 1992, 101–113.

Tilman, D., Cassman, KG., Matson, P.A., Naylor, R., Polasky, S., 2002. Agricultural sustainability and intensive production practices. Nature 418, 671-677

METHODOLOGY FOR LCA OF BIOREFINERIES – A LITERATURE REVIEW

Serina Ahlgren (Swedish University of Agricultural Sciences), Anna Ekman (Lund University), Hanna Karlsson (Swedish University of Agricultural Sciences) and Anna Björklund (KTH, Royal Institute of Technology). *Department of Energy and Technology, PO Box 7032, 750 07 Uppsala, Sweden, serina.ahlgren@slu.se.*

Keywords: LCA; biorefinery; methodology; literature review

ABSTRACT

The number of LCAs of biorefinery systems has increased in recent years, however there is a large variety in how the LCA methodology is used. The aim of this paper was to analyse existing life cycle assessment case studies of biorefinery systems concerning basic key issues related to the LCA methodology, and how these have been handled in the case studies. This is intended to contribute to improved insight of the difficulties when performing LCA of biorefinery systems, which could facilitate future studies.

INTRODUCTION

The current trend in biomass conversion technologies is towards so called biorefineries, where a spectrum of different products allows for a more energy and cost efficient utilization of the biomass. Another trend is the attention given in research, policymaking and media to the environmental impact of biomass systems, especially climate impacts. Over the years, many life cycle assessment (LCA) studies of bioenergy systems have been performed. Still, LCA of bioenergy faces some methodological issues, it has for example during the last years been under heavy debate how to include indirect land use changes in the calculations.

LCA of biorefinery systems make the calculations even more intricate; there are a number of basic LCA key issues that will be relevant to consider. First of all, biorefinery produces several high-value outputs, rather than one main product and by-products. This means that the choice of functional unit will be very important. Further, the environmental impact somehow has to be divided over the high-value products. Also, a biorefinery-LCA with several output products will require much more assumptions and data input, which increases the uncertainty. It will therefore be extra important to define appropriate systems boundaries.

In a project funded by the Swedish Knowledge Centre for Renewable Transportation Fuels (f3), some LCA researchers in Sweden have come together to discuss these issues. The project group consists of representatives from the Swedish University of Agricultural Sciences, Lund University, KTH Royal Institute of Technology, IVL Swedish Environmental Research Institute, SP Technical Research Institute of Sweden and Chalmers University of Technology. The project group will identify and discuss the key issues of BR-LCA and work out recommendations on how they can be handled. The project is to be finalised in September 2013. The present paper will be a part of the outcome of this project.

The aim of this paper is to analyse existing life cycle assessment case studies of biorefinery systems concerning basic key issues related to the LCA methodology, and how these have been handled in the case studies. This is intended to contribute to improved insight of the difficulties when performing LCA of biorefinery systems, which could facilitate future studies.

MATERIALS AND METHODS

In this study, 12 scientific papers published between 2009 and 2013 have been reviewed (Table 1). The articles were found by a screening in which both the publically available Google Scholar and Lund University Library database were used. Screenings for papers were performed in August 2012 and February 2013. The studies were chosen to provide examples of case studies of biorefinery systems and they do not to represent the entire collection of papers in the field. One selection criterion for the papers included in the literature review was that they should present an LCA-based environmental assessment of a system in which more than one valuable product is produced from biomass. The term biorefinery is not specified in all of the included studies, which may have an explanation in the lack of a clear and universal definition of biorefineries. A biorefinery can be anything from a simple ethanol factory to a complex, integrated system in which a number of actors cooperate and a variety of products are produced.

Table 1. Studies used in the analysis

No	**Study**
1	Cherubini & Jungmeier (2010)
2	Cherubini & Ulgiati (2010)
3	(Ekman & Börjesson (2011)
4	Gonzalez-Garcia et al. (2011)
5	Kimming et al. (2011)
6	Lim & Lee (2011)
7	Earles et al. (2011)
8	Souza et al. (2012)
9	Piemonte (2012)
10	Pourbafrani et al. (2013)
11	Tonini & Astrup (2012)
12	Uihlein & Schebek (2009)

RESULTS

The stated **aim** in the majority of studies included in the literature review is to assess, identify, quantify, characterize, investigate or evaluate the environmental impact of a biorefinery system in comparison with a reference system. This either refers to a fossil-based production system (study number 1, 2, 3, 5, 10, 11 and 12) or conventional biofuels (study number 6 and 8). A few studies also aim at identifying hot spots and suggest improvements to lower the environmental impacts of the biorefineries (study number 4, 6, 7, 11 and 12). In none of the studies an intended audience is specified.

The majority of the reviewed LCAs do not specify if **consequential or attributional** modeling is performed. None of the studies referred to the ISO 14040-14044 standards. Study number 5, 6 and 11 define themselves as consequential LCAs. Only study number 3 defines itself as accounting LCA.

The **functional units** (FU) in the reviewed studies are mainly of three types. The first type is one selected product, for example, 1 tonne dissolving cellulose (study number 4), 1 kg propionic acid (study number 3) or 1 kg fuel (study number 9). The second category includes FUs that contain a combination of products produced such as 1000 kg ethanol, 368 kg acetic acid and 55300 square feet oriented strand board panels (study number 7) or MWh of different energy carriers supplied to a system/year (study number 5 and 10). The third category of FU refers to the input of feedstock expressed either as 1 tonne of biomass or waste (study number 11 and 12), 477 ktonnes of biomass (the total annual input) (study number 1) or 1 ha of sugarcane (study number 8) or 1 ha palm oil plantation in 100 years (study number 6). FUs in the third category showed to be most common alternative. The latter FU was in some cases motivated as the only reasonable alternative since one single main product could not be identified. In one case, a sensitivity analysis was performed in which the functional unit was altered (study number 10).

The reviewed studies had different **system boundaries**, cradle-to-gate is one of the most common stated. Also geographical specifications were different and proved to have some impact especially regarding the choice of input data such as type of energy used as input or to be replaced/compared to. This is valid for all studies since they all refer to different geographic regions.

Average **data** is used as input in most of the studies. Only studies number 5 and 11 are the only ones that take more detailed consideration of long or short-term marginal data. Especially the study number 11 makes a detailed sensitivity analysis related to what time perspective that is assumed.

The most common method to **handle multiple output products** is by system expansion. Three studies (3, 4 and 9) use economic allocation in the base case with the motivation that this is suitable to apply also for products with diverse characteristics. Some studies (3 and 10) test the application of other allocation methods, energy or mass based, in a sensitivity analysis. The studies that apply economic allocation based on market prices are those describing systems that either are in operation (study number 4) or that produce products identical to existing alternatives on the market today (study number 3).

DISCUSSION

When doing this review of literature, it could be concluded that the number of LCAs of biorefinery systems has increased in recent years since this approach to biofuels production has gained importance. However, the literature review revealed a large variety in the methodology used in the assessments, and that the methodological choices where not always given much attention even though they have major impact on the end results.

Besides the basic methodological LCA key issues there are also a number of biorefinery or biomass specific key issues, which are more related to the methodology of the impact assessment e.g. land use, biodiversity, accounting method for biogenic carbon both in input biomass and end products. Some of these issues will be treated in the coming project, described in the introduction.

CONCLUSIONS

The complexities involved when performing LCA of biorefinery systems has lead to inconsistency in existing case studies, making comparability among studies difficult. The problem is further enlarged by the lack of proper documentation of assumptions regarding data and methodological choices in many case studies. We see a need for further research on these topics.

REFERENCES

Cherubini, F., Jungmeier, G. 2010. LCA of a biorefinery concept producing bioethanol, bioenergy, and chemicals from switchgrass. *The International Journal of Life Cycle Assessment*, **15**(1), 53-66.

Cherubini, F., Ulgiati, S. 2010. Crop residues as raw materials for biorefinery systems - A LCA case study. *Applied Energy*, **87**(1), 47-57.

Earles, J.M., Halog, A., Shaler, S. 2011. Improving the Environmental Profile of Wood Panels via Co-Production of Ethanol and Acetic Acid. *Environmental Science & Technology*, **45**(22), 9743-9749.

Ekman, A., Börjesson, P. 2011. Environmental assessment of propionic acid produced in an agricultural biomass-based biorefinery system. *Journal of Cleaner Production*, **19**(11), 1257-1265.

Gonzalez-Garcia, S., Hospido, A., Agnemo, R., Svensson, P., Selling, E., Moreira, M.T., Feijoo, G. 2011. Environmental Life Cycle Assessment of a Swedish Dissolving Pulp Mill Integrated Biorefinery. *Journal of Industrial Ecology*, **15**(4), 568-583.

Kimming, M., Sundberg, C., Nordberg, Baky, A., Bernesson, S., Norén, O., Hansson, P.A. 2011. Life cycle assessment of energy self-sufficiency systems based on agricultural residues for organic arable farms. *Bioresource Technology*, **102**(2), 1425-1432.

Lim, S., Lee, K.T. 2011. Parallel production of biodiesel and bioethanol in palm-oil-based biorefineries: life cycle assessment on the energy and greenhouse gases emissions. *Biofuels, Bioproducts and Biorefining*, **5**(2), 132-150.

Piemonte, V. 2012. Wood Residues as Raw Material for Biorefinery Systems: LCA Case Study on Bioethanol and Electricity Production. *Journal of Polymers and the Environment*, **20**(2), 299-304.

Pourbafrani, M., McKechnie, J., MacLean, H.L., Saville, B.A. 2013. Life cycle greenhouse gas impacts of ethanol, biomethane and limonene production from citrus waste. *Environmental Research Letters*, **8**(1), 015007.

Souza, S.P., de Ávila, M.r.T., Pacca, S.r. 2012. Life cycle assessment of sugarcane ethanol and palm oil biodiesel joint production. *Biomass and Bioenergy*, **44**, 70-79.

Tonini, D., Astrup, T. 2012. Life-cycle assessment of a waste refinery process for enzymatic treatment of municipal solid waste. *Waste management*, **32**(1), 165-176.

Uihlein, A., Schebek, L. 2009. Environmental impacts of a lignocellulose feedstock biorefinery system: an assessment. *Biomass and Bioenergy*, **33**(5), 793-802.

REDUCING IMPACTS OF FORESTRY – THE FALLACY OF LOW-INTENSITY MANAGEMENT

Bo P. Weidema, Aalborg University, Skibbrogade 5, 1., 9000 Aalborg, Denmark, bo@ilca.es

Keywords: biodiversity; extensive forestry; forest management; plantation forestry; forest certification.

ABSTRACT

New definitions are provided of intensive and extensive forestry in version 3 of the ecoinvent database. These definitions are based on explicit and easily measured indicators for the most important aspects of forestry management for biodiversity. Unfortunately, many certified forestry products come from what would be classified as intensive forestry in the ecoinvent classification. The real challenge is to develop forest management systems that have a neutral or positive biodiversity impact relative to that of plantation forestry. Such truly extensive, biodiversity-managed forestry is very challenging and not very common today. Ample options exist for increasing yields in intensive and plantation forests, which can be recommended as having lower biodiversity impact than similar products from other management systems, certified or not.

INDICATORS FOR FOREST MANAGEMENT IMPACT ON BIODIVERSITY

One of the most important environmental impacts of forestry is on biodiversity. Many different indicators for forest management impact on biodiversity have been suggested or are already in use, but some are more important than others and some are more easily available.

In the ecoinvent database, a distinction between intensive and extensive forestry has been applied. With the new version 3 of the database, the definition of these two management regimes have been made more explicit, taking into account six of the most important aspects for forest biodiversity, see Table 1. Thereby, a trustworthy assessment of biodiversity impacts of forest practices is facilitated.

Table 1. The ecoinvent v3 definition of extensive & intensive forestry (Weidema et al. 2013).

	Extensive (if all below apply)	**Intensive (if one of the below apply)**
Harvesting technique and patch size	Selective logging	Clear-cut patches or even-aged stands exceeding 250 m length
Stand age	Average stand age >30 years	Average stand age <30 years
Number and nature of tree species	At least three naturally occurring tree species at re-growth	Less than three naturally occurring species at planting/seeding
Amount of deadwood with > 10 cm diameter	Exceeds 5 times the annual harvest volume	Less than 5 times the annual harvest volume

BIODIVERSITY IN FOREST CERTIFICATION SCHEMES

Most forest certification programs unfortunately use criteria and indicators that are less clearly defined, less aligned with the scientific evidence with respect to the importance for biodiversity, and less easily measured (Weidema 2007). The resulting situation is that many certified forest products come from what would be classified as intensive forestry in the ecoinvent classification.

A major problem in the current forest assessments is that they are not related to the productivity of the forest. In semi-managed forests, including most so-called low-intensity, "sustainable" certified forests, the impact on biodiversity is relatively larger per produced unit than in plantation forestry, see Figure 1. Figure 1 shows how natural, undisturbed forests and the marginal plantation forests mark the two extreme ends of a straight iso-biodiversity line, i.e. a line along which forestry types have identical biodiversity impacts as measured by an imaginary, ideal, aggregated indicator of "biodiversity-adjusted hectare-years".

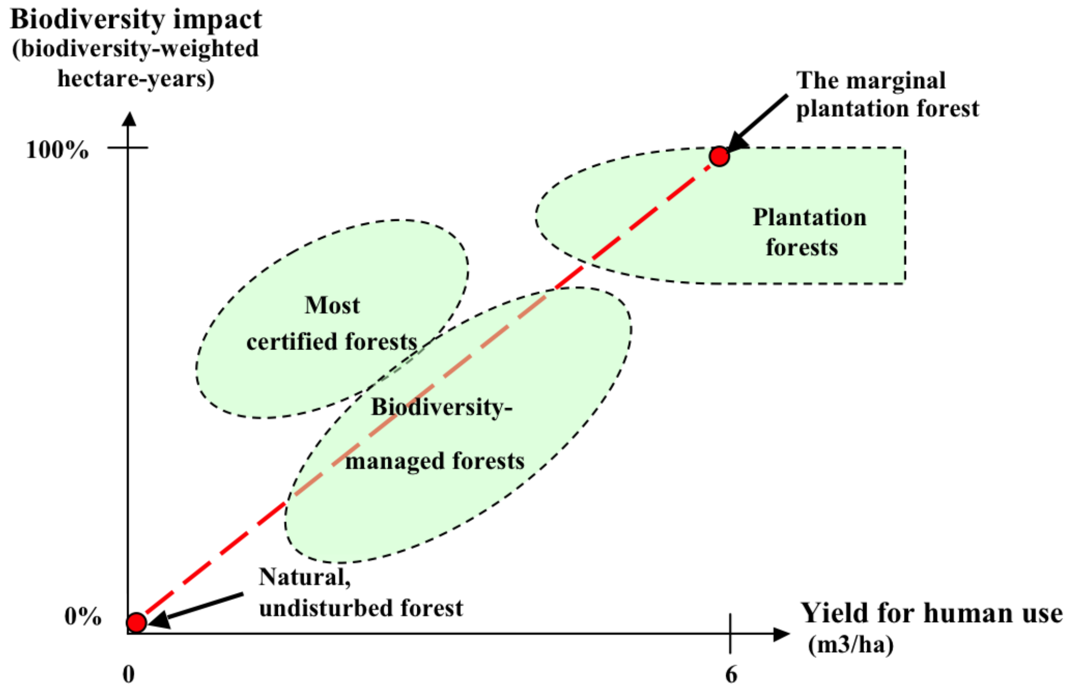


Figure 1: The place of different forest management systems (green dashed ellipse) relative to the iso-biodiversity line (red dashed line), its determining extremes (red dot).

Both ends of the iso-biodiversity line are relatively well-defined: In a natural, undisturbed forest, both the yield of products and the biodiversity impact from management are zero. A plantation forest has a well-defined yield, and the biodiversity impact is close to the maximum 100%, i.e. 1 biodiversity-adjusted hectare-year per hectare-year, corresponding to zero original, endemic species left.

It is less easy to determine the biodiversity impact of those forest management types that lie in-between these two extremes. However, even a low amount of forestry activity implies the removal of sources of deadwood, which is the main habitat influencing overall forest biodiversity. Thus, it should be safe to assume that to remain *at or below* the iso-biodiversity line would require forest management efforts specifically directed to preserve biodiversity. Without judging whether such forests actually exist, we may call such forests for “biodiversity-managed forests”. Any credible forest certification aimed at biodiversity conservation should aim at ensuring that the certified forests are at or below the iso-biodiversity line, since a position above the iso-biodiversity line per definition implies that its products have a higher impact than those of plantation forestry. Likewise, it should be safe to assume that whether certified for “sustainability” or not, most managed forests other than plantations lie well above the iso-biodiversity line.

It is interesting to note that the iso-biodiversity line is a “moving target”, since the marginal plantation forest, i.e. the plantation that will change its area with changes in demand for plantation wood, is likely to have an increasing yield over time because more intensive plantations are more economically competitive. Thus, the iso-biodiversity line will be lowered over time, and a “biodiversity-managed forest” will become even more difficult to realise.

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

This reasoning implies that:

- Plantation products in general can be recommended as having lower biodiversity impact than similar products from other management systems, certified or not,
- The real challenge is to develop forest management systems that are at or above the iso-biodiversity, i.e. that have a neutral or positive biodiversity impact relative to that of plantation forestry. Such truly extensive, biodiversity-managed forestry is very challenging and not very common today. The ecoinvent classification of extensive forests could be used as simple criteria.

Nevertheless, ample options exist to expand biomass production, without increasing impact on biodiversity, or even while reducing impact, particularly if the production in intensive and plantation forests is increased. Intensifying management and choice of species can increase average yields of biomass per hectare by at least a factor 2 from the current average of 3 m^3 (Brown 2000), thus allowing more forest areas for truly extensive management or even to be left in a natural or naturalised state.

REFERENCES

Brown C. (2000). The global outlook for future wood supply from forest plantations. *Global Forest Products Outlook Study. Rome: FAO. Working Paper GFPOS/WP/03.*

Weidema B P. (2007). Framework for and review of biodiversity indicators for forest management in the context of product life cycle assessment. *Draft report prepared for TetraPak. Hørsholm: 2.-0 LCA consultants.*

Weidema B P, Bauer C, Hischier R, Mutel C, Nemecek T, Reinhard J, Vadenbo C O, Wernet G. (2013). Overview and methodology. Data quality guideline for the ecoinvent database version 3. *St. Gallen: The ecoinvent Centre. Ecoinvent Report 1(v3).*

REPRODUCTION OF LAND FERTILITY

Vera Pechenkina. Krasnoyarsk StateAgrarian University. Russia 660036 Krasnoyarsk, Academica Kirenskogo 2 "I" ap.419 e-mail: pechenkinav@rambler.ru

Keywords: fertility; consumption; reproduction; balance; profit.

ABSTRACT

The goal of study is the understanding of impact agricultural production cycles on land fertility and ways of management it. Soil fertility depends on kinds of the fertility reproduction: restricted, simple, extended. Farmer can lose profit from land usage if he has the restricted reproduction fertility. For protection of soil fertility we offer using the self-supporting system of incentives of sustainable land use.

INTRODUCTION

Global croplands and pastures cover 46 million km^2. More than 40 % Earth's land has been created for agriculture. Land has productive function that it produces food, feed, fuel, fiber, etc.The soil fertility is the kingdom of life. We know three kinds of the fertility reproduction: restricted, simple, extended. If we want to survive, we must take care of the soil. The soil today is yesterday's being transformed into tomorrow. Land fertility is result of agricultural production cycles. For plants, nitrogen is food. Understanding soil fertility – the availability of food for plants is a top priority. Based on that need, soil scientist Doug Collins develops practical soil fertility management strategies (Collins, 2012).

Soil organic matter (SOM) plays an essential role and its dynamics merit special interest (Sanchez et al., 1989). SOM contributes significantly to soil nutrient resilience (Baldock and Skjemstad, 2000), renders the physical environment of soil suitable for plant growth. SOM is one in the important indicators of soil quality (Larson and Pierce, 1994; Rosell, et al., 2001) and its management is envisaged to maintain soil fertility and promote sustainable agriculture (Martin et al., 1990).Soils are a significant factor in land use and the important link between climate and biogeochemical earth systems. That is why land use practices and land cover change are always is caseof soil change. Not only the carbon cycle but also the soil cycles have been changed by human land use practices over time.

The natural life cycle of agricultural fields must be maintained through additions to the humus bowl after residues from the previous crop have been depleted, in order to build new organic, biological and mineral nutrition for the next crop. This action cannot be replaced with overdoses of chemical fertilizers, which harm soil life (Caron, 2007).

In the soil management it is very important to take into the consideration the humus state of soil to assure an adequate annual input of locally grown residue into the soil and to supervise that the soil would contain enough of organic matter or humus adequate to the humus capacity characteristic to the according soil type (Kõlli, 1996).Humans must integrate the science of a soil genesis into the methods of food produce without ecological damages.

Practices that reduce losses of nutrients and thereby reduce the potential for negative environmental impact are considered Best Management Practices. It may include erosion and sediment control to reduce movement of soil and nutrients into streams from field edges, such as grassed waterways, buffer strips and riparian buffers. Incorporation of nutrients to reduce off-site movement, volatile losses and odors may also be considered best management practices. Using cover crops to scavenge nutrients remaining in the soil could also be an effective best management practice to reduce the loss of nutrients from a land application site. (Steven,1995).

RESULTS

In life cycle assessment, land use isoftenreferred to as land occupation and land use change as landtransformation.Land fertility is result of agricultural production cycles. In this case land is the subject of labor. Farmer uses the agricultural land improving the biological, physical, and chemical properties of soil to increase the crop capacity. Consequently, farmers improve the subject of labor which apply in the follow cycle production as a tool for affect the seeds and plants.If farmer doesn't care the reproduction fertility in agricultural production cycles he will lose benefits and profits in the future.

Cycle of agricultural usage land begins at the start of field season when production affects the soil as a subject of labor. After seeding the soil becomes the fixed assets because of addition function of soil as a tool of labor. Harvesting stops the function of soil as a tool of labor but the cultivation of land continues for autumn and winter. It reflects dual nature of land function.

Land usage is implementation of soil function as fixed assets and land usage cycle includes land tillage, production, and recovery stages. These stages have the fertility consumption and fertility reproduction. We know three kinds of the fertility reproduction: restricted, simple, extendedthat depends on the ratethe consumption and contribution ofsoil organic matterduring the land usage cycles (Pechenkina,2010).

DISCUSSION

Protection of productive land has become a major priority in many regions of the world. Land degradation by intensive agriculture is a major driver of land loss; a number of national and international programs have responded with land reforms. However, effectiveness of policy efforts often has the limited outcome.

In the course of land redistribution, serving the basis for the Agrarian Reform in Russia, major violations in the reproduction of land, material and technical resources have occurred. As a result, the soil fertility continues to decrease, the land environmental conditions are deteriorating, and the labor tools are not being renovated. In the 90's the process of land degradation has strengthened. The crop rotations were broken that leaded to the intensification of soil erosion as well as its dehumification. Thereduction in reclamation works has resulted in increasing proportions of acidic, waterlogged and saline soils. The issue is to find the balance between the increasing level of food production and the protection soil, its conservation and improvement.

The primary goal of every farmer must be to maintain stable humus in the soil. Organic farmers are interested in reducing the input of manufactured fertilizers and are supposed more on increasing humus in their soils, so that needs of their plants can be fertilized by the nitrogen cycle directly.Understanding the cycling of nitrogen through soils is determinant for number reasons. If farmers don't apply a little extra fertilizer at the proper time, their plants may not produce an economically viable yield. If they apply too much, they are simply wasting money, because fertilizer is expensive and if the plants don't need it, they'll just disregard it. And if the plants don't take up the nitrogen in the soil, there is a chance it can pollute the soil and water.

This is the way of the agricultural development without violating the environmental conditions. Both agricultural and ecological land structure optimization will provide nature with the initial impetus to begin self-healing. It also involves economic mechanisms of managing land system.

We offer using the regional system of economic encouragement for conserving and increasing the soil fertility. It includes land tax, irrational land use fee, land insurance fee, and mortgage. Our calculations (table 1) show the stimulating function of the suggested system for the soil fertility reproduction on the regional level. The system will positively affect the agrarian enterprises of different types of ownership, production volume, technical resources, and food production efficiency.

Table 1. Receipts and expenditure of the land uses, million roubles

Indicator	Kind of reproduction of the soil fertility			Distance
	Restricted	Simple	Extended	
	Receipts			
'Nazarovskoe' Joint Stock Company	1,672	1,865	2,066	394
Educational farm 'Minderlinskoe'	114	126	139	25
Private farm K – 16	3	4	4	0.911
	Expenditure			
'Nazarovskoe' Joint Stock Company	364	213	166	-196
Educational farm 'Minderlinskoe'	34	19	15	-18
Private farm K – 16	0.148	0.089	0.078	- 0.070
	Benefit			
'Nazarovskoe' Joint Stock Company	1,308	1,652	1,900	
Educational farm 'Minderlinskoe'	80	107	124	
Private farm K – 16	3	4	4	

CONCLUSIONS

The management of land usage cycles has to achieve a delicate balance of production and protection for the overall goal of sustainable development which based on ecological, social and economic pillars.

REFERENCES

Baldock, J.A. & Skjemstad, J.O. 2000. Role of the soil matrix and minerals in protecting natural organic materials against biological attack. Organic Geochemistry 31, 697–710.

Caron C. 2007Redefining Soil Fertility.Spring2007. Available at: http://www.mofga.org/Publications/MaineOrganicFarmerGardener/Spring2007/RedefiningSoilFertility

Collins, D. (2012) Soil Testing: A Guide for Farms with Diverse Vegetable Crops Washington State University Extension.EM050E.11 p. Available at: http://cru.cahe.wsu.edu/CEPublications/EM050E/EM050E.pdf

Kõlli, R. 1996. Transactions of the Estonian Agricultural University 187 The pedoecological aspects of sustainable crop product production, pp. 51–54 (in Estonian).

Larson, W.E.; Pierce, F.J. 1994.Conservation and enhancement of soil quality. IBSRAUM Proc.12, 175–203.

Martin, A., Mariotti, A., Balesdent, J., Lavelle, P. &Voattoux, R. 1990. Estimate of organic matter turnover rate in a savannah soil by 13C natural abundance measurements. Soil Biology and Biochemistry 22, 517–523.

Pechenkina V. 2010. Land Usage: Reproduction and Enhancement Efficiency. LAPLambert, pp. 32-95 (in Russian).

Pechenkina V.V.; Kalashnikova N. I. 2011. Environmental management system. International Symposium Euro-Eco Hannover 2011, pp. 60-61. Available at:http://www.eu-eco.eu/abstracts-2011.html

Rosell, R.A., Gasparoni, S.C. & Galatini, S.A. 2001. Soil organic matter evaluation. In Lal, R., Kimble, J.M., Follette, R.F., Stewart, B.A.(eds): Management of Carbon Sequestration in Soils. Advances in Soil Science.CRC Press, Boca Raton, FL.311–322.

Sanches, C.E. & Wood, M.K.1989. Infiltration rates and erosion associated with reclaimed coal mine spoils in west central New Mexico. Landscape and Urban Planning 17, 151–168.

Steven C. Hodges 1995. Soil Fertility Basics, Soil. Science Extension North Carolina State University certified Crop Advisor Training,p.75.Available at:http://www.soil.ncsu.edu/programs/nmp/Nutrient%20Management%20for%20CCA.pdf

SPATIALIZED LIFE CYCLE WATER FOOTPRINTING OF U.S. MILK

Lindsay Lessard[1], Ying Wang[2], Andrew Henderson[3],*

Anne Asselin-Balençon[4], Sebastien Humbert[1] and Olivier Jolliet[4]

1Quqntis International

2Dairy Research Institute

3 University of Texas

4 University of Michigan

**Ying.Wang@rosedmi.com, 10255 W. Higgins Road, Suite 900, Rosemont, IL 60018, USA*

Keywords: water footprint, water use, spatialization, dairy, milk

ABSTRACT

Dairy production in the US at the national scale is a distributed production system that entails great geographic diversity with respect to inputs and outputs. Milk therefore represents an interesting case study to develop and test spatialized life cycle approaches for both inventory and impact assessment.

The study is to be used by the U.S. dairy industry to create a baseline of water footprint, helping that industry and its constituent milk producers to identify areas to target for improvement, explore the changes in impact associated with new management scenarios, and document those improvements.

The result showed that water stress is 146 liters in competition per kg milk consumed and 121 liter in competition per kg milk at farm gate (water consumption is 225 liters per kg milk consumed and 181 liters of water consumed per kg milk at farm gate).

INTRODUCTION

Building upon work in progress within the UNEP-SETAC Life Cycle Initiative on water footprinting, a framework has been developed by Quantis which integrates a comprehensive state-of-the-science compilation of methods, addressing major issues related to water use in LCA, of which a large part is described in this report.

The study is to be used by the U.S. dairy industry to create a baseline of water footprint, helping that industry and its constituent milk producers to identify areas for improvement, explore the changes in impact associated with new management scenarios, and document those improvements. The study is the outgrowth of a January 2009 commitment by the

Innovation Center for U.S. Dairy (representing about 80% of the dairy industry) to reduce greenhouse gas (GHG) emissions of fluid milk by 25% by 2020.

The following report first outlines the methods and indicators used to evaluate the water stress impact of milk production in the U.S. A detailed description of modeled inventory data is provided. Results at the regional and national level are then presented based on 12 main feed crops.

METHODS

Functional unit and allocation

The overall functional unit for environmental impacts across the milk life cycle is one kilogram of fat and protein corrected milk (kg FPCM) consumed in the United States (U.S.). This is consistent with the previous carbon footprint conducted by the University of Arkansas (Thoma et al. 2013).

An intermediate, but equally relevant, functional unit is one kg of FPCM produced, i.e., up to the point at which milk leaves the farm gate. Therefore, we present results per kilogram of at the farm gate as well as per kilogram consumed. The term ‘kg milk’ is used to indicate ‘kg FPCM at farm gate’, when in the context of the field and dairy farm, and ‘kg FPCM consumed’ when in the context of the overall life cycle. Major differences between milk at the farm gate and milk consumed include the allocation to cream (19.8%) and losses at retail and consumer stages (12% and 20%, respectively) as defined in (Thoma et al. 2013). These losses require that more than 1 kg milk be produced in order for 1 kg to be consumed. Therefore, values at farm gate cannot be directly extracted from the overall life cycle, and hence the value of presenting the analysis from both perspectives.

General assessment framework for impact assessment

The framework used in this study, which includes the most up to date water impact assessment methods, is presented shown in Figure 1. Note that this framework focuses on blue water, which is consistent with current developments in the ISO framework, as green water is not extracted by users. Water quality, with respect to freshwater and marine eutrophication, is accounted for in terms of pollution impacts, rather than the conceptual grey water (a volume required to dilute a pollutant)..

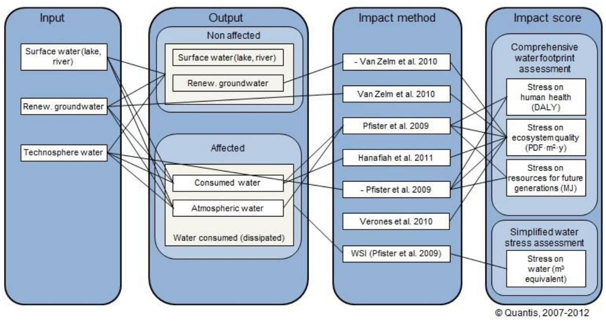


Figure 1 General framework for water stress impact assessment for feed production and on farm water use (grey water not included in the water use part of the study)

A matrix approach was developed to provide the spatialized water stress impact of U.S. milk production (Anne Asselin-Balençon, 2012). The water stress impact allows water use to be related to competition, which allows the analysis to distinguish between water use in water-rich or water-stressed areas. The unit for the water stress analysis is liters of water in competition.

RESULTS AND DESCUSION

Dairy and agriculture are water intensive activities and water use and impacts can vary widely depending on region, crop irrigation and type of crop. Irrigation can account for up to 90% of water withdrawn from available sources. Furthermore, of these irrigation withdrawals, approximately 15% to 35% of worldwide are estimated to be unsustainable. As competition for water resources from other sectors continues to increase, there is a demand for agriculture and dairy industries to improve efficiency of water use. On a dairy farm, water use is mainly associated with irrigation, accounting for up to 90% of on farm water use. Water consumption is 225 liters per kg milk consumed and 181 liters of water consumed per kg milk at farm gate). This water consumed is then combined with the water stress index to deliver the volume of water in competition (Figure 2). Water stress impacts due to milk production at the farm gate are spatially differentiated by region.

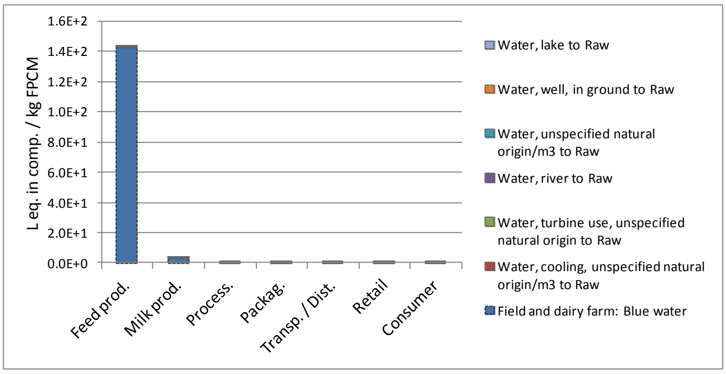


Figure 2 Water stress impact contribution from all stages of the life cycle to national average, combining spatial and nonspatial components

Because a large fraction of milk production takes place in western regions, where many crops also are irrigated, production of milk in those regions will induce water consumption for crops produced locally or regionally, leading to a national average of 121 liters of water consumed for crop production per kg milk produced at farm gate and 146 liters in competition per kg milk consumed.

Figure 3 shows water stress, freshwater and marine eutrophication impacts per kg FPCM, of milk produced in each watershed. Water stress is most significant in the western portion of the country, while overall freshwater eutrophication tends to be higher in the Midwest and East. However, when restricting impacts to areas with phosphorus concentration higher than 100 µg/L– the highest impacts are induced in the California, Missouri, and Upper Mississippi water basins. Variation in marine eutrophication due to nitrogen compounds is reduced relative to the other impacts.

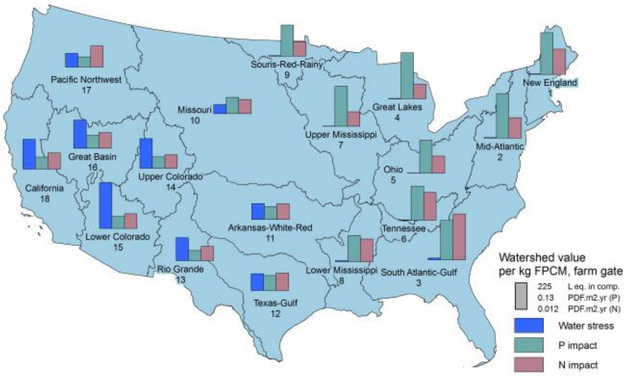


Figure 3 Comparison of watershed-level impacts for water stress, freshwater eutrophication, and marine eutrophication from field and dairy farm

CONCLUSIONS

The water footprint is becoming a more relevant group of impact categories that deserve to be studied in further details since these impacts show very important variation across the country. Water is a local issue impacted by both water supply and watershed characteristics. Water quality and quantity issues are closely linked as the quantity of a stream flow will heavily influence the inherent water quality. For the spatialized assessment of on farm water stress impact, the following key lessons can be drawn:

- Feed production dominates the water stress impact for feed and milk production, therefore source of feed matters to the water footprint of milk production.
- Water stress impact (based on the water stress of the region) varies widely by location.
- Water stress impact of milk production is dominated by a few regions with a combination of high water stress (high irrigation water use) and high crop production.
- Alfalfa hay and silage, grass hay and silage are mainly locally produced and consumed; they are dominant water users in water stressed regions.

The results of the current water stress assessment of milk production in the U.S. reveal certain possible approaches to reduce the milk water footprint:

- Improve supply chain of feed sourcing and supply
- Improve feed ration management and feed conversion efficiency
- Improve efficiency of irrigation techniques
- Improve reuse and recycling of on farm water use

REFERENCES

Asselin-Balençon, A., Henderson, H., and Lessard L. et al;, Spatialized water stress impact of US milk production: A matrix approach, Food LCA 2012, St Malo, France

Thoma, G., Popp, J., and Shonnard, D. et al, . Greenhouse Gas Emissions from Production of Fluid Milk in the US, International Dairy Journal, 2013, 31, p40

WHO NEEDS TO KNOW WHAT ABOUT ENERGY USE? THE PALM OIL BIOFUEL CASE

Magdalena Svanström[*,1], Rickard Arvidsson[2], Kristin Fransson[2], Morgan Fröling[3], Sverker Molander[2]*

[,1]Chemical Environmental Science, Chalmers University of Technology, SE-412 96 Gothenburg, magdalena.svanstrom@chalmers.se*

[2]Environmental Systems Analysis, Chalmers University of Technology

[3]Ecotechnology, Mid-Sweden University

Keywords: energy use indicator, life cycle assessment, palm oil methyl ester, biofuel, energy analysis

ABSTRACT

In life cycle assessments and energy analyses of palm oil biofuel, the choice of energy use indicators has been found to be arbitrary, poorly motivated and poorly described. This paper discusses the system boundaries represented by different energy use indicators and their appropriateness in terms of different environmental concerns. The paper also discusses the need of different energy use information for different actors in the product life cycle and the resulting need to tailor-make assessments and presentations of assessment results to different audiences.

INTRODUCTION

Access to energy is an important precondition for many societal activities and is closely coupled to human development. However, the energy sector can be attributed a large share of the pressures on natural systems. Resource limitations and climate impacts have increased the interest for non-fossil fuels. For bio-based fuels, however, environmental impacts from production can be both larger and of different kind than for fossil fuels. For bio-fuels, energy use has been highlighted as one of the most important environmental impacts to assess (Buchholtz *et al*. 2009). When describing the energy use of a product system, appropriate indicators are needed, which may vary depending on which types of energy that are involved and which types of concerns around energy use that should be emphasized. Furthermore, different actors in the product life cycle may need to be provided energy use information of different kind, depending on which types of decisions that they are involved in.

In this study, energy use indicators that have been reported in studies on palm oil biofuel form the basis for a discussion on the appropriateness of different energy use indicators in different situations and for different audiences.

METHOD

This study is based on an earlier literature review of existing life cycle assessments (LCAs) and energy analyses of palm oil biofuel (palm oil methyl ester; PME) that has been reported elsewhere (Arvidsson *et al*. 2012). The paper reported the different energy use indicators found and the difference in system boundaries that they imply, and it illustrated, quantitatively, the impact of the choice of energy use indicator on the results using literature data. In the study reported here, the material has been further analyzed in terms of the meaning of different energy use indicators, their appropriateness in describing different concerns and their relation to the differing information needs for different actors in the palm oil biofuel product life cycle.

RESULTS

A review of energy use indicators used in different assessments of palm oil biofuel revealed that in LCAs and energy analyses, the choice of energy use indicators has been somewhat arbitrary, and which energy use indicators that are used is both poorly motivated and poorly described (Arvidsson *et al*. 2012). The review identified the energy use indicators listed in the first column of Table 1. Terminology is here slightly different from in Arvidsson *et al*. 2012; common names have been replaced by more descriptive ones in order to facilitate communication. Fossil energy includes mined energy resources: coal, oil, natural gas and uranium. Renewable energy includes biomass, solar, wind and water. Secondary energy only accounts for the energy amount used in the final stage, e.g. as electricity or diesel oil, while primary energy is given as the original energy source and including also losses in the energy sector. Product energy is the energy content of the product. Extracted biomass is all biomass removed from nature, e.g. biomass removed from the field during harvest.

The different indicators highlight different concerns; see the second column in Table 1. An indicator that, for example, only accounts for primary use of fossil fuels, sees the scarcity of fossil fuels (and potentially also the climate impacts that are closely connected to burning of fossil fuels and the resulting carbon dioxide emissions) as the most important challenge, while an indicator that accounts also for primary use of renewable resources does typically not differentiate between renewable and non-renewable energy sources but emphasizes instead the overall restrictions of energy made available to human society. When a technology is assessed for its inherent properties, the use of secondary energy use indicators may seem more relevant than primary energy use indicators, since primary energy use indicators may reveal more about the surrounding infrastructure (background) system than about the actual technology assessed. By adding or subtracting different energy contents, more detailed indicators can be designed. When subtracting the energy content of the product, one may assess whether a product system makes more energy available for further use than is required along the product chain. When adding the energy content of the extracted biomass to the energy use, the scarcity of biomass energy and land for such growth are emphasized.

Several authors have recently emphasized the need to focus on the actors in the product life cycle and select appropriate indicators and system boundaries to make the presented data meaningful to them in relation to their concerns and fields of influence (see e.g. Efroymson *et al*. 2013). The identified energy use indicators were therefore reflected on in comparison to different potential actors. Table 1 also contains a third column in which different actors in the palm oil biofuel life cycle that may need this type of information for their decisions are suggested.

Table 1. Different energy use indicators identified in a review of LCAs of palm oil biofuel, the concern that is addressed by each indicator, and the actor that may need this information in decision-making.

Energy use indicator	**Main concern addressed**	**Actors that may need this information**
Fossil primary energy	Scarcity of fossil fuels; considers both local energy use and surrounding energy system	Countries relying heavily on fossil fuels; industries whose products have a high fossil energy use; actors experiencing fossil fuel scarcity; policy makers striving to decrease fossil fuel use; companies and organizations that want to report carbon footprint and similar type parameters e.g. as part of GRI reporting.
Fossil and renewable secondary energy	Total energy availability in society; considers only local energy use	Actors mainly interested in e.g. the production phase, e.g. in technology development; companies that want to market their products globally and want to provide data that does not depend on national conditions in terms of e.g. the energy system
Fossil and renewable primary energy	Total energy availability in society	Industries whose products have a high energy use; companies and organizations that include total energy use in their reporting
Fossil and renewable primary energy minus product energy	Total energy availability in society; energy still present in product not seen as energy use	Producers of biofuels and similar energy-providing products; consumers with holistic understanding and concerns that are purchasing a new car; policy-makers that decide on research funding and policy measures
Fossil and renewable primary energy with extracted biomass energy	Total energy generation capacity	Actors foreseeing high biomass scarcity; policymakers and researchers striving for long term sustainable energy solutions, policy-makers deciding on policies for land-use

Fossil energy use is thus of particular importance to countries relying heavily on fossil fuels, as this prevents them from escaping their reliance on fossil fuels. Similarly, companies that produce products with a high fossil energy use has obvious interests in this indicator. Note that for such products, the fossil energy use and the fossil and renewable energy use become almost the same. There are also actors that already experience fossil fuel scarcity, for example in rural developing countries, and for those, fossil energy use is also a relevant indicator. Secondary energy use does not include the full life cycle of energy products, and is of particular importance for actors with an influence on a studied product or technology but no influence on the surrounding system, e.g. the energy system in the region. This indicator is of particular interest in technology development, as the secondary energy is strongly related to the technology itself. Other parts of the system may very well have changed before the product even reaches the market. For actors like policy makers, responsible for regions and systems, that do not only require fossil energy but also a considerable share of renewable energy, the fossil and renewable energy indicator is of obvious importance. The energy use indicator where the energy content of the fuel is subtracted from the fossil and renewable energy use is designed for fuels or similar energy-providing products. It is thus relevant primarily to actors that produce or use such products, such as producers of biofuels and the automotive industry. Adding all extracted biomass as energy use further emphasizes biomass scarcity, and is therefore of particular interest for actors that experience or perceive high biomass scarcity as a concern in their long-term planning. Clearly, there is a need to tailor-make assessments and presentations of assessment results to different audiences.

DISCUSSION

The presented energy use indicators may seem simple enough to use. However, there are differences in how they have or might be applied. The extracted biomass, for example, may include anything from only the palm fruits to everything that is removed from the field, potentially even including branches that fall to the ground and are moved. The devil can thus be said to be in the details, which requires careful description and explanation by the assessor. All assessors must therefore not only carefully select energy use indicators but also very clearly describe and motivate which energy use indicator that is being used and how it has been derived.

We experience that the perspective of the actor to which energy use indicators are to provide information has, so far, not been much considered in LCA studies, although this has, as earlier mentioned, been discussed in more recent studies. We believe that to employ such a perspective – i.e. to tailor-make assessments and presentations of assessment results to specific actors – could further increase the use and usefulness of LCAs in society.

There may also be a need of additional energy use indicators to account for some current and upcoming concerns that are not addressed by the five indicators presented here. Today, there are, for example, no energy use indicators that account for the differences between different renewable resources, namely the fund-type (e.g. biomass) and the flow-type resources (e.g. solar energy).

CONCLUSIONS

As different energy use indicators address different concerns, it is important to carefully choose an energy use indicator that is appropriate for the specific situation and the actor that it is to be presented to. There is also a need to develop new energy use indicators that address current and upcoming concerns that are not addressed by the indicators used today.

REFERENCES

Arvidsson R, Fransson K, Fröling M, Svanström M, Molander S. 2012. Energy use indicators in energy and life cycle assessments of biofuels: review and recommendations. *Journal of Cleaner Production 31 (2012) 54-61*. DOI: 10.1016/j.jclepro.2012.03.001

Buchholz T, V A Luzadis, Volk T A. 2009. Sustainability criteria for bioenergy systems: results from an expert survey. *Journal of Cleaner Production 17(Supplement 1):S86-S98*

Efroymson R A, Dale V H, Kline K L, McBride A C, Bielicki J M, Smith R L, Parish E S, Schweizer P E, Shaw D M. 2013. Environmental Indicators of Biofuel Sustainability: What About Context? *Environmental Management (2013) 51:291–306*. DOI 10.1007/s00267-012-9907-5

BROADENING THE SCOPE OF LIFE CYCLE APPROACHES

Wednesday, Aug 28: 10:30 am - 12:00 pm

Session chairs: Andreas Ciroth, GreenDelta, Germany
Yasuhiro Fukushima, National Cheng Kung University, Taiwan

AN ENVIRONMENTAL ASSESSMENT FRAMEWORK WITH SYSTEMATIC REGIONAL AND TIME SCENARIOS

Thomas Gibon, Edgar Hertwich, Richard Wood*

Norwegian University of Science and Technology, Industrial Ecology Programme, Norway

**Realfagbygget, Høgskoleringen 5, NO-7491 Trondheim, thomas.gibon@ntnu.no*

Keywords: life-cycle assessment; hybrid LCA; scenario assessment

ABSTRACT

A multiregional and scenario-based framework for environmental assessment is presented. Applied to energy production systems, this model clearly shows wide variations in various impact categories. An illustration of these variations is provided by the modeling of a concentrated solar power plant. Results show most of the environmental impacts are embodied in infrastructure; hence impacts are also strongly related to the temporal development of the background electricity mix. We conclude that, whereas greenhouse gas emissions are significantly lowered in comparison with fossil-fuel counterparts, material requirements are higher for this kind of technology, and even increasing with time.

INTRODUCTION

Low-carbon energy production technologies are part of the proposed solutions to mitigate anthropogenic greenhouse gas emissions due to current energy systems (Intergovernmental Panel on Climate Change 2011; International Energy Agency 2012). These technologies are expected to rollout significantly on a global scale within the next decades, the most optimistic scenarios foreseeing a 57% share of renewable electricity in the global production mix of 2050 (“2DS scenario” in (International Energy Agency 2012)). While the effect of this deployment on the evolution of anthropogenic greenhouse gas emissions is well analyzed and documented, little is known about the environmental consequences of low-carbon electricity production. Combining life cycle assessment and input-output for that purpose is possible through hybridization, for which a few methods have been described (Suh et al. 2003). The objective of this paper is to illustrate the use of a multiregional and scenario-based framework for environmental assessment.

METHODS

The THEMIS model was used to assess both the potential environmental impacts and resource requirements of the concentrating solar power. The model was developed as part of a UNEP IRP report, “Environmental Sustainability Benchmarking of Low-carbon Energy Technologies”, currently under review. The model features a systematic assessment across nine regions and three years. Based upon Ecoinvent 2.2, with modifications brought from the NEEDS project (ESU and IFEU 2008) as well as the latest energy scenarios from the

International Energy Agency's Energy Technology Perspectives (International Energy Agency 2012) and other sources (Burnham et al. 2011), this model extends the scope of any life-cycle assessment study to a set of local conditions and parameters. A hybridized version of this framework has subsequently been developed (Gibon et al. forthcoming) to tackle truncation bias of system definition in life-cycle assessment (Majeau-Bettez et al. 2011). The EXIOPOL multi-regional input-output database is used in this context to complete physical inventories (Tukker et al. 2013). Inventory data for the concentrating solar power tower plant was gathered from (Viebahn et al. 2008). Material requirements were derived from the life cycle inventory of stressors (elementary flows) for the primary inputs of metals, and from the technology matrix (inter-industry flows) for the secondary inputs of metals and inputs of cement. Furthermore, a contribution analysis for these flows is provided in this study. A comparison with fossil-fuelled power plants is also shown.

RESULTS

Results are shown for the following impact categories: global warming potential, freshwater ecotoxicity, eutrophication, particulate matter formation, as well as cumulated energy demand, land use area, from ReCiPe 1.08 (Goedkoop et al. 2009), and material use. Material use is characterized for primary and secondary aluminium, copper and iron, as well as cement. The selected region is Africa and Middle-East, where CSP power generation is expected to be the highest of the nine regions in 2050.

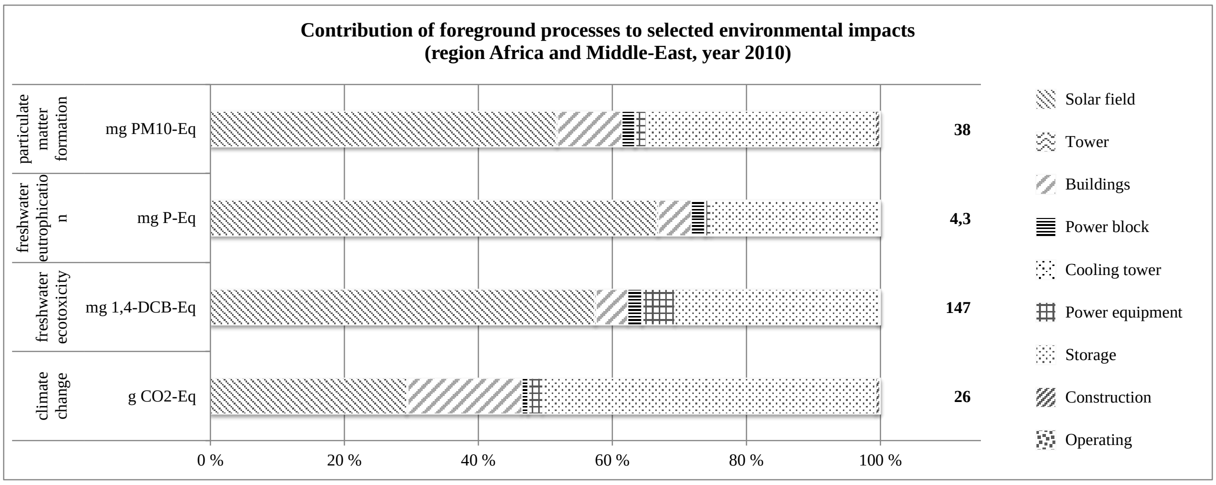


Figure 1. Contribution of foreground processes (plant parts) to selected environmental impacts, broken down and normalized to 100%. Totals are indicated in bold on the right hand side of the figure.

Figure 1 shows the environmental impacts per kWh of electricity generated by a concentrating solar tower power plant. The greenhouse gas emissions are dominated by solar field and storage. Buildings contribute too to the global warming potential, to a lower degree. The remaining selected impact categories follow a similar pattern, with solar field and storage as main contributors. Figure 2 shows a selection of material requirements for the same functional unit. While copper and iron & steel requirements breakdowns follow a similar pattern as for non-GHG environmental impact categories, cement requirements are dominated by the buildings part of the plant.

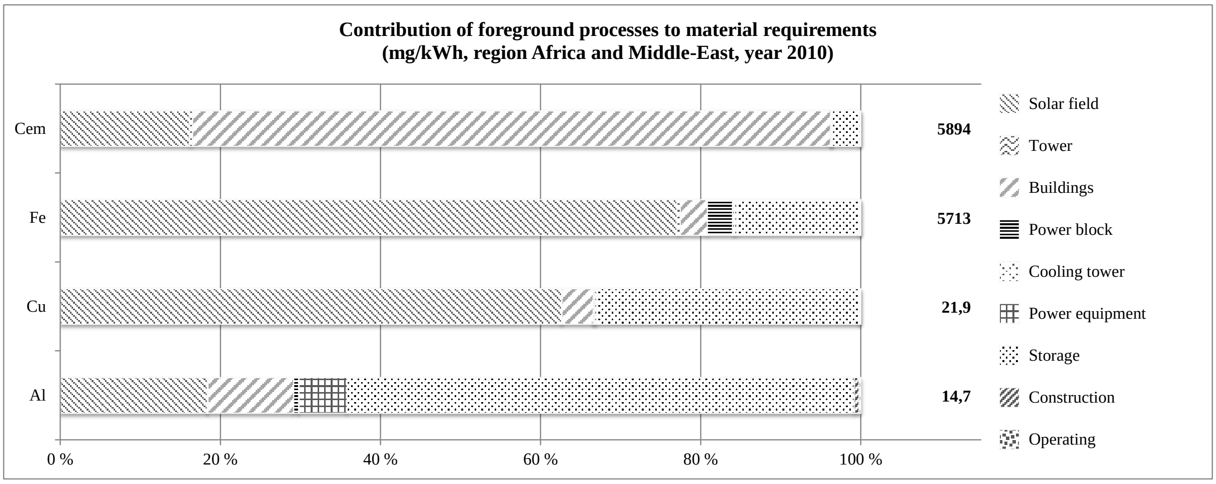


Figure 2. Contribution of foreground processes (plant parts) to selected environmental impacts, broken down and normalized to 100%. Totals are indicated in bold on the right hand side of the figure. Al = aluminium, Cu = copper, Fe = iron & steel, Cem = cement.

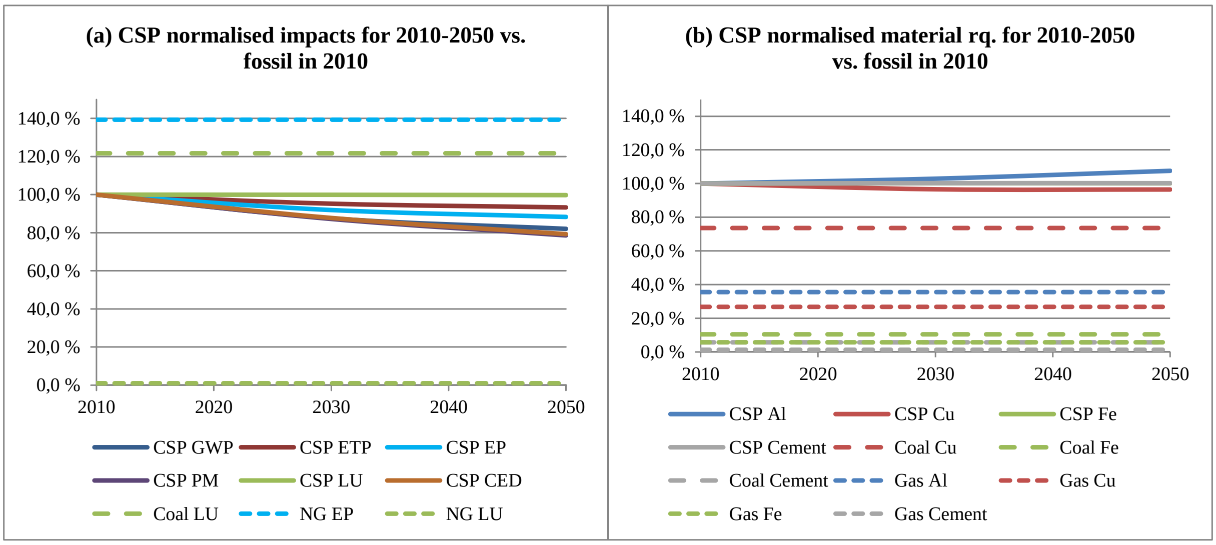


Figure 3. (a) Normalized impacts for the CSP plant ("CSP" on the graph), all set to 100% in 2010, compared with the impacts of a coal power plant (subcritical, "Coal") and a natural gas power plant (NGCC, "NG")[1]. (b) Normalized material requirements for the CSP plant and the fossil-fuelled power plants, all set to 100% in 2010. Abbreviations are the same as in Figure 2. The region is Africa and Middle-East, for the fossil-fuelled power plants, only the results in the 0%-150% range of CSP values are shown.

Figure 3 (a) shows that all selected CSP impacts are lower than for the fossil-fuelled power plants, aside from the land use of the natural gas-fired power plant. All impacts decrease with time. Figure 3 (b) shows an increase of material requirements with time for CSP. This is

[1] GWP = global warming potential, ETP = ecotoxicity potential, EP = eutrophication potential, PM = particulate matter, LU = land use, CED = cumulative energy demand

explained by the fact that the background electricity mix is increasingly composed of low-carbon technologies, themselves being more material intensive than their fossil counterparts.

DISCUSSION

The inventory data was gathered from different sources, and differences in scope are hardly evitable. When material requirements are calculated, it becomes clear that a few specific parts of an electricity plant become primary contributors. The example of concentrating solar plant illustrates the importance of overhead buildings and infrastructure in general in cement requirements.

CONCLUSIONS

Pursuing climate change mitigation goals may entail unforeseen tradeoffs such as high non-climate-related environmental impacts and high material requirements. These tradeoffs can however be quantified by using thorough inventories, and possibly hybrid assessment. Furthermore, regional (not shown here) and time variations can bring interesting insights.

ACKNOWLEDGMENTS

The authors would like to acknowledge Evert Bouman and Mathieu Saurat. This work is part of a project funded by the Research Council of Norway (n° 206998).

REFERENCES

Burnham, A., J. Han, C. E. Clark, M. Wang, J. B. Dunn, and I. Palou-Rivera. 2011. Life-Cycle Greenhouse Gas Emissions of Shale Gas, Natural Gas, Coal, and Petroleum. *Environmental Science & Technology* 46(2): 619-627.

ESU and IFEU. 2008. New Energy Externalities Developments for Sustainability (NEEDS) – LCA of background processes. In *Energy*.

Gibon, T., E. G. Hertwich, R. Wood, J. D. Bergesen, and S. Suh. forthcoming. A multi-regional hybrid input-output life-cycle assessment model for capturing the environmental impact of future technological developments.

Goedkoop, M. J., R. Heijungs, M. Huijbregts, A. D. Schryver, J. Struijs, and R. V. Zelm. 2009. *ReCiPe 2008, A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level*.

Intergovernmental Panel on Climate Change. 2011. *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*.

International Energy Agency. 2012. Energy Technology Perspectives 2012: Pathways to a Clean Energy System.

Majeau-Bettez, G., A. H. Strømman, and E. G. Hertwich. 2011. Evaluation of Process- and Input–Output-based Life Cycle Inventory Data with Regard to Truncation and Aggregation Issues. *Environmental Science & Technology* 45(23): 10170-10177.

Suh, S., M. Lenzen, G. J. Treloar, H. Hondo, A. Horvath, G. Huppes, O. Jolliet, U. Klann, W. Krewitt, Y. Moriguchi, J. Munksgaard, and G. Norris. 2003. System Boundary Selection in Life-Cycle Inventories Using Hybrid Approaches. *Environmental Science & Technology* 38(3): 657-664.

Tukker, A., A. d. Koning, R. Wood, T. Hawkins, S. Lutter, J. Acosta, J. M. Rueda-Cantuche, M. Bouwmeester, J. Oosterhaven, T. Drosdowski, and J. Kuenen. 2013. EXIOPOL - Development and illustrative analyses of a detailed global multiregional environmentally-extended supply and use table/input-output table. *Economic Systems Research* 25(1).

Viebahn, P., S. Kronshage, and F. Trieb. 2008. *New Energy Externalities Developments for Sustainability (NEEDS) – Final report on technical data, costs, and life cycle inventories of solar thermal power plants*.

BRING ON THE 'SOFT' SCIENCES: EXPLORING IMPLICATIONS OF GROUNDING LIFE CYCLE METHODS IN THREE SOCIO-MATERIAL PHILOSOPHIES

Mathias Lindkvist & Henrikke Baumann. Chalmers University of Technology, Sweden.*
** Environmental Systems Analysis, Chalmers, 412 96 Gothenburg, Sweden;*
mathias.lindkvist@chalmers.se

Keywords: LCM; philosophy of science; socio-material; LCA; case studies.

ABSTRACT

By not separating product flows from management, we target the little studied problem of how different management practices actually influence the environment. We test the *socio-material* philosophies actor-network theory, object-oriented ontology and agential realism on the life cycle assessment (LCA) cases bread and cement, through three examples. We conclude that socio-materiality point out that managers could benefit from an increased contextual understanding of the material and energy flows that their decisions influence. For LCA analysts, it highlights that including actual practices and action networks of people handling the flows could be useful for reaching effective use of LCA flow model results.

INTRODUCTION

Despite decades of attention, environmental issues like global warming seem still to be dangerously out of control, and one core area where knowledge is lacking is regarding how different management practices actually influence the environment. We therefore here describe systematic approaches for accounting for both interactions between the people along product life cycles and their interaction with machines and other entities that cause environmental impacts. Thus we hope to develop a presumably central premise of life cycle management (LCM).

Our starting point is that a consistent philosophy of science for LCM now can be found in fields of the social sciences and humanities where a *material turn* has taken place. The idea is that humans and material objects are inseparable and should be described as *socio-materialities*. Socio-materiality has been exploratively combined with the LCA approach in an organization studies context (Baumann, 2008). It is here, for LCM, further illustrated and advocated for by using empirical cases and additional socio-material philosophies.

MATERIALS AND METHODS

Three socio-material philosophies are here explored by applying them to socio-material life cycle studies on bread and cement (Lindkvist & Baumann, 2010). A large number of management practices of potential environmental significance were found — three of them are used here for a socio-material explication.

Bread and cement from an LCA perspective

The bread in our example comes from Swedish cradle-to-gate systems, from agriculture to retailing. Many flows come together in the bakeries, which therefore are important socio-material nodes. Further, LCAs on average bread impacts and different scales of production and bread types exist. Significant environmental impacts are found at most life cycle stages, and different bread systems result in different total environmental loads.

The cement in our example comes from Swedish cradle-to-gate systems, from raw material quarries to the cement plant. LCAs on cement point out large emissions from the production of the intermediary product clinker, where both fossil fuels used for heating and the chemical reactions needed for clinker creation contribute.

Socio-materiality for LCA

Socio-materiality has, in the social sciences where it is adapted from, been used for taking materiality into account in addition to their already well-developed knowledge on interactions between humans. It emphasizes that both humans and material objects influence each other. Thus, for life cycle studies, humans, technical processes and flows are considered simultaneously. The socio-material interactions of life cycle flows are often complex, as illustrated in Figure 1. Multiple actors may handle different parts of a single process or a single actor can be involved several processes. Of particular interest for LCM is that socio-materiality is systematically described in three philosophies: *actor-network theory* (ANT), *object-oriented ontology* (OOO) and *agential realism*. Taken together, they reinforce the need for more systematic socio-material analyses. Also, each of the philosophies highlights different aspects of socio-materiality, which is related to their respective disciplinary origins.

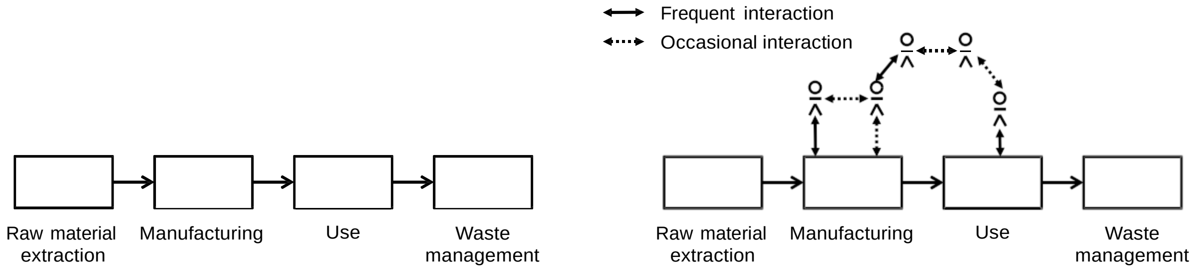


Figure 1. Product flow in LCA (left) and with socio-materiality partly added (right). The frequent and occasional interactions exemplify how interactions have different characteristics.

In **Actor-network theory (ANT)**, humans and material entities are seen as constantly interacting with and influencing each other. It emerged in the early 1980s as an approach for explaining the production of science and technology, and has since spread. A central concept is *translation*, which for example refers to how humans and electrons interact in a laboratory to let electrons leave physical traces that become graphs. Even the electrons are vital for the outcome; material entities are *actants*. (Latour, 2007) In the LCA context, translations take place when humans, for example, operate machines or interpret LCA data and reports.

Object-oriented ontology (OOO), like ANT, treats humans and non-humans as similar regarding how they interact with their surroundings, but it also emphasizes the limitations in how much different entities know and can influence each other. Philosopher Graham Harman has developed OOO since a decade, from phenomenology. Central conceptions are that humans as well as material entities are *objects*, and that they only perceive a limited share or none of other objects' *qualities*. (Harman, 2011) For LCA, these limitations may refer to interfaces that put constraints on how persons, machines and control centers can be managed.

Agential realism, like ANT, views events as ongoing processes where both humans and material objects matter, but also theorizes on how alternatives exclude each other and that humans have but cannot entirely control their ethical responsibility. It grew out of a critique by physicist and feminist philosopher Karen Barad of a solely social focus in the influential texts by social theorist Michel Foucault and feminist scholar Judith Butler. (Barad, 2007) The focus on exclusions may be relevant for LCM when identifying excluded environmentally significant aspects in discussions on outsourcing.

RESULTS

Bread – a socio-material LCA view

The first socio-material bread example centers on the link between production and sales via a bakery CEO, concerning the discarding of unsold products. For one of our studied bakeries this discard rate had increased along with the growth in number of shops owned by the bakery. OOO here helped in pointing out some links in this bread system where information transfer was insufficient. The CEO carried out sales monitoring on his own. With time he found it increasingly difficult to determine production levels relative to actual demand. The bakery had started to deliver to more shops, where proportion of discarded bread increased as well. Also, the sales varied significantly from one day to another, in complex patterns. Using Figure 1, socio-material links are added to the LCA between production and retail processes. These links go through several persons, and in several cases the contacts are only occasional.

The second example concerns a bakery's change of suppliers. A local supplier was replaced by a nationwide organization and this was found to increase the environmental impacts from transports. The reason for the increased transport distances was that the nationwide organization performed larger purchases to pressure purchasing prices. Using agential realism helped in further pointing out that one practice excludes another for several reasons. The bakery joined this nationwide organization since it was too small to handle the increasingly complex fluctuations of the foreign currency rates applicable to many of their ingredients. This was in turn related to a large share of the bakery's production being pastries requiring many more ingredients from exotic countries, such as orange peels and almonds, than ordinary bread. However, they did produce bread as well, and the bulk bread ingredient flour gives rise to significant environmental impacts if supply distances increase. Thus, a small-scale bakery ended up using more distant supplies since trade mechanisms were pressing while not taking into account their previously less environmentally impacting practice.

Cement – a socio-material LCA view

The cement example revolves around the socio-material relevance of maintenance, particularly for the clinker burning oven. Good maintenance can prevent the large additional emissions that each stop of this oven causes through its long heating up sequence. However, using ANT, this socio-material practice can be seen in a different light by taking into account a series of translations that were also netted together. A daily coordination meeting for maintenance activities at one studied plant was set in place to be able to distribute the staff to the most relevant tasks only after several severe breakdowns at the plant had already occurred. Using Figure 1, the production process in LCA is opened up to show how all activities that the maintenance staff control relate to each other in a dynamic pattern.

DISCUSSION

The examples illustrate activities that regulate the environmental impacts, and the difference between the left and the right side in Figure 1 becomes significant. Occasional human interactions are the only management links between sales and production in the first bakery case and dynamic interactions are added to the cement case. The socio-material approach has the advantage of mapping the actual organization around the product flow, instead of the risk that regular LCA is used combined with arbitrary assumptions about the organization.

Also, some practical conclusions for managers and LCA practitioners can be drawn from this study. For managers, complexity and sometimes ‘messy’ situations are probably no surprise, but a more systematic socio-material approach to LCM might be needed before making decisions that will have large impacts on the product flows. Otherwise, good LCM intentions may backlash. For the LCA analyst, taking the humans that control material and energy flows into account might be an effective means for actually, for example, reducing environmental impacts from hotspots pointed out by LCA flow model results.

Eventually, ANT is found to be most straightforward for the analysis among the philosophies. Therefore, it seems to be a good starting point for adopting a socio-material perspective. However, using OOO and agential realism is here found to add some clarifications on limitations in how people and material objects interact and on that many practices cannot easily be combined, respectively. Thus the three philosophies seem complementary.

CONCLUSIONS

We conclude that socio-materiality point out that managers could benefit from an increased contextual understanding of the material and energy flows that their decisions influence. For LCA analysts, it highlights that including actual practices and action networks of people handling the flows could be useful for reaching effective use of LCA flow model results.

REFERENCES

Barad, K. (2007). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning.* Durham, NC & London: Duke University Press.

Baumann, H. (2008). Simple material relations handled by complicated organisation by or ”How many (organisations) does it take to change a lightbulb?” *What is an organization? Materiality, Agency And Discourse*, Montréal, Canada, 21-22 May 2008.

Harman, G. (2011). *The quadruple object*. Winchester, UK, & Washington, USA: Zero Books.

Latour, B. (2007). *Reassembling the social: An introduction to actor-network-theory*. Oxford: Oxford University Press.

Lindkvist, M., & Baumann, H. (2010). The environmental significance of management practices: Exploring the eco-efficiency of 6 cases. *14th European Roundtable on Sustainable Production and Consumption Conference & 6th Environmental Management for Sustainable Universities Conference*, Delft, The Netherlands, 25-29 October 2010.

EXPANDING THE USE OF LIFE-CYCLE ASSESSMENT TO CAPTURE INDUCED IMPACTS IN THE BUILT ENVIRONMENT

John E. Anderson[1], Gebhard Wulfhorst[2], Werner Lang[1,3]*

[1]Institute of Energy Efficient and Sustainable Design and Building,
[2]Department of Urban Structure and Transport Planning,
[3]Centre for Energy Efficient and Sustainable Design and Building,
**John.Anderson@tum.de, Technische Universität München,*
Arcisstraße 21, 80333 Munich, Germany

Keywords: built environment; buildings; transportation; infrastructure; quantitative assessment.

ABSTRACT

The paper presents an expanded methodology for capturing and quantifying greenhouse gas emissions from the built environment. Current research concentrates on individual buildings or entire metropolitan regions. These frameworks are however limiting as they do not represent typical construction patterns – renovation and new construction of individual buildings within existing cities. In this paper we illustrate how life-cycle assessment can be used to evaluate the environmental impacts from induced impacts – the impacts resulting from the interaction of a building and its surrounding urban context. The results show the importance of induced impacts, particularly transportation and infrastructure, in capturing and quantifying all greenhouse gas emissions, and therefore for realizing climate mitigation.

INTRODUCTION

Life-cycle assessment is a proven method for the environmental evaluation of buildings (Ramesh, Prakash, & Shukla, 2010) (Sharma, Saxena, Sethi, Shree, & Varun, 2011) and infrastructure (Chester & Horvath, 2012). Research is increasingly focusing on the larger urban scale (Rickwood, Glazebrook, & Searle, 2008) (Glaeser & Kahn, 2010). However, individual buildings are not isolated objects, but rather integrated into the surrounding built environment. Alternatively focusing on an entire city ignores typical patterns of construction (i.e., renovations and new construction of buildings in existing cities). Thus analysis bridging the individual building scale and the urban scale is needed to assess actual construction patterns and to capture currently missing environmental outputs.

METHODOLOGY

In addition to embodied (i.e., material) and operational (i.e., electricity, heating) impacts for a building, we introduce a third category, induced impacts – the environmental impacts resulting from the interactions between an individual building and its urban surroundings. The paper presents results from the analysis of a six-story multi-family house in Munich, Germany constructed in 2011. Embodied (i.e., material production and end-of-life disposal), operational (i.e., heating, hot water, and electricity), and induced (i.e., personal mobility and road infrastructure) impact categories are analyzed for greenhouse gas emissions. The analysis uses process-based life-cycle assessment (LCA).

Analysis methodology and data sources

The process-based life-cycle assessment uses data from the Ecoinvent database (Swiss Centre for Life Cycle Inventories, 2010). Embodied impacts are calculated for the production and end-of-life disposal for twenty two structural and architectural materials for the case study building. Structural materials evaluated include concrete, concrete blocks, timber materials (oriented-strand board, sawn timber hardwood, and softwood). Architectural materials include flooring (natural stone, ceramic tile, cement plaster, and cement mortar), weather proofing, insulation, concrete roof tiles, gypsum plaster board, stucco, crushed gravel, window frames, and glazing.

The functional unit of analysis is carbon dioxide emissions per person per year. Based on the average living space per person in Munich, 36.5 m^2/person, the building would house 28 people (Bayerisches Landesamt für Statistik und Datenverarbeitung, 2011), (Statistisches Amt München, 2012). A life-span of 60 years is used for the analysis. Operational demands are determined for heating (5,470 kWh/yr-person), hot water (458 kWh/yr-person), and electricity (1,656 kWh/yr-person) (Nemeth & Lindauer, 2013) (Vereinigung der Bayerischen Wirtschaft, 2012) (Rheinisch-Westfälisches Institut für Wirtschaftsforschung, 2011) . Emissions for space heating are from gas (Kirchner & Matthes, 2009) (Schaechtele & Hertle, 2007). Hot water emissions are from generation by equal parts oil, gas, and electricity (Kirchner & Matthes, 2009), (Schaechtele & Hertle, 2007) (Umweltbundesamt, 2012).

Induced impacts expand upon the typical life-cycle assessment analysis to include results from transportation infrastructure and transportation use. Road infrastructure is based on typical road construction in Germany for a life-span of 30 years (Poxleitner, 2013) (Milachowski, Stengel, & Gehlen, 2011). Road construction is based on 4 cm asphalt surface layer, 8 cm asphalt binder layer, 22 cm asphalt base layer and a 51 cm frost blanket (Milachowski et al., 2011). Environmental outputs from the materials based on the Ecoinvent dataset; construction, maintenance, and end-of-life processes are not currently included. The allocation of road infrastructure to the case study building is based on the width of the building as per the payment scheme for public road funding as outlined by the Germany Building Code (Bundesministerium der Justiz, 2013).

Transportation use impacts include the embodied impacts for automobile and train vehicles and for operational use of both modes. Embodied emissions for automobiles (Helms et al., 2011) are calculated for the average automobile ownership rate for Munich (Landeshauptstadt Muenchen - Referat fuer Stadtplanung und Bauordnung, 2010). Embodied emissions are also included for the construction and maintenance of public transport railway vehicles (Stripple & Uppenberg, 2010) factored by the average travel distance in Munich (Landeshauptstadt Muenchen - Referat fuer Stadtplanung und Bauordnung, 2010). Emissions for automobile use (INFRAS, 2010) is combined with average travel patterns for Munich (Landeshauptstadt Muenchen - Referat fuer Stadtplanung und Bauordnung, 2010). The same travel survey is used for public transportation usage combined with the associated emission factors (IfEU - Institut fuer Energie- und Umweltforschung, 2011). Further detailed information regarding data sources can be found in (Anderson, Wulfhorst, & Lang, 2013).

RESULTS

The results of the expanded assessment for quantifying CO_2 impacts of the built environment are presented in Table 1.

Table 1. Emission results for the case study illustrate the importance of the operational and transportation phases (units are kg CO_2/yr-person).

Embodied		Operational			Infrastructure	Transportation			
Materials	Disposal	Heating	Hot water	Electricity	Road material	Car (embodied)	Car (use)	Train (embodied)	Train (use)
198	49	1105	526	937	8	227	1250	8	269
4.33%	1.07%	24.14%	11.49%	20.48%	0.17%	4.96%	27.31%	0.17%	5.88%

DISCUSSION AND CONCLUSION

The importance of transportation emissions (38%) is second only to operational emissions (56%). The second induced phase, road infrastructure, is very low (less than 1%) due to the density of the building location and the choice of the functional unit (i.e., per person). An alternative urban structure of single family homes would increase these emissions by 10 fold; however this would still result in fewer than 2% of total emissions. The embodied impacts from the building are also relatively low (5%).

The paper illustrates the importance of induced transportation impacts in capturing the full spectrum of greenhouse gas emissions for the built environment. Future research will explore the variance in transportation emissions due to the location of the building within the urban structure (i.e., city-center versus suburban locations).

REFERENCES

Anderson, J. E., Wulfhorst, G., & Lang, W. (2013). Life-cycle assessment of induced impacts in the built environment. sb13 munich - Implementing Sustainability - Barriers and Chances (pp. 37–38). Fraunhofer IRB.

Bayerisches Landesamt für Statistik und Datenverarbeitung. (2011). Bestand an Wohngebäuden und Wohnungen in Bayern (p. 19). Munich.

Bundesministerium der Justiz. (2013). Baugesetzbuch. Retrieved from http://www.gesetze-im-internet.de/index.html

Chester, M., & Horvath, A. (2012). High-speed rail with emerging automobiles and aircraft can reduce environmental impacts in California's future. Environmental Research Letters, 7(3), 34012.

Glaeser, E. L., & Kahn, M. E. (2010). The greenness of cities: carbon dioxide emissions and urban development. Journal of Urban Economics, 67(3), 404–418.

Helms, H., Joehrens, J., Hanusch, J., Hoepfner, U., Lambert, U., & Pehnt, M. (2011). UMBReLA - Umweltbilanzen Elektromobilität Ergebnisbericht (p. 54). Heidelberg.

Hendrickson, C. T., Lave, L. B., & Matthews, H. S. (2006). Environmental Life Cycle Assessment of goods and Services: An Input-Output Approach (p. 262). Washington D.C.: Resources for the Future.

IfEU - Institut fuer Energie- und Umweltforschung. (2011). TREMOD - Transport Emission Model. Heidelberg.

INFRAS. (2010). Handbook emission factors for road transport (HBEFA).

Kirchner, A., & Matthes, F. (2009). Blueprint Germany - A strategy for a climate safe 2050 (p. 468). Berlin.

Landeshauptstadt Muenchen - Referat fuer Stadtplanung und Bauordnung. (2010). Mobilitaet in Deutschland - Alltagsverkehr in Muenchen, im Muenchner Umland und im MVV-Verbundraum (p. 43).

Milachowski, C., Stengel, T., & Gehlen, C. (2011). Life cycle assessment for road construction and use (p. 19). Brussels.

Nemeth, I., & Lindauer, M. (2013). Calculations from the Centre for Engery Efficient and Sustainable Design and Building, Technische Universität München (not published).

Poxleitner, F. (2013). Landeshauptstadt München, Baureferat - Straßenbautechnik, Personal discussions. Munich, Germany.

Ramesh, T., Prakash, R., & Shukla, K. K. (2010). Life cycle energy analysis of buildings: An overview. Energy and Buildings, 42(10), 1592–1600. doi:10.1016/j.enbuild.2010.05.007

Rheinisch-Westfälisches Institut für Wirtschaftsforschung. (2011). Erhebung des Energieverbrauchs der privaten Haushalte für die Jahre 2006-2008 (p. 189).

Rickwood, P., Glazebrook, G., & Searle, G. (2008). Urban structure and energy—a review. Urban policy and research, 26(1), 57–81.

Schaechtele, K., & Hertle, H. (2007). Die CO2 Bilanz des Bürgers - Recherche für ein internetbasiertes Tool zur Erstellung persoenlicher CO2 Bilanzen (p. 115). Retrieved from http://www.umweltdaten.de/publikationen/fpdf-l/3327.pdf

Sharma, A., Saxena, A., Sethi, M., Shree, V., & Varun. (2011). Life cycle assessment of buildings: A review. Renewable and Sustainable Energy Reviews, 15(1), 871–875. doi:10.1016/j.rser.2010.09.008

Statistisches Amt München. (2012). Statistisches Taschenbuch (Statistical Yearbook) 2012 (p. 194). Munich.

Stripple, H., & Uppenberg, S. (2010). Life cycle assessment of railways and rail transports: Application in environmental product declarations for the Bothnia Line (p. 190). Retrieved from http://www.ivl.se/webdav/files/B-rapporter/B1943.pdf

Swiss Centre for Life Cycle Inventories. (2010). Ecoinvent life-cycle database V2.2.

Umweltbundesamt. (2012). Entwicklung der spezifischen Kohlendioxid-Emissionen des deutschen Strommix 1990-2010 und erste Schätzungen 2011 (p. 5).

Vereinigung der Bayerischen Wirtschaft. (2012). Energetische Gebaeudesanierung in Bayern (p. 94). Munich.

FROM DETAILED LCA TO SIMPLIFIED MODEL: AN ORIENTED DECISION MAKERS APPROACH TO ASSESS ENERGY PATHWAYS

Pierryves Padey[1,2], Denis Le Boulch[2], Isabelle Blanc[1]*

[1] MINES ParisTech, 1, rue Claude Daunesse, F-06904 Sophia Antipolis Cedex, France
[2] EDF R&D, Les Renardières 77818 Moret sur Loing Cedex, France
E-mail contact: pierryves.padey@mines-paristech.fr

Keywords: Energy pathway; LCA; Simplified model; Global Sensitivity analysis

ABSTRACT

Literature reviews of energy pathways have shown a large variability of the environmental impacts over their systems. This leads decision/policy makers to sometimes consider LCA as inconclusive. We developed a methodology to assess environmental impacts of energy pathways through a simplified model: a parametric model elaborated with key parameters explaining most of the pathway variability. It is derived from the definition of a reference model enabling to calculate environmental impacts of a large sample of representative systems of energy pathways. Identification of key parameters is done using Global Sensitivity Analysis and Sobol indices. Illustration of such approach is done by defining a simplified model for assessing the GHG performance of photovoltaic electricity produced with Cadmium Telluride modules in France.

INTRODUCTION

Energy pathways can be assessed through literature reviews accounting for various specific systems. These studies highlight a wide range of possible environmental impacts (IPCC, 2011) and lead decision and policy makers to sometimes consider LCA as inconclusive (Brandão, Heath, & Cooper, 2012). For example, the photovoltaic electricity pathway is made of various systems encompassing a large technological and geographical heterogeneity (Kim, Fthenakis, Choi, & Turney, 2012) leading to a wide range of impacts. Detailed LCA of a system within an energy pathway being site and technology-specific, is only representative of single situations and cannot be representative at large for any energy pathway. To get a comprehensive explicit analysis of the environmental performance profile of an energy pathway, there is a need for a new type of models considering the technical, temporal and geographical heterogeneity of the systems sample composing this pathway.

We developed a methodology to generate such type of models, called simplified models. It enables encompassing energy pathway's variability by analysing their impacts over a large sample of representative systems using Monte-Carlo simulations. Applying Global Sensitivity Analysis approach (Saltelli, 2004), we then generate simplified models based on key parameters explaining most of the variance of the studied pathway. We now apply this methodology to define a simplified model estimating the GHG performances for photovoltaic (PV) electricity produced with Cadmium Telluride (CdTe) modules in France.

METHODS

We developed a methodological framework in five steps to assess an energy pathway and to generate its related simplified model (Padey, Girard, le Boulch, & Blanc, 2013). As a first step, the level of generalization is defined, i.e, what variability is accounted for, by specifying the geographical, temporal and technological coverage of the studied pathway.

We then need to define an explicit reference model as a second step. Such model is defined according to the specifications from step 1. It relies on the setting of a parameterized model such as the approach developed by Zimmermann (2012) built with independent variables, and on the characterization of its parameters through their interval and probability distributions, being as well compliant with the specifications from step 1. Based on the parameters characterization, a systems sample representing the energy pathway is generated by Monte Carlo simulations, to create its environmental profile.

To estimate the share of variance due to each parameter and their combinations, we followed a Global Sensitivity Analysis (GSA) and derived the related Sobol indices (Sobol, 2001). This third step enables ranking parameters influence and identifying which one are keys, i.e. explaining most of the environmental impact variance.

In step 4, the sample scattered plot is reorganized as a function of the key parameters and a general regression approach is used to calculate the median parametric equation. It enables estimating the impacts of various systems as a function of the key parameters, being thus the simplified model. In addition of the simplified model, on the scattered plot, non key parameters contributions are represented with the extreme boundaries and the, 1^{st} and 3^{rd} quartile of the sample.

Finally, in step 5 we compare the results of the simplified model with results from literature to assess the validity of the simplified model estimates.

RESULTS

We applied this methodology to define a simplified model estimating the GHG performances (in g of CO_2 eq/kWh) for a specific energy pathway: PV electricity produced with 3kWp CdTe installations in France.

The process chain analysis for PV module manufacture has been kept from the ecoinvent database (Hischier et al., 2009) to define the parameterized model. However, module area is parameterized according to the module efficiency as well as the electricity mix for manufacturing at the location of the module production. Variability sources are identified by seven uncorrelated parameters (Figure 1).

Parameter	Description	Characterization
Installation type	Selection of the architecture, Discrete choice between 2 options : Integrated or mounted	Expert judgment, 50% mounted, 50% integrated
Irradiation (Irr)	Annual irradiation received per m^2 in [kWh./ m^2.y]	Based on information provided by a collaborative website BDPV, (2013)
Performance Ratio (PR)	Takes into account: shadowing losses, connection losses, inverters losses in [%]	Based on works from Leloux, Narvarte, & Trebosc (2011)
Module Efficiency	Percentage of solar energy to which the module is exposed and converted into electrical energy in [%]	Data from the database Posharp, (2013)
Lifetime (LT)	Considers the entire period when the system is installed on the roof in years [y]	[20;30], Truncated normal law centered on 25 years, SD=2 , expert

Module Loss	Considers the loss of system efficiency during the lifetime compared to initial efficiency in [%]	[0.5; 1] uniform distribution; expert judgment
Country of module production	Country where the module is built influences the electricity mix required for the manufacturing	Origin of production from Dominguez-Ramos, Held, Aldaco (2010); electricity mix composition from IEA, (2013)

Figure 1. Explicit parameters of the reference model: description and characterization

25’000 Monte Carlo simulations have been sampled and GHG performances have been estimated for these scenarios creating the GHG performance profile of the energy pathway. Key parameters have been identified according to their Sobol indices values (Figure 2).

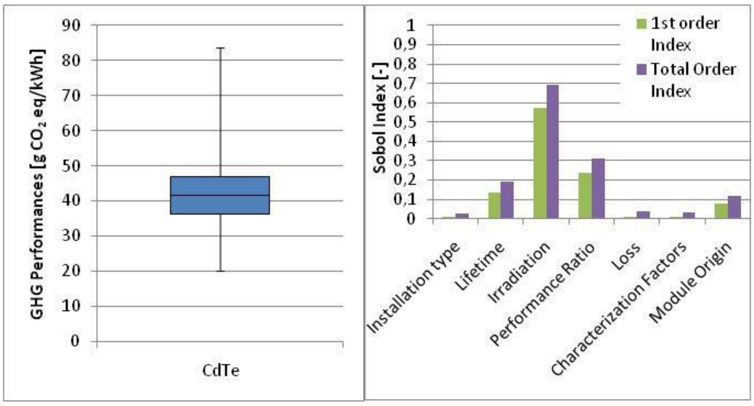


Figure 2. Boxplot of the PV electricity GHG performances (left), Sobol indices for each parameter (right).

The irradiation, performance ratio and lifetime are found to be the three most influencing parameters (79% of the overall variance explained). Thereby we propose the following parameterized equation estimating the GHG performance of the CdTe PV electricity pathway:

GHG performances CdTe = !"!#$"!!"#$.!" / !".!".!"" with R^2= 0.79

The simplified model is expressed as a function of the product of the three main parameters, as well as a validity assessment on Figure 3.

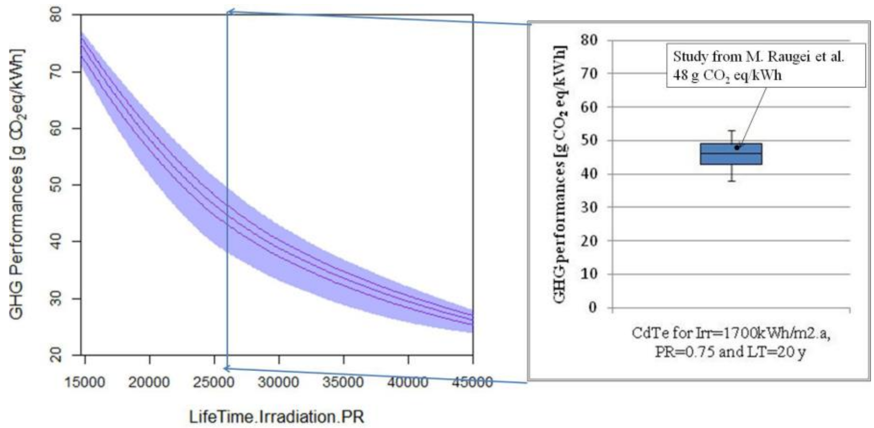


Figure 3. Simplified model (left) and literature comparison with a specific CdTe system (right)

DISCUSSION

Using this parametric equation enables estimating the electricity GHG performances of 3kWp CdTe PV systems installed in France only knowing three key parameters.

The reference model (step 2) is complex to define as it requires the collection of a large number of data; it also requires identifying independent parameters, in order to apportion the overall environmental performances variability to parameters variability. Whenever new data become available, a new reference model is to be redefined.

The number of key parameters selection is a choice, according to the level of simplification decided; three, two or even one parameter can be selected. The less parameters are chosen, the simpler is the model, but with potentially less accurate estimates.

CONCLUSIONS

Simplified models, according to this approach, have two significant outcomes for decision makers: the environmental impact profile of an energy pathway is explicitly characterized while access to impacts of systems is easily provided only knowing a restricted but key number of information. However, setting such approach requires the definition of an explicit reference model and access to a large amount of data that are complex to get today. Development of technical databases is fundamental to provide efficient policy support tools.

REFERENCES

BDPV. (2013). Collaborative PV module installations map. Retrieved from http://www.bdpv.fr/carte_installation.php

Brandão, M., Heath, G., & Cooper, J. (2012). What Can Meta-Analyses Tell Us About the Reliability of Life Cycle Assessment for Decision Support? *Journal of Industrial Ecology*, *16*, S3–S7.

Dominguez-Ramos, A., Held, M., Aldaco, R., Fischer, M., & Irabiena, A. Carbon footprint assessment of photovoltaic modules manufacture scenario. Presented at ESCAPE20.

Hischier, R., Weidema, B., Althaus, H.-J., Bauer, C., Doka, G., Dones, R., … Wernet, G. (2009). *ecoinvent database V 2.2*. Swiss Centre for Life Cycle Inventories.

IEA. (2013). IEA Electricity mix statistics. Retrieved from http://www.iea.org/stats/index.asp

IPCC. (2011). *Special Report on Renewable Energy Sources and Climate Change Mitigation.* (O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, … C. von Stechow, Eds.). United Kingdom and New York, NY, USA: Cambridge University Press.

Kim, H. C., Fthenakis, V., Choi, J.-K., & Turney, D. E. (2012). Life Cycle Greenhouse Gas Emissions of Thin-film Photovoltaic Electricity Generation. *Journal of Industrial Ecology*, *16*, S110–S121.

Leloux, J., Narvarte, L., & Trebosc, D. (2011). Performance Analysis of 10,000 Residential PV Systems in France and Belgium. Presented at the 26th European Photovoltaic Solar Energy Conference and Exhibition, Hamburg.

Padey, P., Girard, R., le Boulch, D., & Blanc, I. (2013). From LCAs to Simplified Models: A Generic Methodology Applied to Wind Power Electricity. *Environmental Science & Technology*,

Posharp. (2013). PV Module Efficiency database. Retrieved from http://www.posharp.com/photovoltaic/solarmfg/database.aspx

Raugei, M.; Bargigli, S.; Ulgiati, S. (2007). Life cycle assessment and energy pay-back time of advanced photovoltaic modules: CdTe and CIS compared to poly-Si. *Energy*, *32*, 1310–1318.

Saltelli, A. (2004). *Sensitivity analysis in practice : a guide to assessing scientific models*. Hoboken, NJ: Wiley.

Sobol, I. . (2001). Global sensitivity indices for nonlinear mathematical models and their Monte Carlo estimates. *Mathematics and Computers in Simulation*, *55*(1–3), 271–280.

Zimmermann, T. (2012). Parameterized tool for site specific LCAs of wind energy converters. *The International Journal of Life Cycle Assessment*, *18*(1), 49–60.

HOW CAN TEMPORAL CONSIDERATIONS OPEN NEW OPPORTUNITIES FOR LCA INDUSTRY APPLICATIONS?

Didier Beloin-Saint-Pierre[1], Annie Levasseur[2], Ariane Pinsonnault[2], Manuele Margni[2], Isabelle Blanc - Mines Paristech[1]*
[1]MINES ParisTech, 1 rue Claude Daunesse, F-06904 Sophia Antipolis cedex
**didier.beloin-saint-pierre@mines-paristech.fr*
[2]CIRAIG, École Polytechnique de Montréal

Keywords: Dynamic; Life Cycle Assessment; ESPA Method; Time; Modeling.

ABSTRACT

Opportunities of considering time in LCA studies are shown through our "dynamic" system and impact modeling of different domestic hot water systems. Our "dynamic" carbon footprint modeling changed the conclusion of the equivalent "non-dynamic" evaluation which shows that temporal consideration might provide a more representative assessment. The temporally characterized distributions of elementary flows we used also bring new analysis opportunities for practitioners. As an example, we believe that such information will enable the simple identification of products with high potential for future environmental improvement. Describing the temporal distributions of natural resource extraction could be another opportunity for dynamic modeling as they would provide valuable information on when and how consumption could be an issue.

INTRODUCTION

Most of today's life cycle assessment (LCA) studies are not considering nor identifying how time might affect environmental impact assessment. This simplification in modeling has been an increasing concern for LCA specialists (Field et al. 2000; Finnveden et al. 2009; Reap et al. 2008). Current "dynamic" LCA studies have shown that accounting for temporal variability increases results representativeness and might, in some cases, modify conclusions of their "non-dynamic" counter parts. Those demonstrations were done, either by modeling how the system itself varied throughout the life cycle (Collinge et al. 2011; Field et al. 2000; Pehnt 2006) or with "dynamic" impact assessment methods (Field et al. 2000; Kendall 2012; Levasseur et al. 2010; Shah and Ries 2009). To build on those developments, Collinge et al. (2013) recently proposed a methodology where time is considered for both system and impact modeling. The used "dynamic" system modeling method is based on the work of Heijung and Suh (2002) and is expected to face an implementation challenge because of the increase in data to manage. This database-expansion shortcoming can be partly solved by the recently developed enhanced structure path analysis (ESPA) method (Beloin-Saint-Pierre and Blanc 2011). We can then combined the ESPA method with the "dynamic" impact assessment method developed by Levasseur et al. (2010), to make a specific study of domestic hot water (DHW) production and then identify new opportunities brought forth by time considerations.

METHODOLOGY

Our new generic "dynamic" methodology starts with the use of the ESPA method (Beloin-Saint-Pierre and Blanc 2011). The main advantage of this method comes from the use of relative temporal distributions to describe elementary flows (extractions and emissions) and process flows of a system. With this specific information structure, the defined processes can be used for any study/systems while allowing for the calculation of specific temporally descriptive Life Cycle Inventories (LCI). Those temporally descriptive LCI can then be used by any "dynamic" impact assessment methods that use temporal distributions as inputs.

The second step of this methodology requires the use of the "dynamic" carbon footprint impact assessment approach (Levasseur et al. 2010). "Dynamic" characterization factors are used to calculate the impact on radiative forcing at any time following an emission. These characterization factors were developed, basically, by using the same approach as the one used by the Intergovernmental Panel on Climate Change (IPCC) for Global Warming Potential (GWP). The combination of a temporally descriptive LCI with those characterization factors provides the time-dependent impact on radiative forcing caused by the studied system.

CASE STUDY

Two different scenarios are compared for DHW production over an 80-year period (2011-2091). In the first scenario, an average of 140 liters of water is fully heated each day with the use of the French electricity mix. In the second scenario, the same average amount of water is heated by a solar thermal system combined with a gas auxiliary system. Both systems have an assumed lifespan of 20 years and provide the same water temperature throughout a standard year. The energy consumption of those systems is evaluated for each month of a standard year and takes place mostly in the winter. The monthly consumption variation will only affect the electricity mix in this modeling since everything else is assumed to vary yearly.

Only the differences in those two scenarios were considered to simplify the systems modeling step and because similarities would not help in differentiating results. This means that *the presented absolute values are not representative of the full carbon footprint for a liter of warm water*. This system simplification will not affect our ability to present the opportunities of considering time in LCA studies. Table 1 presents the few key aspects which summarize the main differences between the scenarios.

Table 1: Key aspects of the water heating systems scenarios for the case study

Aspects	Electrical water heating	Solar + gas water heating
Energy inputs	French electricity mix (low voltage)	Annual irradiation: 1440 kWh/m^2 Gas: European average gas commodity
Temporal precision	Annual and Monthly	Identical for Annual and Monthly studies
Installation	Only auxiliary is considered	Solar thermal system and auxiliary are considered

We also need to mention that we were able to temporally characterized 85% of the supply chain's elementary flows which are based on the ecoinvent 2.2 database information. This means that only 85% of the elementary flows and impacts are considered in this assessment.

RESULTS

Figure 1 presents 85 % of the CO_2 emissions (partial LCI) of both scenarios over the full lifecycle (2011-2091) with an annual temporal distribution format. The data is aggregated for each year since this is the required input for the used "dynamic" impact assessment method. 2011 is the year of installation with no DHW production. From this figure, we can easily identify the past, present and future CO_2 emissions. Discrete CO_2 emissions for the Solar-Gas scenario correspond to the fabrication of a solar system every 20 years.

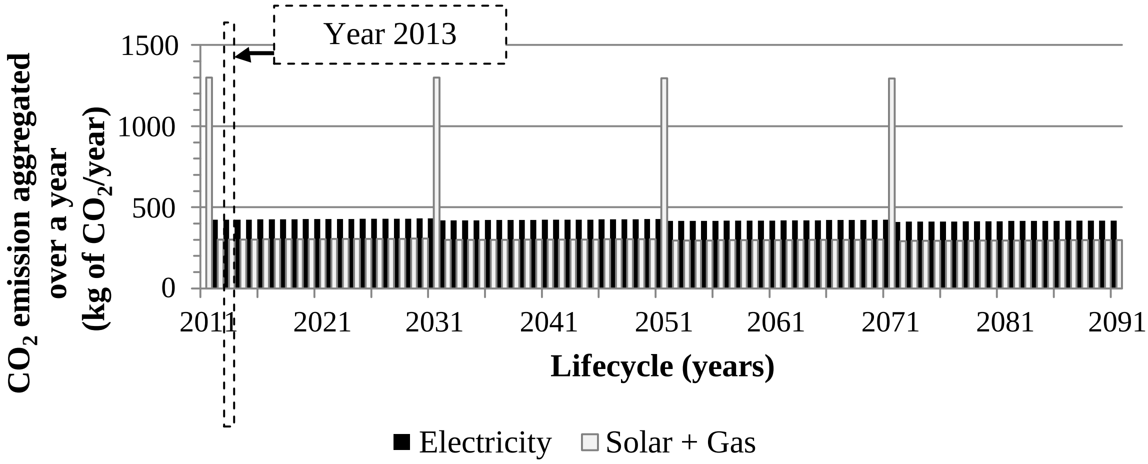


Figure 1: Annual temporal distribution of CO_2 emissions for the case study scenarios

Table 2 presents the modeled 100-year cumulated carbon footprint of both systems with different levels of temporal precision. A "non-dynamic" (traditional) carbon footprint evaluation of both systems is also presented for comparison purposes (Assessment 1).

Table 2: Traditional and "dynamic" carbon footprints of scenarios (tons of CO_2 eq.)

Assessments	Electricity	Solar + Gas
(1) Non-dynamic (traditional)/85% impact	28.9	30.9
(2) 85% dynamic/85% impact (***annual precision***)	19.3	21.2
(3) 85% dynamic/85% impact (***monthly precision***)	23.4	21.2

A "non-dynamic" / traditional LCA study would suggest that a full electrical system to produce DHW would be better in France. However, moving to a monthly dynamic LCA study clearly reverses the result trend. The monthly "dynamic" modeling takes into account the higher winter electricity carbon footprint and suggests that a solar + gas system offers a better performance.

DISCUSSION

The results of table 2 highlight an example of a study where conclusions differ between a traditional and a "dynamic" assessment. This change-in-trend result can be added to the examples of the cited literature where conclusions are affected by time considerations. We think this makes a case for the necessity of questioning the representativeness of "non-dynamic" LCA study, at least for the evaluation of carbon footprint.

We also identified some interesting analysis opportunities with the temporal distribution of CO_2 emissions (partial LCI) presented in figure 1. It will first help in the identification of the moments of pollutant emissions. In this case study, the LCI results would instantly show when CO_2 emissions of solar system replacement are occurring (every 20 years). Temporally characterized LCI could also be used in order to evaluate the proportion of emissions which occur in the future. This will enable the identification of products/systems with high potential for future environmental improvements. We could then find the processes of the supply chain, which are linked to those future emissions (e.g. energy consumption and solar systems) and improve them. Finally, we think that temporal distributions of natural resource extraction would also be invaluable information for many producers because it would identify the moment when it might be an issue. For example, we show, indirectly, that both systems are linked with future consumption of fossil fuels and recommend appropriate measures.

CONCLUSIONS

In this research, we made an evaluation of the carbon footprint of different domestic hot water production system with a novel “dynamic” LCA methodology which showed changing trends between traditional and “dynamic” carbon footprint assessment. This would suggest then that “dynamic” LCA studies are an opportunity for more representative environmental assessment. The ability to identify moments of environmental effect, products with high potential for future environmental improvement and moments of natural resource extraction are other opportunities we identified.

REFERENCES

Beloin-Saint-Pierre, Didier and Blanc, Isabelle (2011), 'New spatiotemporally resolved LCI applied to photovoltaic electricity', *LCM* (Berlin).

Collinge, W. O., et al. (2011), 'Enabling Dynamic Life Cycle Assessment of Buildings with Wireless Sensor Networks', *2011 Ieee International Symposium on Sustainable Systems and Technology (Issst)*, 6.

Collinge, William O., et al. (2013), 'Dynamic life cycle assessment: framework and application to an institutional building', *International Journal of Life Cycle Assessment*, 18 (3), 538-52.

Field, Frank, Kirchain, Randolph, and Clark, Joel (2000), 'Life-Cycle Assessment and Temporal Distributions of Emissions: Developing a Fleet-Based Analysis', *Journal of Industrial Ecology*, 4 (2), 71-91.

Finnveden, G., et al. (2009), 'Recent developments in Life Cycle Assessment', *Journal of Environmental Management*, 91 (1), 1-21.

Heijungs, Reinout and Suh, Sangwon (2002), *The Computational Structure of Life Cycle Assessment*, ed. Arnold Tukker (First edn., ECO-EFFICIENCY IN INDUSTRY AND SCIENCE, 11; Dordrecht, The Netherlands: Kluwer Academic) 241.

Kendall, Alissa (2012), 'Time-adjusted global warming potentials for LCA and carbon footprints', *International Journal of Life Cycle Assessment*, 17 (8), 1042-49.

Levasseur, A., et al. (2010), 'Considering Time in LCA: Dynamic LCA and Its Application to Global Warming Impact Assessments', *Environmental Science & Technology*, 44 (8), 3169-74.

Pehnt, Martin (2006), 'Dynamic life cycle assessment (LCA) of renewable energy technologies', *Renewable Energy*, 31 (1), 55-71.

Reap, John, et al. (2008), 'A survey of unresolved problems in life cycle assessment', *The International Journal of Life Cycle Assessment*, 13 (4), 290-300.

Shah, Viral and Ries, Robert (2009), 'A characterization model with spatial and temporal resolution for life cycle impact assessment of photochemical precursors in the United States', *The International Journal of Life Cycle Assessment*, 14 (4), 313-27.

LIFE CYCLE ASSESSMENT (LCA) OF NANOMATERIALS: A COMPREHENSIVE APPROACH

*Hidalgo, C.; González-Gálvez, D.; Janer, G.; Escamilla, M., Vázquez-Campos, S.**
Leitat Technological Center. c/ de la Innovació, 2 08225 Terrassa (Barcelona), Spain,
svazquez@leitat.org

Keywords: LCA; nanomaterials; modelling; environmental impact; human health.

ABSTRACT

LCA is a suitable method to assess the environmental performance of nanotechnology-based products, although challenges remain due to uncertainties and data gaps. LEITAT participates in different European projects, such as NANOMICEX, NANOPOLYTOX, NEXTEC, EUROTAPES and NANOSOLUTIONS, which contribute in filling in these gaps. Selected representative nanotechnology-based products were modelled, including all life cycle stages: raw materials, synthesis, functionalization, product manufacturing, use and end-of-life processes. When human health and ecotoxicological impact factors for released nanoparticles are integrated in LCA models, results show that their potential effect can be relevant in toxicity categories; thus such factors should be included to LCA approaches. Toxicity to workers is likely to be more relevant, so combined approaches of LCA and Risk Assessment (RA) are proposed.

INTRODUCTION

Nanomaterials (NM) and nanotechnology-based products are widely used nowadays in different applications. This trend has brought controversy due to the lack of data on their potential impact on human health and environment. Although LCA is considered as the best approach to assess the environmental behaviour of emerging technologies, currently the potential impacts of the released NM associated to human and environmental health are not yet introduced in LCA databases and several uncertainties and data gaps exist (Hischier, 2012). The main goal of applying LCA approaches in nanotechnology-based products is thus to derive characterization factors for NM using existing models as a starting point. Inventory and impact data could be included in LCA databases and impact methods to allow performing comprehensive LCA studies on nanotechnology-based products and their applications, comparing them to conventional materials, and providing the basis for future regulations and policies in this field.

LCA toxicity models are designed to evaluate toxicity hazards for the environment and the general population. However, human workplace exposure can be considerably higher than that occurring via the environment. Very little information is available on the risks of workers exposed to NM. In order to broad the scope and include safety and social issues in the sustainability assessment, for human toxicity category the impact for both workers and general population should be assessed combining LCA and RA methodologies (Grieger, 2012). This is the approach of NANOMICEX, which is aimed to apply LCA knowledge achieved in projects such as NANOPOLYTOX and the standardized LCA methodology to define working exposure scenarios and to perform a complete RA in all life cycle stages of ENM included in conventional materials (paints and inks).

MATERIALS AND/OR METHODS

A complete methodology has been developed in order to assess the life cycle of different types of nanotechnology-based products. The methodology used allows adapting the existing databases and impact assessment methods in order to include specific and new data of NM potential impacts. The study has been performed in accordance to the LCA ISO-framework (ISO 14040:2006 and ISO 14044:2006). Calculations have been done using SimaPro software, and taking as a base Ecoinvent Database and ReCiPe method. In the inventory phase resources used, energy, emissions, waste, and NM emissions to the environment were included. Research projects generate inventory data, especially related to NM releases and interactions. NM can be released to the environment during all their life stages and depends on their concentration in the product, the lifetime of the product, the way that the NM are incorporated in the final product, its use and disposal.

The ReCiPe Impact Assessment method has 18 midpoints indicators, which have a low level of uncertainty, and three endpoints indicators, aimed to do easier results interpretation but with a higher uncertainty: i) damage to human health (HH), ii) damage to ecosystem diversity (ED) and iii) damage to resource availability (Goedkoop, 2009). ReCiPe model does not contain characterization factors specific for nanoparticles. Within its set of impact categories, Human Toxicity and Freshwater Ecotoxicity were considered the most relevant categories in terms of the possible impact of released NM.

Models and factors for toxicity effects in LCA are based on the relative risk and associated consequences of NM and chemicals that are released into the environment. The derivation of these characterization factors requires taking into consideration the environmental and biological fate, human exposure, and the toxicological responses. The characterization factors for these categories have been estimated following the principles of the USEtox model (Rosenbaum, 2008), which is approved by UNEP-SETAC as the preferred model for characterization modelling of human and ecotoxicity impacts in LCIA.

The general equations to generate fate factors in the USEtox model are not directly applicable to NM. NM characteristics governing their fate (size, shape, porosity, agglomeration state, surface area, surface charge, composition, density, reactivity, etc.) have been considered in our studies in order to predict their environmental distribution.

Four nanocomposites were studied in NANOPOLYTOX. Release, exposure, fate and (eco)toxicity of NP were assessed in order to derive characterisation factors on freshwater ecotoxicity and human toxicity. Release and exposure were estimated based on the processes typology and data from literature. Fate was modelled adapting USEtox model and introducing the main physico-chemical characteristics of each nanoparticle, obtained from experimental data of the project and literature. For toxicity effect factors, ecotoxicity data were collected from experimental project data and literature; and oral and inhalation human toxicity data were collected from literature. Two scenarios were defined, a probable and a worst case scenario (which combine probable and worst case fate factors, toxicities and NM releases). The combination of fate, exposure and toxicity factors in USEtox proportioned the final characterisation factors. These factors were applied to NM release quantified in each stage in order to obtain their potential impact. These impact values were added to environmental impacts results from each process calculated with ReCiPe method.

RESULTS

NANOMICEX and the other projects cited are ongoing, therefore in this section only results of NANOPOLYTOX project are described although the approach for the rest of the projects are similar and advances in NANOPOLYTOX are serving as basis for ongoing projects. In NANOPOLYTOX, four nanocomposite materials were analysed. As a case example, main results for 3% MWCNT in polypropylene (MWCNT-PP) and 3% TiO_2 in polyamide (TiO_2-PA) nanocomposites are discussed in the following sections.

Environmental impacts were assessed at midpoint and endpoint level in order to see the relative contribution of the different life stages and the main impacting parameters. General distribution of all studied NM followed a similar scheme; in all production and transformation processes, electricity was the most impacting parameter. Due to energy consumption, climate change appeared to be the most relevant impact category at endpoint level, both on HH damage (84% for MWCNT; 83% for TiO_2) and ED damage (97% for MWCNTs; 95% in TiO_2). At endpoint level, characterization factors of freshwater ecotoxicity and human toxicity due to released NM were added to final results. In use stage, only the impacts from released NP were considered, with no impacts coming from other sources during the application of composites. Results for the defined worst scenario are shown in the tables 1 and 2.

Table 1. Endpoint categories at damage level for MWCNT-PP (1 kg). Worst case scenario

	HUMAN HEALTH (HH)		ECOSYSTEM DIVERSITY (ED)		RESOURCE AVAILABILITY	
	Stage contr	Value (DALYs)	Stage contr	Value (sps·year)	Stage contr	Value ($)
Synthesis MWCNT	5%	1.73E-06	4%	7.19E-09	3%	4
Composite MWCNT-PP	49%	1.70E-05	48%	8.03E-08	55%	82
Use	0%	7.21E-11	0%	4.64E-12	0%	-
Mechanical recycling	46%	1.60E-05	48%	8.07E-08	43%	64
TOTAL	**3.48E-05**		**1.68E-07**		**150**	
Relative contribution	**Process**	**99%**	**Process**	**99.997%**	**Process**	**100%**
CNT released (all stages) /process	**CNT released**	**1%**	**CNT released**	**0.003%**	**CNT released**	**-**

Table 2. Endpoint categories at damage level for TiO_2-PA (1 kg). Worst case scenario

	HUMAN HEALTH (HH)		ECOSYSTEM DIVERSITY (ED)		RESOURCE AVAILABILITY	
	Stage contr	Value (DALYs)	Stage contr	Value (sps·year)	Stage contr	Value ($)
Synthesis TiO_2	15%	2.53E-05	12%	7.76E-08	12%	47
Functionalisation TiO_2	29%	4.78E-05	20%	1.25E-07	22%	88
Composite TiO_2-PA	16%	2.65E-05	14%	8.48E-08	12%	47
Use	1%	9.72E-07	0%	4.41E-12	0%	-
Chemical recycling	39%	6.54E-05	54%	3.34E-07	55%	220
TOTAL	**1.66E-04**		**6.22E-07**		**402**	
Relative contribution	**Process**	**76%**	**Process**	**99.97%**	**Process**	**100%**
TiO_2 released (all stages) /process	**TiO_2 released**	**24%**	**TiO_2 released**	**0.03%**	**TiO_2 released**	**-**

DISCUSSION

In MWCNT-PP nanocomposite, mechanical recycling and composite synthesis are the stages with higher contribution in the three damage levels, whereas synthesis of NP (fluidized bed deposition) has lower impacts associated. Globally, TiO_2-PA composite has higher potential damage values in the three levels than MWCNT-PP, since particles are functionalized before application into composite (stage with relevant impacts) and waste treatment was chemical recycling, which has higher impacts than mechanical recycling. TiO_2 synthesis process (flame spray pyrolysis) has also higher impacts than MWCNTs synthesis, especially in Resources Availability category, due to a higher energy demand.

The relative contribution of released NM to environmental impacts was included at damage on HH and ED. Released MWCNT along life cycle contributed only to 1% on HH and 0.003% on ED. Higher contributions are found in synthesis process. In the case of MWCNT toxicity, effect on workers was also assessed for synthesis and nanocomposite stages with higher values, which corroborated the convenience of perform Risk Assessment in the different stages of the life cycle together to environment assessment. In the case of TiO_2-PA nanocomposites, the relative contribution of released particles is higher, being a 24% for human health damage and 0.03% in ecosystem damage indicator.

CONCLUSIONS

LCA approach for nanotechnology and nano-products can provide useful information about the main environmental impacts and benefits of this emerging technology. Prospective LCA approaches are needed and experimental data on characteristics and toxicity of nanoparticles coming from research projects should be included in LCA methodologies. Adapted exposure and fate modelling are needed in order to have complete results on the environmental performance of nano-products during all life cycle stages. LCA information should be used together with other methodologies such as RA to obtain a deep comprehension on the interactions of NM and the environment and the potential damage on environment and human health in all life cycle stages and exposure levels.

REFERENCES

Goedkoop M., Heijungs, Huijbregts M., de Schryver A., Struijs J., van Zelm R. (2009). ReCiPe 2008, A life cycle impact assessment method which comprises harmonised indicators at the midpoint and at the endpoint level. *First edition. Report I: Characterisation. VROM, 132 + 44 pp.*

Grieger K. D., Laurent A., Miseljic M., Christensen F., Baun A., Olsen S. I. (2012). Analysis of current research addressing complementary use of life-cycle assessment and risk assessment for engineered nanomaterials: have lessons been learned from previous experience with chemicals? *J. Nanoparticle Res. 14:958.*

Hischier R, Walser T. (2012).Life cycle assessment of engineered nanomaterials: state of the art and strategies to overcome existing gaps. *Sci. Total Environ. 2012 May 15;425:271..*

Rosenbaum R.K., Bachmann T.M., Swirsky Gold L., Huijbregts M.A.J., Jolliet O., Juraske R., Koehler A., Larsen H.F., MacLeod M., Margni M., McKone T.E., Payet J., Schumacher M., van de Meent D., Hauschild M. (2008). USEtox – the UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment. *Int. J. Life Cycle Asess. (2008) 13:532.*

LIFE CYCLE ASSESSMENT OF COMPRESSED AIR ENERGY STORAGE (CAES)

Evert A. Bouman, Martha M. Øberg, Edgar G. Hertwich*

**Industrial Ecology Programme, Department of Energy and Process Engineering, Norwegian University of Science & Technology (NTNU), Høgskoleringen 5, NO-7491 Trondheim, Norway, evert.bouman@ntnu.no*

Keywords: CAES, LCA, Wind power

ABSTRACT

This paper discusses the potential environmental impacts associated with the use of a Compressed Air Energy Storage (CAES) as a means of stabilizing the electricity output of a wind farm with a capacity of 150 MW. An integrated hybrid life cycle assessment model was employed to model the potential environmental impacts of several compressed air energy storage systems. Results show that the potential environmental impacts associated with compressed air energy storage are strongly correlated with the size and (method of) construction of the underground storage cavity. We conclude that this particular means of energy storage is, from an environmental perspective, only advisable under certain conditions, such as the expectation of a very long (centuries) operational lifetime or the occurrence of a natural storage location eliminating the need for large infrastructural operations.

INTRODUCTION

As the growing importance of climate change mitigation becomes more apparent, the drive for the implementation of renewable energies technology increases. When the grid penetration of renewable power, such as photovoltaic and wind power, becomes significant, there is a need for energy storage technologies to solve the intermittency issues, inherent to the fluctuating nature of the power source (i.e., fluctuating diurnal and seasonal variations in wind and incident sunlight). To ensure grid stability, an energy storage technology can be used (Beaudin, Zareipour et al. 2010).

The International Energy Agency (IEA) provides assessments of the share of wind power energy in the electricity mix. For the widely used Blue map scenario, global wind power production is expected to constitute a significant share in the electricity mix (International Energy Agency 2010).

Compressed Air Energy Storage is one of the energy storage technologies considered for reducing intermittency. Two types of CAES systems can be defined. Conventional CAES, and adiabatic compressed air energy storage (ACAES). In conventional CAES, stored air is used to decrease the need for input compression to a natural gas turbine, thereby greatly increasing the efficiency of the natural gas power generation. In ACEAS, no fossil fuel is required. To date, two conventional CAES systems are functional and operating. One plant, located in Huntorf, Germany, has been running since 1978 with a capacity of 290 MW and storage capacity of 4 hours (Succar 2011). A 110 MW system with a considerable longer storage capacity of 26 hours is located in McIntosh Alabama (Marean 2009). Both CAES plants use solution-mined salt caverns as air storage location. A demonstration plant operating on the adiabatic CAES principle is scheduled for completion in 2016 (RWE Power AG 2010).

This paper discusses the potential environmental impacts associated with the use of CEAS and ACEAS as a means of stabilizing the electricity output of a wind farm with a capacity of 150 MW. Where others have reported the potential environmental benefits of implementing CAES systems (Chen, Cong et al. 2009; Jubeh and Najjar 2012) and life cycle energy and greenhouse gas emissions were reported by (Denholm and Kulcinski 2004), to the authors' knowledge, no life cycle efforts have been made to quantify full potential environmental impacts in a systematic way.

METHODS

An integrated hybrid life cycle assessment (HLCA) model was employed to model the potential environmental impacts of several compressed air energy storage systems(Gibon, Hertwich et al. 2013; Wood, Hertwich et al. 2013). We model a traditional process based Life Cycle Assessment and complement this with economic data were this is available. Ecoinvent v2.2 is used for the physical background inventory (Dones, Bauer et al. 2007). The HLCA economic background data uses the EXIOPOL environmentally extended Input/Output database, aggregated to nine regions, but with a disaggregated electricity sector (Tukker, Koning et al. 2013). The results from the Life Cycle Inventory are characterized using the ReCiPe hierarchist impact assessment method, containing 18 impact categories (Goedkoop, Heijungs et al. 2013). The fugitive emission for the fossil fuel extraction processes are updated with emissions published in (Burnham, Han et al. 2012) to obtain a better representation of associated impacts of fossil fuel extraction in the background. All results are calculated on a kWh^{-1} functional unit basis and we employ a cradle-to-gate perspective.

RESULTS

We investigate both CAES and ACAES in connection with three types of underground storage: a leached salt dome, a porous rock formation, and a mined hard rock cavern. Each system is connected to a 150 MW wind farm consisting of 2 MW turbines. Main assumptions are that the air storage volume is assumed equal for all different types of storage. The lifetime of the plant, excluding the storage volume, is assumed to be 40 years. The storage volume is assumed to have a 100 year lifetime. An annual operation time of 2000 hours per year is assumed for the different CAES systems, which equals a capacity factor of roughly 23%.

The foreground system of the CAES plant consists of: gas turbine, compressor, heat expanders modeled by a steam turbine proxy, plant construction, components, underground air storage and operation (Nakhamkin 2008). The foreground system of the ACAES system consists of: Plant construction, compressor, underground air storage, thermal energy storage heat expanders, other components and operation. (Biasi 2009). A contribution analysis for a selection of impacts for the CAES and ACAES with a hard rock cavern is presented in Figure 1. Analysis of the model results shows that a large part of the environmental impacts is associated with the electricity generation by the wind farm and (in the case of CAES) fossil fuel combustion, which is modeled as input to the operation foreground process. The construction of the storage cavern also contributes significantly to the environmental impacts. This is especially the case for the variant in which the system is connected to a leached salt dome (not presented in the Figure). The required energy and water to dissolve a salt dome large enough to satisfy operating conditions as specified below results in an increase in environmental impacts, suggesting that a 100 year timeframe might not be appropriate for this kind of technology.

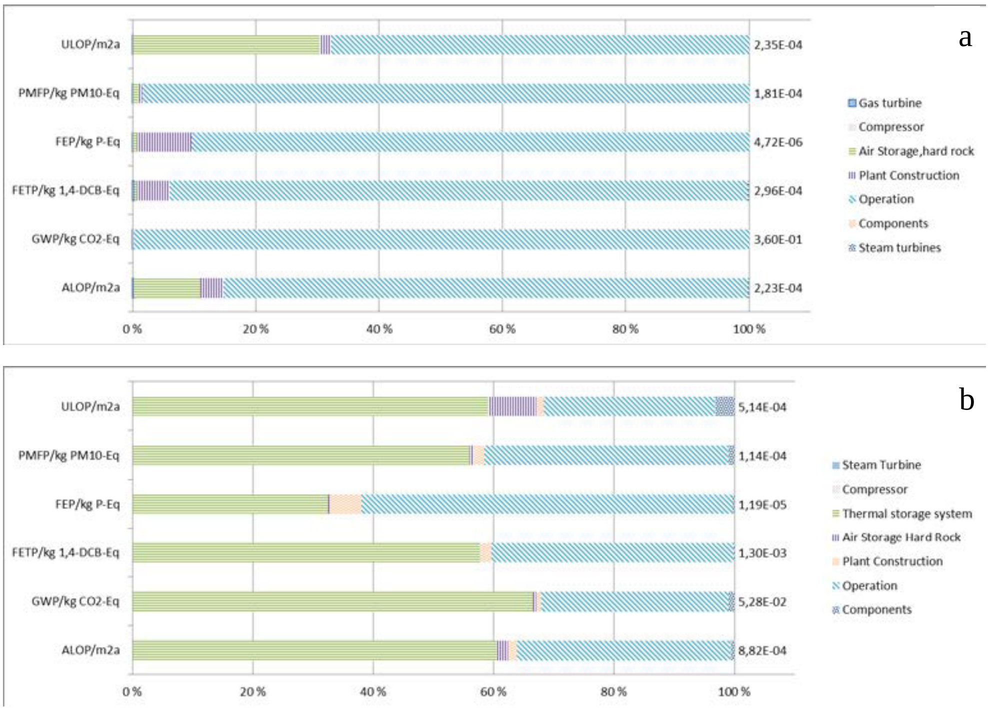


Figure 1: Foreground contribution analysis of the production of 1 kWh of electricity from a CAES (a) and ACAES (b) with a hard rock mined volume for a selection of impact categories: Urban land occupation (ULOP), Particulate matter formation (PMFP), Freshwater eutrophication (FEP), Freshwater ecotoxicity (FETP), Global warming potential (GWP) and Agricultural land occupation (ALOP).

DISCUSSION

In this paper, we have taken a conservative approach regarding some of the engineering assumptions. The results indicate that the solution mining of a salt rock cavern contributes to a large extent to the potential environmental impacts of the storage systems. Furthermore, it is assumed that the waste stream of salt mining should be treated. It is possible that in many cases the solution can be disposed of more easily. This assumption, in combination with the

100 year timeframe, leads to an overestimation of the impact of the salt dome. However, we feel that these results cannot be ignored as they indicate a large sensitivity of CAES towards the construction of the underground storage unit.

CONCLUSIONS

The HLCA-results show that the design and processing of underground air storage have a large influence on the final outcome of the study. Compressed air energy storage, as a means of mitigating intermittency in wind power production can be favorable in certain conditions, especially when geological conditions are well suited for implementation and no energy has to be spent on the creation of a cavern. In general we conclude that the ACAES cases have a lower impact compared to the CAES cases, due to fact that no fossil fuel is combusted. However, the impacts for a CAES plant are lower than those from natural gas power plant. For ACAES, an important part is the thermal energy storage and developing of the thermal mass with high heat transfer capabilities and low environmental impact is crucial to improve overall performance of the system.

REFERENCES

Beaudin, M., H. Zareipour, et al. (2010). "Energy storage for mitigating the variability of renewable electricity sources: An updated review." Energy for Sustainable Development **14**(4): 302-314.

Biasi, V. d. (2009). "Fundamental Analyses to Optimize Adiabatic CAES Plant Efficiencies." Gas Turbine World: 26-28.

Burnham, A., J. Han, et al. (2012). "Life-Cycle Greenhouse Gas Emissions of Shale Gas, Natural Gas, Coal, and Petroleum." Environmental Science & Technology **46**(2): 619-627.

Chen, H., T. N. Cong, et al. (2009). "Progress in electrical energy storage system: A critical review." Progress in Natural Science **19**(3): 291-312.

Denholm, P. and G. L. Kulcinski (2004). "Life cycle energy requirements and greenhouse gas emissions from large scale energy storage systems." Energy Conversion and Management **45**(13-14): 2153-2172.

Dones, R., C. Bauer, et al. (2007). Life Cycle Inventories of Energy Systems: Results for Current Systems in Switzerland and other UCTE Countries. Dübendorf, CH, Swiss Centre for Life Cycle Inventories.

Gibon, T., E. Hertwich, et al. (2013). An environmental assessment framework with systematic regional and time scenarios. LCM 2013. Gothenburg, Sweden.

Goedkoop, M., R. Heijungs, et al. (2013). ReCiPe 2008: A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level.

International Energy Agency (2010). "Energy Technology Perspectives 2010: Scenarios & Strategies to 2050." 710.

Jubeh, N. M. and Y. S. H. Najjar (2012). "Green solution for power generation by adoption of adiabatic CAES system." Applied Thermal Engineering **44**: 85-89.

Marean, J. B. (2009). Compressed air energy storage engineering and economic study. New York NY, New York State Energy research and development authority.

Nakhamkin, M. (2008). 150-300-400 MW CAES Plants Based on Various Combustion Turbines. Energy Storage & Power Corporation (ESPC). http://www.espcinc.com/library/150-300-400_MW_CAES_Brochure.pdf.

RWE Power AG (2010). ADELE - Adiabatic compressed-air energy storage for electricity supply.

Succar, S. (2011). Compressed Air Energy Storage, CRC Press.

Tukker, A., A. d. Koning, et al. (2013). "EXIOPOL - Development and illustrative analyses of a detailed global multiregional environmentally-extended supply and use table/input-output table." Economic Systems Research **25**(1).

Wood, R., E. Hertwich, et al. (2013). Results of an Economic Assessment using Hybrid-IO Analysis for the Life-Cycle Impacts of Prospective Technologies. LCM 2013. Gothenburg, Sweden.

SUSTAINABLE PRODUCTION 1

Wednesday, Aug 28: 10:30am - 12:00pm

Session chairs: Björn Johansson, Chalmers University of Technology, Sweden
Mahesh Mani, University of Maryland, College Park, United States of America

A CRADLE-TO-GATE LIFE CYCLE ASSESSMENT OF AN INDUSTRY CLUSTER OF FIVE CHEMICAL COMPANIES

Frida Røyne [a], Johanna Berlin [a], Emma Ringström [b], Anna Martha Coutiño [b]*
[a] SP Technical Research Institute of Sweden
[b] AkzoNobel
** Corresponding author. Gibraltargatan 35, 40022 Göteborg, Sweden, frida.royne@sp.se*

Keywords: life cycle assessment; industry cluster; chemical industry

ABSTRACT

This paper presents a cradle-to-gate life cycle assessment of an industry cluster in Sweden, consisting of five chemical companies. The purpose of the study is to quantify the upstream and onsite environmental impacts, and to identify environmental hot spots in the system. The results show that upstream processes account for higher environmental impacts in all environmental impact categories than onsite processes. A few of the incoming streams account for a large proportion of the environmental impacts compared to their share of total incoming weight, and should therefore be the subject of future emission reduction strategies.

INTRODUCTION

The industrial cluster in our study consists of the chemical companies AGA, AkzoNobel, Borealis, INEOS and Perstorp, and is situated in Stenungsund, Sweden. The companies produce a variety of products, such as chemicals, plastics, gases and fuels. They also interact strongly with each other in terms of material exchange: energy integration however is still limited. The heart of the cluster is the Borealis steam cracker plant which supplies the companies with raw materials. The cluster is accounting for ~5 % of Sweden's total fossil fuel usage (mainly feedstock), and is a major emitter of fossil CO_2.

The companies are working towards a common sustainability goal to 2030: that the cluster should be based mainly on biogenic feedstock and renewable energy. In order to evaluate the environmental implications of this and other strategies, assessing the environmental impacts of the current system is crucial for comparing environmental advantages and drawbacks.

Life cycle assessments on industrial clusters remain scarce (Dong et al., 2013; Tian et al., 2013) but the method has previously been successfully applied in such studies (Liu et al., 2011).

METHOD

Our approach is to study the cluster as a unit in the foreground system. The background system consists of those flows going into and coming out from the cluster. The functional unit of the study is the total production of the system within the year 2011.

The assessment is a cradle to gate study, covering all life cycle activities associated with the extraction, handling and processing of raw materials and energy inputs to the cluster, and production processes within the cluster. The manufacturing of production equipment, buildings and other capital goods is not included, in agreement with (Chen et al., 2013) and (Bösch et al., 2007). Transportation of incoming stream to the cluster is not included, but will be included at a later stage. The great amount of incoming raw material streams requires some cut-off, but less than 5 % has been excluded.

The data is site specific for the processes within the cluster, and generic (collected from databases) for the raw materials supplied to the cluster. 80 % of the data was collected from Ecoinvent and Plastics Europe, while 20 % was collected from AkzoNobel’s own database. The site specific data are for 2011. For one of the companies, data was not available. Since this company is estimated to have a small share of the total impact of the cluster, and also only to a limited extent will be affected by future changes, the company was still included and data was estimated based on 2010 data and input and output flows from the other companies. The electricity mix is a self-modeled mix for the companies reporting having a specific deal with the energy company, or Nordic mix if electricity was bought from the spot market.

The following environmental impact categories are relevant for the study (EPD®, 2012) and are included: global warming potential (GWP), abiotic depletion (AD) , acidification potential (AP), ozone-depletion potential (ODP), ground level ozone creation potential (POCP) and eutrophication potential (EP). The impact assessment was carried out according to the CML 2001 method.

RESULTS

Table 1 presents the results from the LCA in absolute value for the different impact categories and in percentage distribution for inflows to the industry cluster and on site impacts.

Table 1 Results from characterization and relative contribution per subsystem.

Category	*Unit*	*Total value*	*Upstream (%)*	*Onsite (%)*
GWP	kg $CO_{2\ eq}$	$2.36*10^9$	60 %	40 %
AD	kg Sb_{eq}	$4.06*10^7$	100 %	N/A
AP	kg $SO_{2\ eq}$	$1.09*10^7$	96 %	4 %
ODP	kg R-11 $_{eq}$	475	100 %	0 %
POCP	kg $C_2H_{4\ eq}$	$2.16*10^6$	58 %	42 %

EP	kg $PO_4^{-3}{}_{eq}$	$3,08*10^6$	97 %	3 %

A recent carbon footprint study on an industrial park shows similar results with regards to distribution of greenhouse gases, with ~55 % upstream and ~45 % onsite (Dong, et al., 2013). Onsite greenhouse gas emissions of the Stenungsund cluster correspond to 1.5 % of the total 61.4 mill ton emissions of greenhouse gases in Sweden in 2011 (Naturvårdsverket, 2013).

GWP and POCP are the environmental impact categories with the largest onsite shares (40 % and 42 % respectively), indicating that combustion of fuels in the cluster play a significant role. Apart from that, production of the incoming streams has the largest environmental impact contribution. Table 2 demonstrates the contribution of those streams with the highest contribution, in comparison with their relative share of the weight of the total of incoming flows.

Table 2 Contribution to emission categories from those materials and energy inflows to the cluster with the largest environmental impact contribution, relative to their share of the weight of total incoming flows.

Inflows to the cluster	*Share of upstream flow (in %)*	*Share of total emissions (in %)*					
		GWP	*AD*	*AP*	*ODP*	*POCP*	*EP*
Ethane, propane and butane	40.5	24	57	53	93	38	57
Naphtha	13.1	5	17	6	0	4	2
Natural gas	5.1	3	7	1	0	>1	>1
Rape oil	4.8	6	1	19	>1	>1	22
Ethylene	4.6	6	8	4	0	3	1
Vinyl chloride	2.4	3	2	1	>1	>1	>1
Ammonia	1.3	3	1	>1	0	>1	>1
Bio-ethanol	0.5	1	>1	2	>1	>1	4

DISCUSSION

Conducting a cradle-to-gate LCA of a chemical industry cluster has been proven feasible. The way industrial clusters are constructed provides both advantages and challenges when conducting an LCA. An advantage is that interactions between the companies in terms of material exchange makes it possible to complement missing data and ensure data quality. A challenge is the complexity of the system, with numerous inputs and outputs. Conducting a cradle-to-grave study would have added further value for future strategy assessments, but it would be extremely time-consuming, as the fate of the multitude of products is difficult to map. The main uncertainties in the study relate to the data on upstream production processes, since the data are from databases, and do not necessarily reflect actual production processes.

Indicating that upstream processes have a higher environmental impact that onsite processes adds a useful aspect, as it becomes clearer what future strategies should concentrate on. The same applies to the division of environmental impact contribution of the inflows to the cluster. Ethane, propane and butane make up 40.5 % of the weight of inflows, and contribute heavily to all environmental impact categories (24 % - 93 %).

CONCLUSIONS

A cradle-to-gate life cycle assessment was conducted for a chemical industry cluster. Upstream processes account for a larger share of all the environmental impact categories than onsite emissions. Global warming potential and ground level ozone creation potential are the environmental impact categories with the largest onsite shares; indicating that the processes resulting in the associated emissions are system hot spots. The fossil raw materials ethane, propane and butane account for a great proportion of all the environmental impact categories, and should therefore also be the target of future environmental strategies. The LCA will be used as a reference scenario in future studies where the environmental implications of switching to biogenic feedstock and extending process integration will be evaluated.

Aknowledgements This study was carried out under the auspices of the Skogkemi (Forest Chemistry) project, and has been cofounded by Vinnova.

REFERENCES

Bösch, M. E., Hellweg, S., Huijbregts, M. A. J., & Frischknecht, R. (2007). Applying Cumulative Exergy Demand (CExD) indicators to the ecoinvent database. *International Journal of Life Cycle Assessment, 12*(3), 181-190.

Chen, B., He, G., Qi, J., Su, M., Zhou, S., & Jiang, M. (2013). Greenhouse gas inventory of a typical high-end industrial park in china. *The Scientific World Journal, 2013*.

Dong, H., Geng, Y., Xi, F., & Fujita, T. (2013). Carbon footprint evaluation at industrial park level: A hybrid life cycle assessment approach. *Energy Policy*.

EPD®. (2012). Product Category Rules CPC Group 341: Basic organic chemicals. www.environdec.com: The International EPD® System

Liu, Q., Jiang, P., Zhao, J., Zhang, B., Bian, H., & Qian, G. (2011). Life cycle assessment of an industrial symbiosis based on energy recovery from dried sludge and used oil. *Journal of Cleaner Production, 19*(15), 1700-1708.

Naturvårdsverket. (2013). Svenska utsläpp av växthusgaser. from http://www.naturvardsverket.se/Sa-mar-miljon/Statistik-A-O/Vaxthusgaser--nationella-utslapp/

Tian, J., Guo, Q., Chen, Y., Li, X., Shi, H., & Chen, L. (2013). Study on industrial metabolism of carbon in a Chinese fine chemical industrial park. *Environmental Science and Technology, 47*(2), 1048-1056.

ENHANCING THE LIFE-CYCLE ENVIRONMENTAL PERFORMANCE OF AN ENERGY SYSTEM FOR THE COPRODUCTION OF SYNTHETIC BIOFUELS AND ELECTRICITY

Diego Iribarren[a], Ana Susmozas[a], Javier Dufour[a,b]*

[a] Instituto IMDEA Energía, Móstoles 28935 (Spain)

[b] Rey Juan Carlos University, Móstoles 28933 (Spain)

** Corresponding author: Javier Dufour. Instituto IMDEA Energía. Av. Ramón de la Sagra, 3, E-28935 Móstoles (Spain). E-mail: javier.dufour@imdea.org*

Keywords: biomass gasification; Fischer-Tropsch; life cycle assessment; power generation; process simulation.

ABSTRACT

Fischer-Tropsch (FT) synthesis coupled with combined-cycle strategies could be a sustainable pathway for biofuel and power generation. The present work deals with the life cycle assessment of four alternative FT-based systems to identify the best option in terms of global warming and cumulative energy demand. All systems involve poplar biomass gasification, biosyngas conditioning, Fischer-Tropsch synthesis, refining, and power generation. Different configurations are defined by taking into account further electricity production using clean syngas or further processing of the FT tail gas via autothermal reforming (ATR) or membrane separation. Key inventory data are provided through process simulation. The ATR system potentially arises as the most favorable option. The products from this system show significant benefits when compared to equivalent conventional products.

INTRODUCTION

The shortage of fossil fuels and the growing energy demand have led to increasing energy prices. This situation, along with environmental concerns (e.g., global warming), has motivated the search for energy systems which result in a clean and sustainable energy sector.

The Fischer-Tropsch (FT) synthesis is a well-known chemical process for the production of liquid hydrocarbons from syngas. There is a growing interest in this process as it could be a sustainable pathway for biofuel generation, having the potential of being coupled with combined-cycle strategies to coproduce electricity from renewable resources (Iribarren et al., 2013). Since multiple FT-based configurations are possible, the present work uses the life cycle assessment (LCA) methodology to evaluate the global warming impact and the cumulative energy demand of a set of relevant alternatives.

METHODS

The goal of this study is to evaluate and contrast the life-cycle global warming and energy performance of four alternative FT-based systems for the coproduction of synthetic biofuels and electricity. The functional unit (FU) for the LCA of each system was defined as 1,000 t of wet biomass to be processed in the FT plant. All systems cover from biomass cultivation to the supply of the products at plant (cradle-to-gate approach). Hybrid poplar (50% moisture) was selected as the biomass feedstock since it is a short-rotation plantation, i.e. it can be grown with little input and in relatively small areas (Gasol et al., 2009).

Figure 1 shows a simplified diagram of the four FT-based systems under evaluation. For all these systems, the common processes that take place in the FT plant include biomass pretreatment, syngas production via poplar biomass gasification, biosyngas conditioning, hydrocarbon production through FT synthesis, refining, and power generation. The present work considers a base case for the coproduction of synthetic biofuels and electricity, as well as three potential modifications of this base case that define three alternative systems.

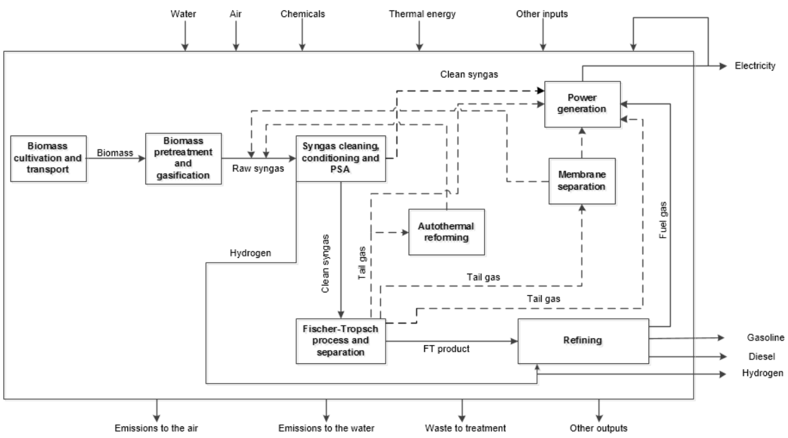


Figure 1. Simplified diagram of the four FT-based systems. Dotted arrows represent flows that are not common for all systems.

The base case study is herein detailed, as it is the basis for the definition of the remaining systems. In the plant, the poplar feedstock is milled and dried before entering the low-pressure indirect gasifier, in which raw biosyngas is generated. The produced syngas undergoes conditioning, which includes tar reforming, scrubbing, acid gas removal through absorption with amines, and a LO-CAT® process (Spath et al., 2005; Susmozas et al., 2013). Clean biosyngas presents an H_2/CO molar ratio of 2.5. Since the FT reaction needs an H_2/CO molar ratio of approximately 2, a small amount of H_2 is separated in a pressure swing adsorption (PSA) unit with 85% efficiency before entering the FT reactor. Part of the separated H_2 is used in the refining area. The syngas stream is fed to the FT reactor, in which CO and H_2 react to produce a hydrocarbon mixture. An FT slurry reactor with 80% CO conversion was considered. This reactor uses a Co catalyst and operates at 200 ºC and 25 bar. At the exit of the FT reactor, two streams are obtained: wax (C_{20+}) and a stream made up of C_1-C_{20} hydrocarbons and unconverted syngas. The latter is cooled down in order to separate the tail gas (C_1-C_4 and unconverted syngas) from the C_{5+} fraction. The C_{5+} stream is then processed in the refining area along with the wax stream, producing diesel, gasoline, and fuel gas (C_1-C_4). The tail gas and the fuel gas are used in the power generation section, which consists of a combined cycle with a gas turbine and a steam turbine with three pressure levels (87/31/2.4 bar). This combined cycle makes the plant energetically self-sufficient (Liu et al., 2011).

The remaining three systems under examination are similar to the "base case", but they take into account relevant modifications in its configuration. The "syngas power case" considers that part of the conditioned syngas (20%) is sent directly to power generation in order to increase the electricity output. In the "ATR case", part of the produced tail gas (30%) undergoes autothermal reforming (ATR) so that hydrocarbons react with O_2 and steam producing syngas (Zahedi Nezhad et al., 2009), which (after being conditioned) is recycled to the FT rector in order to increase the fuel output. Finally, in the "membrane case", the produced tail gas undergoes membrane separation, thus obtaining a hydrogen-rich stream (90 vol% purity) suitable for the FT process (after conditioning) and a hydrocarbon-rich stream which is fed to the power generation section.

Key inventory data for the operations carried out in the FT plants were obtained through process simulation in Aspen Plus®. The poplar feedstock was defined as a non-conventional component by specifying its proximate and ultimate analyses. The gasification section was modeled according to Susmozas et al. (2013). The product from the FT reactor was assumed to consist only of paraffins. The refining area was simulated based on literature data (Swanson et al., 2010; Iribarren et al., 2013). Inventory data for background processes were taken from the ecoinvent database, while data for poplar cultivation were based on Gasol et al. (2009).

RESULTS

The global warming impact potential (GWP) and the cumulative non-renewable (fossil and nuclear) energy demand (CED) of each FT-based system were calculated. Table 1 presents the GWP results and the life-cycle energy balances (estimated as the difference between the potential energy output and the CED indicator) of the evaluated systems. Based on these results, the ATR and membrane cases were found to be the best configurations. In particular, the ATR case study was selected as best option since it represents a more well-established configuration with reduced GWP.

Table 1. GWP and life-cycle energy balance of each case study (values per FU)

	Base case	**Syngas power case**	**ATR case**	**Membrane case**
GWP (kg CO_2 eq)	70,327.25	93,980.93	14,703.73	17,237.54
Energy balance (MJ)	2,078,126.77	1,697,408.83	2,195,995.74	2,427,665.64

DISCUSSION

The GWP and CED indicators of the energy products from the best-performing system (i.e., the "ATR case") were compared with those of their conventional equivalent products: fossil gasoline, fossil diesel, grid electricity, and steam-methane-reforming hydrogen (Dones et al., 2007; Susmozas et al., 2013). As can be observed in Figure 2, energy products from the FT system were found to involve much more favorable results.

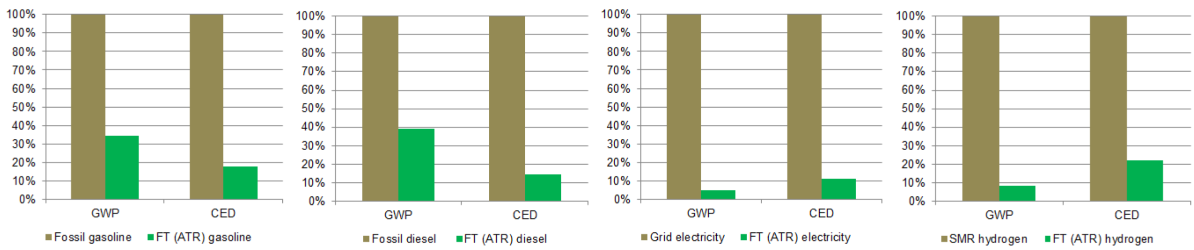


Figure 2. GWP and CED results of FT products (based on the ATR case study) relative to their conventional equivalent products

CONCLUSIONS

FT-based systems proved to have the potential of supplying energy products with a promising life-cycle performance in terms of global warming and energy balance. Therefore, fuels and electricity from this type of bioenergy systems could contribute favorably to the future energy sector.

REFERENCES

Dones, R., Bauer, C., Bolliger, R., Burger, B., Faist Emmenegger, M., Frischknecht, R., Heck, T., Jungbluth, N., Röder, A., & Tuchschmid, M. (2007). *Life cycle inventories of energy systems: Results for current systems in Switzerland and other UCTE countries, ecoinvent report No. 5*. Dübendorf, Switzerland: Swiss Centre for Life Cycle Inventories.

Gasol, C.M., Gabarrell, X., Anton, A., Rigola, M., Carrasco, J., Ciria, P., & Rieradevall, J. (2009). LCA of poplar bioenergy system compared with *Brassica carinata* energy crop and natural gas in regional scenario. *Biomass & Bioenergy*, *33*, 119–129.

Iribarren, D., Susmozas, A., & Dufour, J. (2013). Life-cycle assessment of Fischer-Tropsch products from biosyngas. *Renewable Energy*, *59*, 229–236.

Liu, G., Larson, E.D., Williams, R.H., Kreutz, T.G., & Guo, X. (2011). Making Fischer-Tropsch fuels and electricity from coal and biomass: Performance and cost analysis. *Energy & Fuels*, *25*, 415–437.

Spath, P., Aden, A., Eggeman, T., Ringer, M., Wallace, B., & Jechura, J. (2005). *Biomass to hydrogen production detailed design and economics utilizing the Battelle Columbus Laboratory indirectly-heated gasifier*. Golden, USA: NREL.

Susmozas, A., Iribarren, D., & Dufour, J. (2013). Life-cycle performance of indirect biomass gasification as a green alternative to steam methane reforming for hydrogen production. *International Journal of Hydrogen Energy*, in press.

Swanson, R.M., Satrio, J.A., Brown, R.C., Platon, A., & Hsu D.D. (2010). *Techno-economic analysis of biofuels production based on gasification*. Golden, USA: NREL.

Zahedi Nezhad, M., Rowshanzamir, S., & Eikani, M.H. (2009). Autothermal reforming of methane to synthesis gas: Modeling and simulation. *International Journal of Hydrogen Energy*, *34*, 1292–1300.

EVALUATION OF BRAZILIAN SCENARIOS OF REVERSE LOGISTICS OF AIR COMPRESSORS USING THE LIFE CYCLE ASSESMENT

Vanessa Mesquita Santana, Federal University of Santa Catarina. Edivan Cherubini, Federal University of Santa Catarina. Cristiane Maria de Léis Federal, University of Santa Catarina. Sebastião Roberto Soares, Federal University of Santa Catarina. * Centro Tecnológico CTC, Campus Universitário -Florianópolis - SC – Brazil. Zip code: 88040-970 e-mail: vasantana@gmail.com.*

Keywords: Reverse logistic scenarios; air compressor; Life Cycle Assessment.

ABSTRACT

In order to reduce environmental damage on the activity of transporting goods, this article carried out the environmental analysis of reverse logistics for an air compressor. We compared three scenarios: a Hypothetical Scenario (HS), a Possible Scenario (PS) and a scenario suggested in the literature called Reference Scenario (RS), using the methodology of Life Cycle Assessment (LCA), standardized by the ISO 14040/14044 (2006). The results showed that the possible scenario of reverse logistics which uses almost exclusively railroad has approximately 20% less environmental impacts than the reference scenario.

INTRODUCTION

Currently the demand from consumers regarding environmental issues has required industry seek for more sustainable solutions in production and final disposal of their products. The National Policy on Solid Waste in Brazil, created in 2010 states that the industry is responsible to manage the end-of-life of their products. Thereby, the reverse logistics has an important role to reduce costs and environmental impacts on the supply chain.

Therefore this paper aims to compare, from an environmental point of view, three scenarios of reverse logistics of a product, not accounting the impacts of the production of this product.

The first reverse logistics scenario was proposed by Zanghelini (2013), who considered, on his analysis, only the transport of old compressors made only by truck. The second scenario is hypothetical: it considers transportation using rail lines in Brazil, and the third will be called a "possible scenario": it considers transportation using rail lines and roads. The methodology used was the Life Cycle Assessment (LCA) standardized by ISO 14040 and 14044 (2006). The functional unit was the reverse logistic of 1 air compressor delivered in Joinville, Santa Catarina State in southern Brazil.

METHODS

The Reference Scenario (RS) was taken from Zanghelini (2013), who proposed a model based on regional spots of collection of compressors. In the South of Brazil the collection spot is located in Florianópolis. In the Southeast, it is in São Paulo; Center West in Campo Grande; North in Marabá, Northeast in Salvador. After being collected, the compressors will be sent to Joinville-SC, where the company that will recycle the compressors is located. The quantities of products generated after the end-of-life were determined according to their consumption flow, given by the industrial concentration of each region of Brazil, considering that for each old compressor there would have a new one to replace it. All the transportation in this scenario is by truck.

For Hypothetical Scenario (HS) it was used the same collection spots of the RS however the transportation of the compressors was done by railroads only, some of which already exists in Brazil and some of them are still expected to be implemented by the Brazilian government.

The Possible Scenario (PS) used the same collections spots of RS and HS, but with the transportation was done partly by railroad and partly by truck. This scenario represents a feasible alternative for the actual reverse logistic applied by the company.

In these scenarios, quantities of compressors collected after its usage were determined according to the specific Gross Domestic Product (GDP) of each Brazilian region. Regarding the technical procedures, the study aimed to collect data through observations and analysis of hypothetical distribution channels of the company through rail networks, based on ANTF, 2012 (National Association of Railway).

The environmental impacts of the three distribution channels were analysed qualitatively and quantitatively through the SimaPro software with the CML baseline 2000 method regarding to the following impact categories: Abiotic Depletion and Global Warming Potential plus the Total Accumulated Energy Demand.

RESULTS

The results showed that the Hypothetical Scenario (HS) it's the preferable scenario from an environmental point of view, followed by the Possible Scenario (PS). The Reference Scenario (RS) was the worst alternative. The distribution channels that have more railroads presented less environmental impacts, justifying investment in railroad construction in Brazil. Figure **1** shows that Scenario HS has approximately 55% less impact than RS and approximately 13% less impact than PS in all categories.

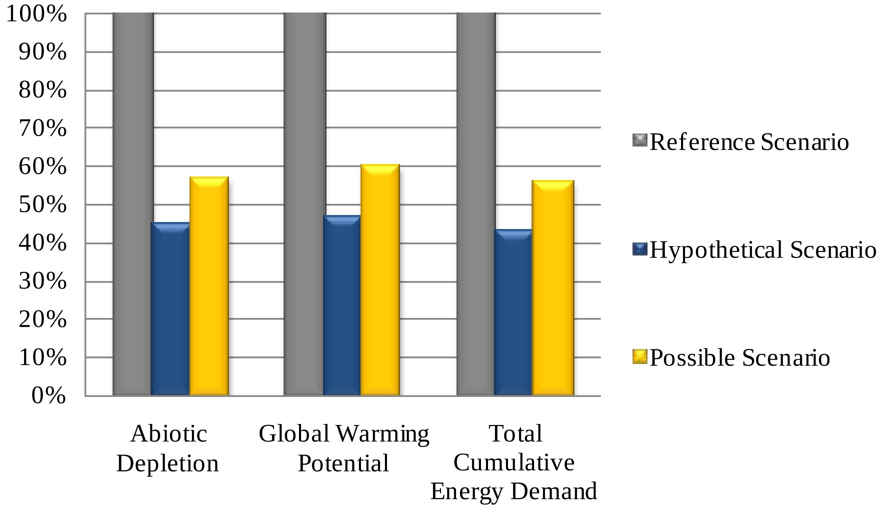


Figure 1- Graph comparing the environmental impact categories analysed between scenarios RS, HS and PS.

Evaluating separately each scenario it was noticed that for the HS the South/South route showed the best environmental performance (Figure 2) with 3% of the total impact caused by this scenario, this can be explained due to the short distance between the collection spot and the company in Joinville and a percentage of contribution in mass of 16.5% of the total compressors used in Brazil, followed by routes North/South and Center West/South with approximately 14% of the environmental impacts. The route Northeast/South had a contribution of 30% of impacts mainly due the long distance between the collection spot and the company once the mass contribution percentage (13.5%) of the compressors are closely to the South/South and North/South routes. The Southeast/South route was the main contributor of environmental impacts, with approximately 37% of total impacts caused by the reverse logistics. Despite the distance being not too large, this route accounts for 55.3% of the total weight of the countries compressor.

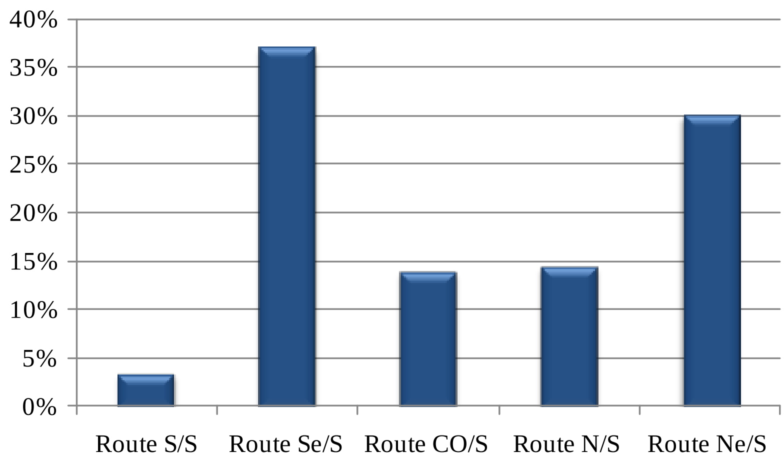


Figure 2- Graph of environmental impacts comparing the distribution channels in HS.

Analysing the PS, we can verify that South/South route was the one with the best performance (Figure 3) with 5% of the total impact caused by this scenario. However this scenario still represents a greater impact when compared to HS. This is due to the fact that in the South/South route in PS the transportation was made only by truck once currently in Brazil there aren't any available railroads in this route.

The short distance and a percentage of 16.5% mass contribution of compressors still represent lower environmental impacts in South/South route when comparing the five routes. Center West/South, North/South and Northeast/South routes has a contribution of 14%, 23% and 27% in environmental impacts, respectively. The transport (i.e. only by railroad) Northeast/South remains the same as in HS, but by having a large distance from the other regions the impact in this route remains high. The route Southeast/South remains the one with the greatest environmental impact with 33% of the impacts in this scenario. For despite the small distance between the collection point and the company in Joinville this route continues contributing 55.3% of the total mass of compressors of the country.

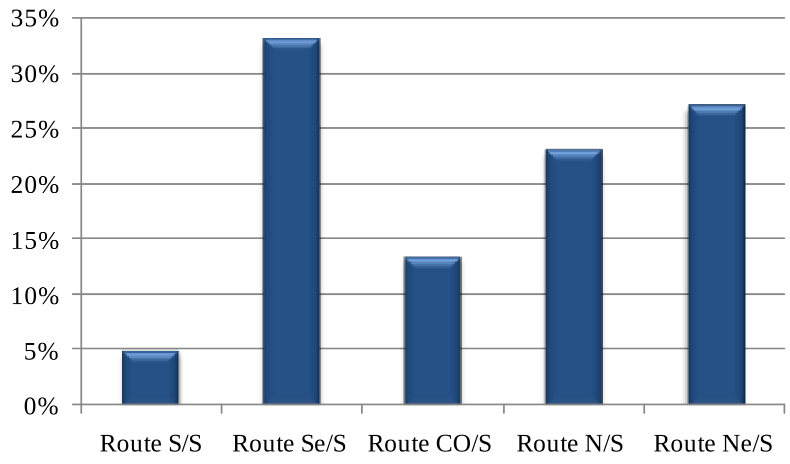


Figure 3- Graph of environmental impacts comparing the distribution channels in PS.

CONCLUSIONS

It can be concluded that among the three scenarios, Hypothetical Scenario is the best environmental one due the exclusively use of railroads. We could also notice that the route from Florianópolis to Joinville, both in HS and PS, has a small contribution to the environmental impacts on the LCA of the reverse logistics of this product because of the short distances.

REFERENCES

ISO, Environmental Management (2006a) – Life Cycle Assessment: Principles and Framework. ISO 14040:2006. International Organization for Standardization. Geneva, Switzerland.

ISO, Environmental Management (2006b) – Life Cycle Assessment: Requirements and Guidelines. ISO 14044:2006. International Organization for Standardization. Geneva, Switzerland.

Zanghelini, G. M. (2013). Study of scenarios for post-use of an air compressor based on LCA: Influences of the system boundary in the results. 142p. Master in Environmental Engineering, Federal University of Santa Catarina – Florianópolis. Available on: <http://www.ciclodevida.ufsc.br/publicacoes.php>.

FACTORY OF THE FUTURE – TOWARD A NEAR-ZERO ENVIRONMENTAL FOOTPRINT IN WOOD PANELS MANUFACTURING

Emil Popovici[1], Enrico Benetto[1], Giorgio Cerniglia[2], Marko Becker[2]*

[1]*Public Research Centre Henri Tudor (CRPHT /Resource Centre for Environmental Technologies (CRTE)- 6A, avenue des Hauts-Fourneaux, L-4362 Esch-sur-Alzette, Luxembourg*

[2] *KRONOSPAN Luxembourg S.A.*

**Corresponding author: emil.popovici@tudor.lu*

Keywords: eco-design; OSB; MDF; LCA.

ABSTRACT

Factory of the Future – “Demonstration of the production of wood panels with near zero environmental footprint” is a project funded by the Life+ Programme of the European Commission. Now in its first of three years of running, this project aims to create, through an “eco-design of a factory” concept, a largely near self-sufficient production facility in Sanem (Luxembourg) with low environmental impact by combining the best practices in the field of production and use of energy, water and raw materials supply. The use of Life Cycle Assessment (LCA) applied to the entire production site and then to specific products is envisioned for monitoring the progress towards near-zero environmental footprint and for communication purposes.

KRONOSPAN AND ITS PRODUCTS

Kronospan facility in Sanem (Luxembourg) produces around 500 versions of two types of wood panels boards used mainly in building sector, furniture and packaging: oriented strand boards (OSBs) and medium-density fibreboards (MDFs).

OSB is a wood panel built up in three layers of strands (wood flakes) bonded in with a resin in different orientations i.e. the outer layers strands are arranged at right angles to those in the middle layer (CEN, 1997).

The OSB production at Kronospan is made in several steps (Figure 1): “logging”(reception and storage of wood logs); “flaking” (debarking and stranding of logs flaking); “drying”(drying of wood strands from 50 to 150% of moisture content to 5%); “screening”(screening of dry strands to separate the finest); “blending and forming” (blending of strands with adhesives mixture, wax and hardener and forming in order to obtain a mat), and “pressing”(strong pressure is applied to the mat to get the OSB).An additional final step of sanding and finishing could be required for some OSB products according to their use (Benetto et al., 2009).

MDF is a composite panel product composed primarily of cellulosic fibres bonded and cured under heat and pressure (ANSI, 2002).

The current production process of MDF (Figure 1) consists of a reduction of wood in small chips, which are then proportioned, filtered, washed, softened thermally, and mechanically transformed into fibres, which are then mixed with a synthetic resin being used as adhesive. The pasted fibres are then dried, assembled and compressed in a hot press to give it the desired thickness.

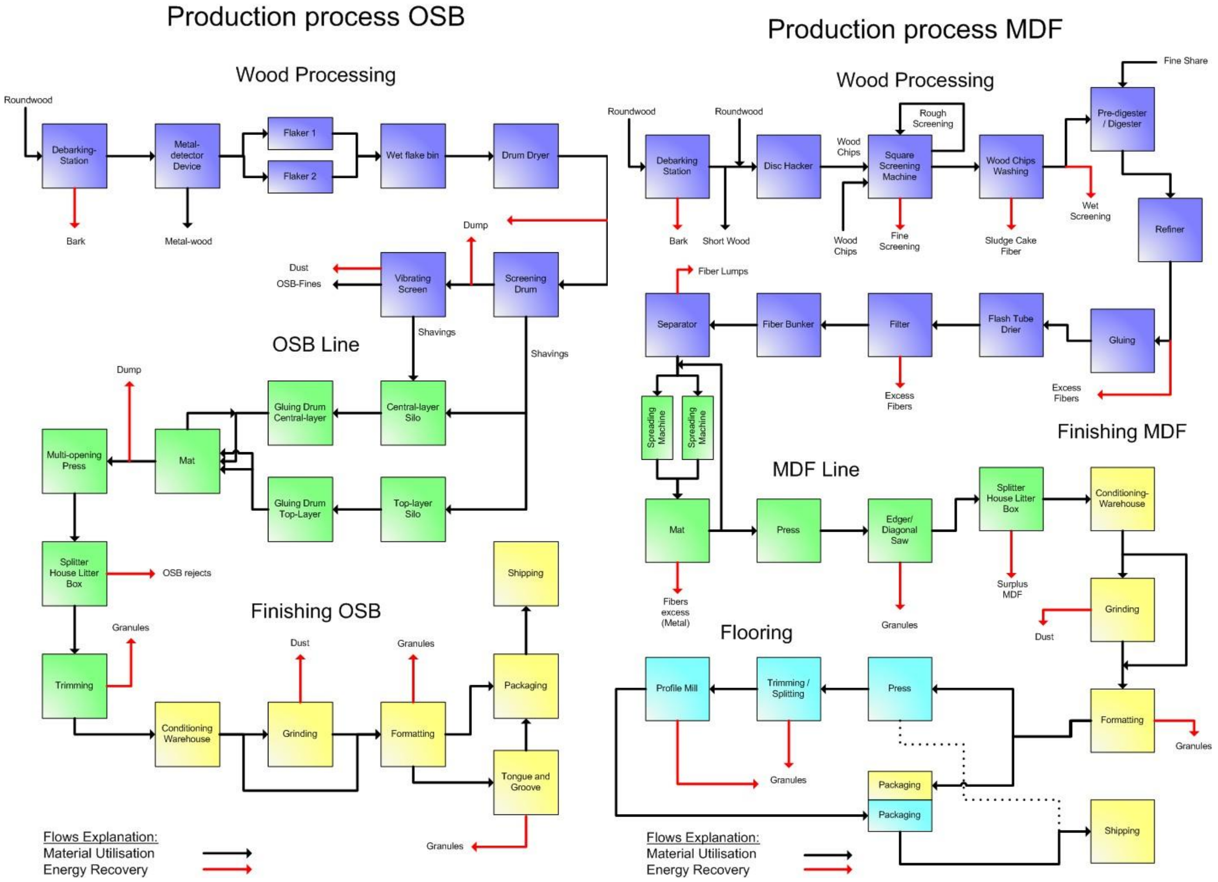


Figure 1.Kronospan OSB and MDF flow sheet

PAST EFFORTS OF REDUCING ENVIRONMENTAL IMPACT

Several projects have already been successfully implemented on Sanem site, dedicated to the improvement of the products and production process, both from an environmental and technical point of view:

- The first wood fired thermal oil boiler with a "self-cleaning" construction (the "Flossenkessel") was installed leading to a higher production and efficiency;
- Wet Electro Static Precipitators (WESP) were installed to the OSB and MDF presses, the first to be used in wood-based panel industry;
- The development of the world's first exhaust gas cleaning installation for the MDF-dryer, a two stage washing unit with chemical treatment of organic compounds solved

in the water.

- An innovative drying system was implemented for the production of OSB panels resulting in a dramatic decrease of VOC was achieved, exceeding 95%, as well as a 10-20% decrease in fossil fuel use and GHG emissions on-site (Benetto et al., 2009).This project has been awarded the title of "Best of the Best" from a shortlist of 22 "Best" LIFE Environment projects in 2008-2009.

With these steps Kronospan already has an impressive record of innovation and environmental improvement. The current project aims to make another huge leap forward.

ECO-DESIGN OF THE FACTORY OF THE FUTURE

The wood panel industry is generally very environment oriented, as protecting natural resources goes hand in hand with ensuring future availability of wood and thus business continuation. A list of typical efforts towards this direction is outlined below:

- Non-reusable and non-recyclable materials are used for energy production, typically large amounts (up to 90%) of wood biomass;
- Energy efficiency is increased as much as possible;
- Waste water is recycled for e.g. glue mixing, washing of raw materials,...

However, not all facilities use the same input wood type and have the same availability of waste wood. Therefore efforts are very much dependent on the situation of the particular production facility.

In the case of the Kronospan's production site in Sanem, while previous improvement has always targeted specific parts of the production line, within this project the aim is to achieve a full-scale demonstration of a the concept of "eco-design of a factory". This will be achieved by letting all elements work synergistically allowing relying almost on renewable resources, such as rain water and wood waste, while the production volume and quality is maintained.

The idea is to combine the already present cutting edge installations in both production lines (OSB and MDF) with new equipment, such as a Combined Heat and Power (CHP) unit and rain capturing units.

The improvements of present equipment needed are estimated thorough an analysis of the current production lines, determining the exact state with respect to the objectives. For instance, wood production requires thermal energy (heat) for the drying process, and electricity for other equipment (e.g. conveyor belts, presses, etc.). Maximum energy efficiency and minimum fossil energy use will be ensured through enhancements as follows:

- The energy efficiency of the OSB production line is significantly increased by a pre-drying of the wet wood flakes using excess heat from the process;
- Heat and electricity could be produced from renewable sources using a cogeneration process, excess electricity being provided to the local power grid;
- The remaining energy required for the production of OSB and MDF panels would be powered almost entirely by biomass.

Important quantities of drinking water are used today for cleaning and steam generation. In order to lower the consumption the water efficiency of the steam generator will be increased with around 20%. After the installation of the capturing units, over 50% of the current consumption will be assured by rain water and around 15% from the condensation water, recycled from the OSB production process.

The expected results are to cut the current use of fossil fuels for thermal energy by 90%; cut over 80% of the current CO_2 eq. emissions from fossil fuels and cut 70-75% of the currently consumed town water. The facility could also generate biomass origin electricity to the power grid, equivalent to the household use of over 22 000 persons.

Special attention is given to the management of the supply chain, from a lifecycle perspective, in order to increase the availability of the raw material without pressuring on the forests cycle and minimizing the transport distances. The biomass will be covered for the largest part by on-site sources with a 40% of the required wood and the remainder will be purchased from nearby certificated management forests. To this aim, the use of LCA is instrumental to avoid the move of pollution along the lifecycle of the products as well as to monitor and prove the progress towards near-zero environmental footprint. LCA will allow to downscale the environmental improvements reached at the site level to the specific families and types of products.

CONCLUSION

This project will demonstrate a viability of a new concept: “the eco-design of a factory”. The project will innovate the production methodology to reach a low environmental footprint wood panel production line, which is at the same time economically sustainable. An increased autonomy in the manufacturing processes also means that the production process are less vulnerable to fluctuations in fuel, raw material and water prices, thus increasing in the future economic viability of the project.

This demonstration will become a window of any other industry to understand that the concept could be successful both in technical and financial terms in a wide range of industries.

REFERENCES

ANSI (2002). MDF for Interior Applications, *ANSI A208.2-2002 Gaithersburg, Composite Panel Association. 2002, p. 3.*

Benetto E., Becker M., Welfring J. (2009). Life Cycle Assessment of Oriented Strand Boards, *Environmental Science & Technology 2009, vol. 43(15), 6003-6009.*

CEN (1997) Oriented Strand Boards Definition (OSB). Definitions, Classification and Specifications, *EN 300-97, CEN, 1997, p. 6.*

INFORMATION STRUCTURE FOR MANUFACTURING SUSTAINABILITY ASSESSMENT: STEP FOR LCA

Y.F. Zhao (1), N. Perry (2), H. Andriankaja (3)*

(1) McGill University (2) Arts et Metiers ParisTech, I2M (3) U. Bordeaux, I2M

** I2M - UMR 5295 - Arts et Métiers ParisTech, F-33400 Talence, France - nicolas.perry@ensam.eu*

Keywords: manufacturing process, information model, STEP

ABSTRACT

Environmental performances need product, processes and life cycle modeling and evaluations. There is direct need of assessment tools to monitor and estimate environmental impact generated by different types of manufacturing processes. Indeed, eco design and products optimizations can be done with the manufacturing process choices. But the manufacturing systems are very complex and they are driven by physicals laws that are heavy to model. This research proposes a manufacturing informatics framework for the assessment of manufacturing sustainability based on an EXPRESS information model developed to represent sustainability information. It is the first step of association of sustainability information with product design specification. In the next phase of research, investigation will be conducted to integrate sustainability information model and existing standardized product design model ISO 10303 AP 242.

INTRODUCTION

The manufacturing industry is often cited as the cause of many environmental and social problems, yet it is acknowledged as the main mechanism for change through economic growth (Baldwin 05). Industry is confronted with the challenge of designing sustainable products and manufacturing processes. Many sustainable development strategies have been proposed by government agencies and academia since the late 1990s. Research in sustainable manufacturing field can be categorized into the following four main themes (Mayyas 2012, Ashby 2009, Barker 2007, Govetto 2008, Perry 2012, Vijayaraghavan 2010): a) Life-Cycle Assessment (LCA), b) design-for-X principles and design for sustainability, c) end-of-life studies, and d) energy efficiency monitoring and studies. But it remains a lack of manufacturing system and sustainability information integration hampers the widespread adaptation of the best sustainability practices in the manufacturing industry.

INFORMATION MODELS OF PRODUCT DESIGN AND MANUFACTURING PROCESSES

In recent years, information technology has become increasingly important in the manufacturing enterprise. Effective information sharing and exchange among computer systems throughout a product's life cycle has been a critical issue (ITM 1995, Lee 1999). An information model is a representation of concepts, relationships, constrains, rules, and operations to specify data semantics for a chosen domain of discourse. Amongst these information models, the STEP and STEP-NC information models are the most advanced and standardized ones, developed by ISO committee to provide the basis for product design, machining standardization, and integration of part inspections with machining. The information is modeled in EXPRESS language. STEP Application Protocol (AP) 203 editions 1 & 2 (ISO10303 1994, 2007 & 2009) (Configuration Controlled 3D Designs of Mechanical Parts and Assemblies) provides the data structures for the exchange of configuration-controlled 3D designs of mechanical parts and assemblies. AP 203 comes from ISO 10303 product data standard, and is not a data standard for configuration management of a product throughout its entire life cycle. The AP is centered on the design phase of mechanical parts and the high-level information entities.

PROPOSED MANUFACTURING INFORMATICS FRAMEWORK FOR THE INTEGRATION OF LCA AT DESIGN STAGE

In order to integrate LCA information into the product design stage, necessary information must be properly represented and associated to the product PLM information. In the proposed research, a case study was first conducted to examine what LCA information should be modeled. Composite parts give interesting examples on a simple piece such as a pedal crank developed with recycled carbon fibers for thermoset organic matrix composite as shown in Figure 3. During the design, product models have to integrate materials information such as matrix composition, reinforcement type (glass, carbon, aramid, and natural), their architecture (unidirectional, woven) and the structure composition (orientations of the different layers in the depth of the product). Other information like inserts or coating completes the bill of material. Currently in STEP AP 203, only very limited material information is modeled as shown in the following entities in table 1. To associate composite material information to a product design, the following entities were developed in this research. The new entities are written in bold-italic.

Figure 1: pedal crank made with recycled Carbon Fibers (developed at I2M) (Perry 2012)]

```
ENTITY Material_identification;
   material_name : STRING;
   items : SET[1:?] OF material_item_select;
END_ENTITY;

TYPE material_item_select = SELECT
   (Anisotropic_material,
    Braided_assembly,
    Coating_layer,
    Isotropic_material,
    Laminate_table,
    Part_view_definition,
    Substance_view_definition,
    Woven_assembly);
END_TYPE;

ENTITY Composite_material_identification
   SUBTYPE OF (Material_identification);
DERIVE
   composite_material_name : STRING :=

SELF\Material_identification.material_name;
END_ENTITY;

TYPE material_item_select = SELECT
```

```
ENTITY composite_matrix
ABSTRACT SUPERTYTPE OF (ONEOF (mud, cement,
polymers, metals, ceramics));
   name:                STRING;
END_ENTITY;

ENTITY composite_resin ABSTRACT SUPERTYPE
OF (ONEOF (polyester_resin,
vinylester_resin, epoxy_resin,
shape_memory_polymer_resin));
   name:                STRING;
   material_property:   STRING;
END_ENTITY;

ENTITY composite_reinforcement
ABSTRACT SUPERTYOP OF (ONEOF (glass_fibre,
carbon_fibres, aramid_fibres,
boron_fibres));
   name:                STRING;
   architecture:        fibre_architecture;
END_ENTITY;

ENTITY fibre_architecture;
ABSTRACT SUPERTYPE OF (ONEOF
(short_fibre_reinforced,
```

`(Anisotropic_material,`
`Braided_assembly,`
`Coating_layer,`
`Isotropic_material,`
`Laminate_table,`
`Part_view_definition,`
`Substance_view_definition,`
`Woven_assembly`
`Composite_material);`
`END_TYPE;`
	`continuous_fibre_reinforced));`
	`name:                STRING;`
	`direction:           fibre_directions;`
	`END_ENTITY;`
	
	`ENTITY fibre_directions;`
	`SUPERTYPE OF (ONEOF (continuous_aligned,`
	`discontinuous_aligned, discontinuous_random,`
	`unidirectional, woven));`
	`END_ENTITY;`

Table 1: STEP AP203 entities enriched with composites material information

Manufacturing data must also been included in order to ensure the product / material / process combined design in the case of composite parts. Promoting recycled carbon fibers eco-design (Perry 2010) imposes to access to material data (from end of life scenario and properties) at the early stage of the design. It means developing specific data storage for material properties (depending to the recycling process) and properties models prediction (based on the different type of fibers) as illustrated on Figure 2.

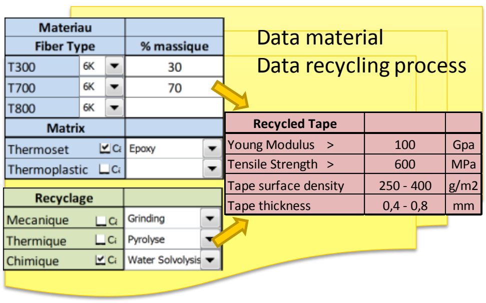


Figure2: Recycling End of Life scenario and product/material properties evaluation tool.

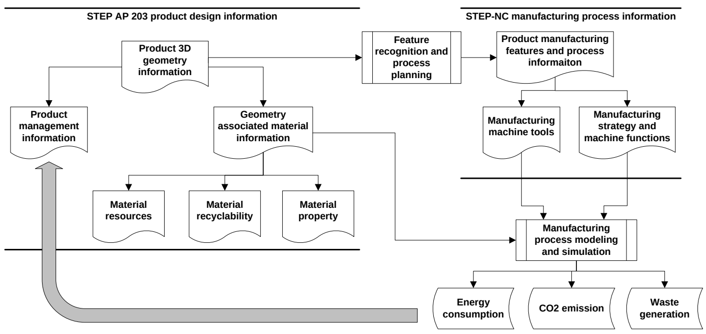


Figure3:Proposed information framework for integrating LCA in product design stage

Currently in STEP AP 203, the limited material information, shown above in unbolt entities, is not associated to design geometry. The material information is defined only for annotation display. In order to fully integrate material information with design process, the association between product geometry and its material must be semantic. Today no integrated environment allows taking all these facets into consideration. And the next step is to compare, for an expected set of functions, the n-plet (Mayyas 2012) in order to optimize both technically, but also environmentally with specific focus such as material resources minimization (mix of less material and improved end of life possibilities), energy optimization and/or pollution reduction. These multi objective optimization needs to handle all these data, models, life stages, functional unit definition in a coherent environment and at the early stage of product development. STEP and STEP-NC is the most suitable information structure framework that needs to be enriched by the environmental aspects of the product/process data as shown in Figure 3. Eventually, with the proposed information framework, LCA related information is integrated to the design and process planning aspects of product development. The LCA knowledge and data accumulated throughout a product life cycle can be fed back to the product design stage to improve new product development and to reduce environmental impact.

FUTURE WORK AND CONCUSIONS

The research reported in this paper is the very beginning stage of developing an information framework to support the integration of LCA at the product design stage. A simple case study was conducted to examine what composite material information should be defined in association with product design information. The next steps of the proposed research are for the data structure level: i) identify the Product Life Phases needs in terms of environmental data versus the existing data into STEP, ii) identify a dynamic ontology of environmental data for product development, iii) structure the data and evaluation models to propose, usable simulation results for decision making, and iv) propose a STEP extension for End of Life support. For the data acquisition level: i) low level implementation (at the process level for the manufacturing phase) in order to enrich STEP with environmental concepts and start creating data base for process evaluation and optimization, ii) develop design approach and integrated tools specification based on STEP.

Sustainable product design and manufacturing is the future of today's manufacturing industry. The lack of manufacturing system and sustainability information integration hampers the widespread adaptation of the best sustainability practices in the manufacturing industry. In order to provide product designer with comprehensive material and environmental related information at the design stage, a complete information structure must be developed to associate sustainability information with product design information and product manufacturing process. This research proposes to develop such an information framework based upon STEP and STEP-NC information models. An initial case study was conducted to identify composite material information that should be defined for product design.

REFERENCES

Baldwin, J.S., et al., Modelling manufacturing evolution: Thoughts on sustainable industrial development. Journal of Cleaner Production, 2005. 13(9): p. 887-902.

Mayyas, A., et al., Design for sustainability in automotive industry: A comprehensive review. Renewable and Sustainable Energy Reviews, 2012. 16(4): p. 1845-1862.

Ashby, M., et al., Life-cycle cost analysis: Aluminum versus steel in passenger cars. Materials and the Environment, 2009: p. 161-245.

Barker, S. and A. King, Organizing reuse managing the process of design for remanufacture (DFR). POMS 18th Annual Conference, 2007.

Govetto, S., et al., End-of-life vehicle recycling based on disassembly. Determining the Environmental Impact of Disposal, Recycling and Remanufacturing Strategies, 2008. 12(2): p. 153-156.

Perry, N., et al., Improving design for recycling - Application to composites. CIRP Annals - Manufacturing Technology, 2012. 61(1): p. 151-154

Vijayaraghavan, A. and D. Dornfeld, Automated energy monitoring of machine tools. CIRP Annals - Manufacturing Technology, 2010. 59(1): p. 21-24.

ITM (Information Technology for Manufacturing), in National Research Council Report. 1995, National Research Council

Lee, Y.T., An overview of information modeling for manufacturing systems integration, in NISTIR 6382. 1999, National Institute of Standards and Technology.

ISO, ISO 10303-1: Industrial automation systems and integration - Product data representation and exchange - Part 1: Industrial Automation System and Integration - Product Data Representation and Exchange Part 1: Overview and Fundamental Principles. 1994.

ISO, ISO 10303-203: Industrial automation systems and integration - Product data representation and exchange - Part 203: Application Protocols: Configuration controlled 3D design. 2007.

ISO, ISO 10303-203:2009: Industrial automation systems and integration - Product data representation and exchange - Part 203: Application protocol: Configuration controlled 3D design of mechanical parts and assemblies. 2009.

Perry, N. and W. Uys, Knowledge integration based on road mapping and conceptual framework approach to ease innovation management. IJCAT, 2010. 37(3-4): p. 165-181.

Mayyas, A., et al., Using Quality Function Deployment and Analytical Hierarchy Process for material selection of Body-In-White. Environmental Product Declaration, 2011. 32(5): p. 2771-2782.

LIFE HAPROWINE: WINE SUSTAINABLE PRODUCTION

Soledad Gómez Jesús Angel Díez, Marta Cano - Fundación Patrimonio Natural de Castilla y León. Lorena Pereda, Rocío Clemente, Marta López, Yolanda Núñez - Fundación Centro Tecnológico de Miranda de Ebro. Cristina Gazulla - UNESCO Chair in Life Cycle and Climate Change (ESCI-UPF). Viviana Carrillo, Flora D'Souza, Alexander Liedke – PE International.*

**Edificio PRAE C/ Cañada Real 306. 47008 Valladolid. España soledad.gomez@patrimonionatural.org*

Keywords: BATs; Sustainable Production; Vineyard; Wine Elaboration.

ABSTRACT

One of the most ambitious goals of the European project LIFE HAproWINE (LIFE08/ENV/E/000143) is to achieve sustainable production both in the vineyard and at the winery. In this sense, a set of technological alternatives has been identified and assessed from an environmental and economic point of view, with the aim of establishing a prioritization to determine 'the sustainable production'. Thus, a new methodology has been developed in order to get the prioritization of diverse techniques and alternatives for different processes.

All this work is based on the information collected from the participating wineries in the project, located in Castilla y León region (Spain), and from the members of the HAproWINE Stakeholders Advisory Committee.

INTRODUCTION

The sustainability of vineyard and wine elaboration processes can be improved by using techniques which are able to optimize the energy efficiency and to reduce the inputs, as well as the outputs leading to a reduction in volume of waste for recuperation or recycling. In order to obtain environmental benefits, old equipment can be replaced by new one. However, any renewal is likely to entail additional costs for many wineries, not only due to the possible economic investment required for its implementation but also to costs associated with updating the production line or because of new training needs related to changes in the processing operations. Therefore, when evaluating the different techniques it is necessary to achieve a sustainable balance between the industrial process, product quality, economic development and consumption of resources (economic costs, time of adequacy, etc.).

The purpose of this study is to carry out a prioritization or sequential classification of the technologies involved in the wine making process. In order to define sustainable production in the vineyard and at the winery, technologies that are currently available in the market, and technologies established in Castilla y León have been analysed from an environmental and economic point of view.

The compiled information has allowed the analysis of environmental feasibility of the best available techniques (BATs), which were identified on the basis of the most significant environmental aspects and "in situ" winery data. BATs are defined in Directive IPPC. Art.3.10. (The European Parliament, 2010) as the "*most effective and advance stage in the development of an activity and its methods of operation, which indicate the practical suitability of particular techniques for providing, in principle, the basis for emission limit values designed to prevent or eliminate or, where that is not practicable, generally to reduce an emission and its impact on the environment as a whole*".

A study of the environmental load for each of the considered techniques is carried out, using for this purpose commercial environmental databases. Thus, the environmental profile of each technique is obtained through the evaluation of different impact categories, by applying the Life Cycle Assessment (LCA) methodology. On the other hand, economic load has been quantified, taking into account both investment and annual operating costs, for each one of the techniques and on the basis of information collected in 2010 from diverse collaborators in Castilla y León.

MATERIALS AND/OR METHODS

Environmental methodology

The impact assessment of the selected techniques is carried out applying the LCA methodology to the inventory data. Inventory flows are classified according to their potential effect on the impact categories and the indicator results for these categories are calculated at the characterization stage. The optional stages of normalization and weighting are not considered, because they bring subjectivity to the study.

LCA study has focused on the use phase, excluding infrastructure, of each analysed process in order to define indicators which allow the prioritization of best available techniques (Figure 1). The work team has selected CLM 2001 (Guinée, 2002) as evaluation method at the software SimaPro 7 and has used the environmental information gathered in Ecoinvent database (Frischknecht et al., 2005).

Economic methodology

The economic load for each technique was calculated considering investment in machinery and equipment as well as costs incurred during their use or maintenance in the first year. This economic information was provided by Spanish suppliers of the wine sector.

BATs Prioritization methodology

The prioritization methodology is based on the results of applying both economic and environmental methodologies. For the environmental assessment, only "global warming" category has been considered, given the current importance of carbon footprint indicator. This category assesses the impact of the greenhouse gases quantified in kilograms of carbon dioxide equivalent.

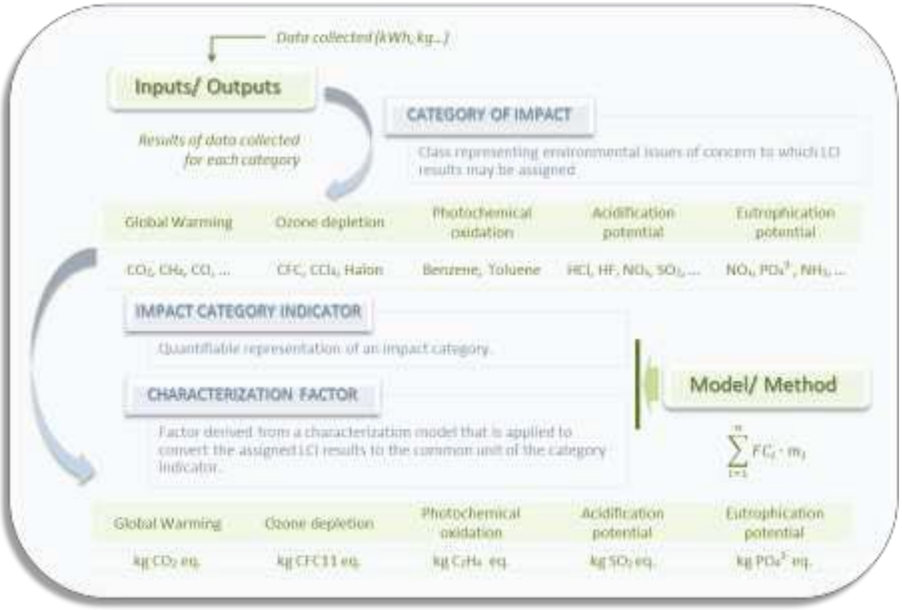


Figure 1. Scheme of the characterization process (CTME, 2012).

To apply the prioritization methodology, it was necessary to establish the reference techniques for each process, which is defined as the most common and usual technique in the sector, regardless the size of the winery. For this process, information collected from wineries and from meetings with the Stakeholder Group of the LIFE HAproWINE project, together with bibliographic information, was used. Each selected technique was compared with the reference technique with the objective of identifying those that improve the reference values and those less favoured according to the set of environmental and economic criteria. Mathematically, this methodology can be described as shown below.

N, set of k alternatives; P, set of i processes and R, set of reference techniques

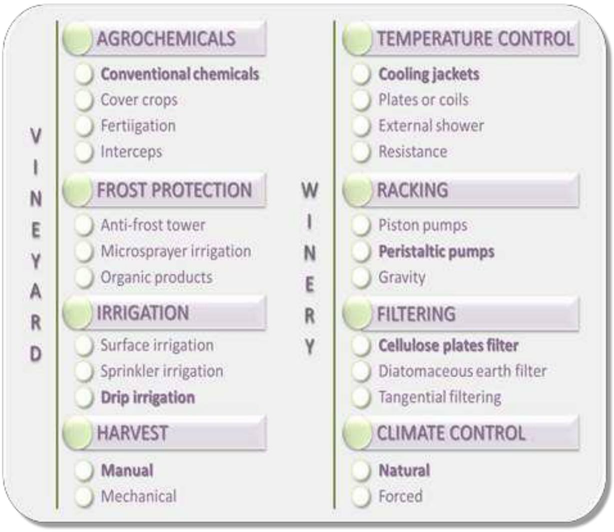
$$\forall\ i \in P \ is\ selected\ k\ \in N, and$$

$$\left(\frac{€_i}{\sum_{i=1}^{n} €_i} \times 100 + \frac{CO_{2\,i}}{\sum_{i=1}^{n} CO_{2\,i}} \times 100\right)_{Ref} - \left(\frac{€_i}{\sum_{i=1}^{n} €_i} \times 100 + \frac{CO_{2\,i}}{\sum_{i=1}^{n} CO_{2\,i}} \times 100\right)_{k} \rightarrow T_i$$

Prioritization of the alternatives is achieved based on the obtained values of T_i, where T_i is the rating obtained by each technique.

$$T_{k1} \geq T_{k2} \geq T_{k3} \geq \cdots \geq T_{kn}$$

Figure 2 presents the studied techniques and the reference technique for each process. The reference technique is highlighted in bold, except in the category “frost protection”, where the Reference Technique is “no technique”.



N={conventional chemicals, interceps, cover crop, fertigation, without any frost protection system, anti-frost-tower, micro-sprinkler, organic products for protection against frost, without irrigation system, surface irrigation, sprinkler irrigation, drip irrigation, manual harvesting, mechanical harvesting, cooling jackets, plates – coils, external showers, resistances, piston pump, peristaltic pump, gravity, cellulose plates, diatomaceous earths, tangential filtering, natural climate, forced climate}

P={agrochemicals, frost protection, irrigation, harvesting, control of temperature in tanks, racking, filtering, climate control}

R={conventional chemicals, no technique frost protection, drip irrigation, manual harvesting, cooling jackets, peristaltic pumps, filter plates, natural climate}

Figure 2. Studied techniques - Wine sector of Castilla y Léon (CTME, 2012).

RESULTS AND CONCLUSIONS

Techniques responsible for minimising the impact were determined, considering techniques with minimum values in the economic and in the environmental evaluation at the same time (Figure 3).

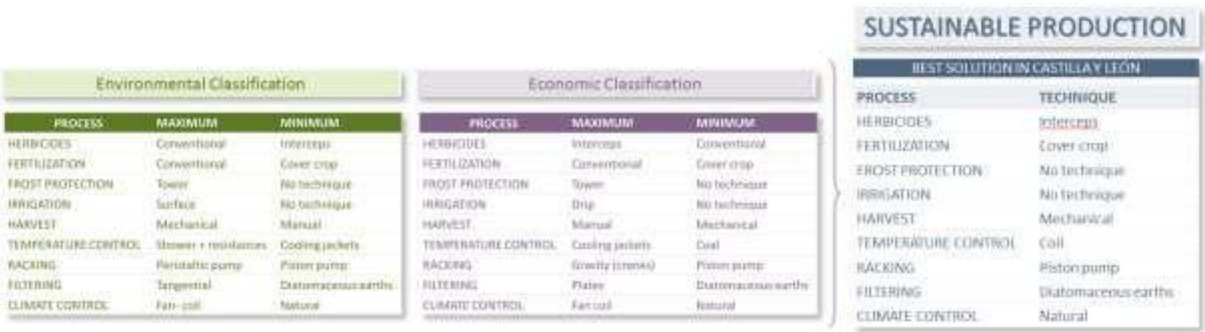


Figure 3. Sustainable vineyard and wine elaboration processes (CTME, 2012).

In conclusion, it can be said that the principal benefits, as expected, fall on those techniques that can be avoided and therefore, that are not present in all wineries, such as frost protection systems, irrigation systems and climate control systems. Thus, it is also observed that there are not significant changes based on the size of wineries.

REFERENCES

The European Parliament and the Council of the European Union (2010). Directive 2010/75/EU of the European Parliament and the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control). Official Journal of the European L 334/17 (17.12.2010).

Guinée, J. B. (Ed.). (2002). *Handbook on Life Cycle Assessment - Operational Guide to the ISO Standards. Series: Eco-efficiency in industry and science*. Kluwer Academic Publishers. Dordrecht.

Frischknecht, R. et al (2005). The ecoinvent Database: Overview and Methodological Framework. *International Journal of Life Cycle Assessment*, 10(1), 3-9.

MANAGING ENVIRONMENTAL SUSTAINABILITY IN THE TEXTILE SUPPLY CHAIN

Mireille Faist Emmenegger[1], Katharina Meyer[2], Michela Gioacchini[2], Daniele Massetti[2], Heinz Zeller[2], Rainer Zah[1]*

[1] Empa / Quantis Switzerland/Germany [2] HUGO BOSS Ticino SA
**Quantis Switzerland / Germany, glaTec Technology Center, Überlandstrasse 12 ,8600 Dübendorf, Switzerland.*

Keywords: textiles; environmental sustainability; LCA

ABSTRACT

The project EcoLogTex will deliver a methodology and a tool to evaluate alternatives for textile supply chains taking into account the environmental impact through Life Cycle Assessment (LCA), plus costs and timing, thus satisfying corporate social responsibility constraints. The results of this project will allow textile companies to efficiently optimize their supply chains and suppliers to benchmark themselves.

An essential requirement for the tool is to study textile production pathways and determine data gaps. To this aim we prepared specific questionnaires for every productive step, tested them and collected data from suppliers along the supply chain, starting from the fiber production up to the assembly of a finished garment. In this paper we present first results of the suppliers' assessment.

INTRODUCTION

The project EcoLogTex will deliver a new methodology and a tool to evaluate alternatives for textile supply chains taking into account the environmental impact through Life Cycle Assessment (LCA), plus costs and timing, thus satisfying corporate social responsibility constraints. The results of this project will allow textile companies to efficiently optimize their supply chains and suppliers to benchmark themselves (Rizzoli et al. 2013).

LCAs of textile products typically show, on the one hand, that the use phase accounts for the highest relative contribution to the environmental impacts (e.g. (Cotton Inc. 2012), (Laursen et al. 2007), (Cartwright et al. 2011)). On the other hand, many studies (among other those previously cited) also indicate that there is much room for improvement in the production phase of textiles (see also (van der Werf and Turunen 2008), (Franov 2009), (Nielsen and Nielsen 2009)). On the whole, however, only few data on textile LCA is publicly available.

An essential requirement for the tool was therefore to study textile production pathways and determine the areas where data is needed, in order to plan and realize a high quality data collection. To this aim we prepared specific questionnaires for every productive step, tested them and collected data from suppliers along the supply chain, starting from the fiber production up to the assembly of a finished garment. In this paper we present first results of the suppliers' assessment.

MATERIALS AND METHODS

The suppliers received questionnaires which they filled with data from their company. This data includes energy, chemical and water use, waste as well as emissions in water and air. After verifications of plausibility and interaction with the suppliers for correction and/or completion of data, the values were modeled into an inventory using the ecoinvent database v2.2 (www.ecoinvent.org) for background data.

Suppliers along the whole textile chain were asked to fill in data. The main steps in the chain (each step corresponding to a questionnaire) are the following – the order is not fixed as some processes can happen at different stages of the chain: cotton cultivation resp. sheep farming, scouring (wool), mercerizing, bleaching and dyeing, spinning, knitting, weaving, finishing, assembly.

The questionnaires are used as online forms in the EcoLogTex tool (Rizzoli et al. 2013). The tool defines modeling of emissions (mainly for the agricultural step, for example the nitrate leaching in cotton cultivation or the methane emissions from sheep farming), allocation rules and normalization to the functional unit.

For the evaluation of the companies, nine midpoint indicators following the recommendations of ILCD (EC-JRC 2011) have been chosen. These are global warming potential, water depletion, freshwater eutrophication, marine eutrophication, acidification, freshwater toxicity, human toxicity, land use and abiotic resource depletion.

RESULTS

The following picture shows draft results for two European spinning mills, spinning mill 1 and spinning mill 2. Spinning mill 1 processes mainly cotton fibres, spinning mill 2 mainly wool fibres. The main impacts' contributors are indicated in the diagram. The upstream processes for the fibre production are not included; only the transport of the fibre is taken into account.

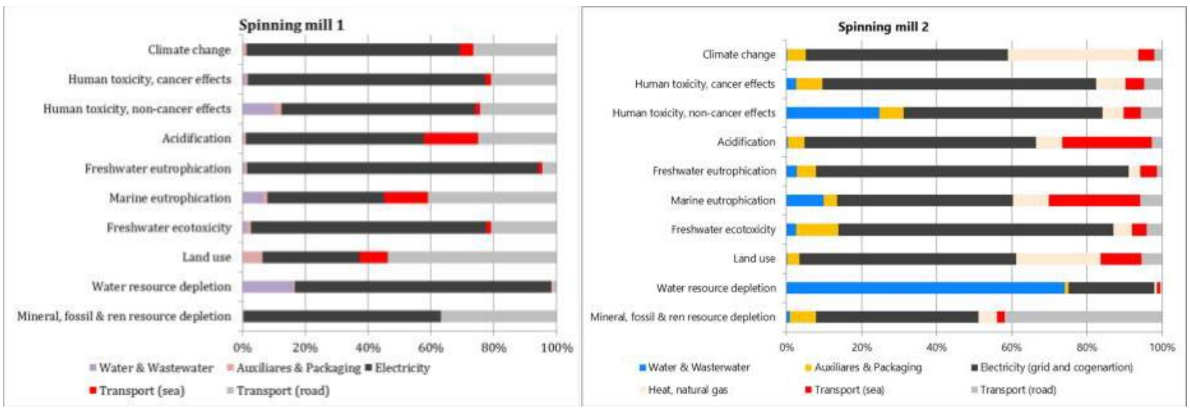


Figure 1: Results of selected indicators for two European spinning mills. The assessment includes the transport of the fiber but not its production.

Main contributors for the impacts in all categories for spinning mill 1 are electricity use and transports of spinning mill 1. Water use and wastewater disposal as well as packaging and auxiliaries account for no more than 17% of the impacts in all indicators. The results for spinning mill 2 show a similar pattern, with energy and transports being the most important contributors again. However, in this case, the water use is higher and influences the results more. This higher consumption can however not be attributed only to the different fibre but also to different production methods.

The following picture shows the Global Warming Potential (GWP) results for 4 spinning mills: C1 (processing mainly cotton, located in Asia), C2 (cotton, Europe), W1 and W2 (both: wool, Europe). The results show that for the same type of fibre processed, the results can vary greatly.

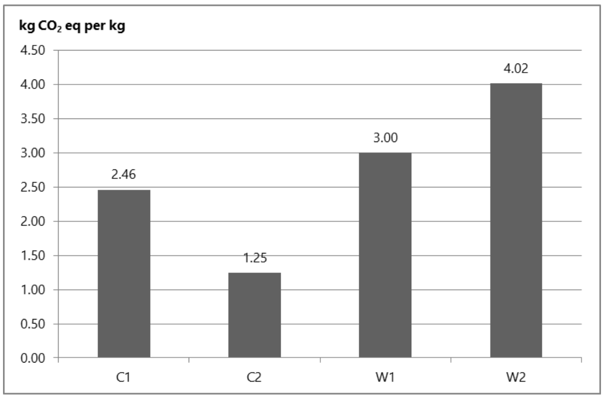


Figure 2: GWP results for four spinning mills using cotton (C1 and C2) and wool (W1 and W2). The assessment includes the transport of the fibres but not their production.

The inclusion of the fibre in the assessment in the case of C2 shows the great importance of the cotton cultivation process for all indicators, as we can see in figure 4.

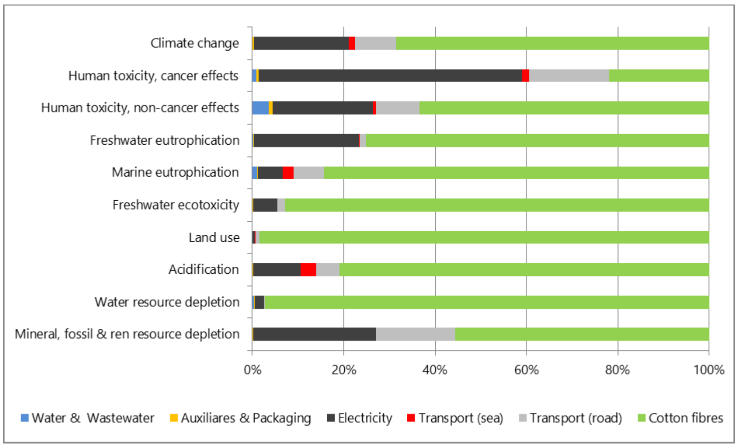


Figure 3 Results of selected indicators for a European spinning mill. The assessment includes the transport of the cotton and its production.

DISCUSSION AND CONCLUSIONS

One main difficulty of this type of assessment is to have the questionnaires understood and filled in correctly by the suppliers. At the present stage much effort has been invested to answer questions received from the suppliers, adapt the questionnaires to make them more comprehensible and easier to be answered. The testing phase of the questionnaires was also longer than planned as the contacts between Hugo Boss and suppliers operating at the beginning of the supply chain (which usually are not direct contacts) had first to be established. Furthermore, the lapse of time between sending out the questionnaires and receiving them back filled amounted to several months. After that, additional time was needed to clarify answers and obtain still missing ones. The evaluation of questionnaires shows that for the same process, here spinning, the results can vary greatly. In the case of the spinning mills, the electricity use and the transport of the fibre greatly influence the results.

This approach allows a thorough assessment of the environmental impacts of suppliers, who thereby also receive an interesting feedback on their activities. The environmental performance can be used as a criterion in the choice of the supplier as well as in the design of the product. However, enough support must be provided to the company answering the questionnaire to ensure the quality of the data.

REFERENCES

Cotton Inc. (2012). The life-cycle inventory & life cycle assessment of cotton fiber & fabric: Executive Summary. *Cotton Incorporated: Cary, USA.*

Cartwright, J., et al.. (2011). Assessing the environmental impacts of industrial laundering: Life cycle assessment of polyester/cotton shirts. *Donald Bren School of Environmental Science and Management, University of California: Santa Barbara, USA.*

EC-JRC European Commission-Joint Research Centre - Institute for Environment and Sustainability. (2011). International Reference Life Cycle Data System (ILCD) Handbook- Recommendations for Life Cycle Impact Assessment in the European context. *First edition November 2011. EUR 24571 EN. Luxemburg. Publications Office of the European Union*

Laursen, S.E., et al.. (2007). EDIPTEX – Environmental assessment of textiles. Working Report No.24. *Danish Ministry of the Environment: Copenhagen, Denmark.*

Rizzoli, A. E., Zeller, H., Faist, M., Montemanni, R., Gioacchini, M., & Nembrini, N. (2013). EcoLogTex: a software tool supporting the design of sustainable supply chains for textiles. *Information and Communication Technologies, 138*.

van der Werf, H.M.G. and L. Turunen. (2008). The environmental impacts of the production of hemp and flax textile yarn. *Industrial Crops and Products. 27(1): p. 1-10*.

METHODOLOGICAL ISSUES IN LCA OF WASTEWATER TREATMENT COMBINED WITH PHA BIOPOLYMER PRODUCTION

Sara Heimersson[a], Magdalena Svanström[a], Fernando Morgan-Sagastume[b], Gregory Peters[a], Alan Werker[b]*

[a]Chemical Environmental Science, Chalmers University of Technology, Sweden. [b]AnoxKaldnes AB, Sweden
**Corresponding author: Kemivägen 10, SE-412 96 Göteborg, Sweden*
sara.heimersson@chalmers.se

Keywords: Life cycle assessment; polyhydroxyalkanoates; system boundaries; allocation; bio-production.

ABSTRACT

Production of polyhydroxyalkanoates (PHAs) by mixed microbial cultures utilising the organic content of wastewaters is one of the technologies studied in the EU project ROUTES. When comparing the life-cycle environmental impacts of simultaneous wastewater treatment and production of PHA-rich biomass to traditional wastewater and solids treatment, the handling of this multi-functionality is critical for the results. Only one LCA of such a system has been found in the literature. The current paper identifies substitution and allocation based on chemical oxygen demand removal as two possible options to account for the multi-functionality of the system. Examples based on literature data were used to show that for global warming potential, the choice of allocation method can substantially affect the results.

INTRODUCTION

Polyhydroxyalkanoates (PHAs) are thermoplastic polymers of increasing interest since they are biodegradable and can be produced from renewable resources, e.g. crops and organic wastes, which are also cheaper feedstocks. To date, PHA production with pure cultures is the most common approach but the interest in mixed-culture PHA production is increasing due to its lower demands on sterility, equipment and control (Chanprateep, 2010).

In the project “ROUTES – Novel processing routes for effective sewage sludge management” under the EU seventh framework programme, PHA production by mixed cultures in tandem with municipal wastewater (WW) and sludge treatment is one of the technologies under study (Braguglia et al., 2012). Volatile fatty acids, produced from sludge acidogenic fermentation, are utilised for PHA production by activated sludge biomass with increased PHA-accumulation capacity. The PHAs can be recovered from the polymer-rich biomass, either on-site or elsewhere. In the ROUTES project, municipal WWT with simultaneous production of PHA-rich biomass is compared to a reference wastewater treatment plant (WWTP) using life cycle assessment (LCA), in order to gain insights into the potential environmental impacts of the process and its units. However, such a comparison faces methodological challenges, in particular the need to account for the added function of PHA generation. This problem is aggravated by the state of development of the technology, which is currently being prototyped at pilot scale. Full-scale applications are only foreseen in the future. Therefore, the amount of environmentally relevant data available in the literature is limited and actual process designs integrated into local infrastructures cannot be fully specified.

Despite these challenges, doing LCAs on technologies that are under development has a value since environmental hotspots can be identified from which further process development can be optimised and potential areas of application with improved environmental performance can be identified. This work discusses approaches for dealing with the multi-functionality of systems producing value-added by products, such as PHAs, from required waste management services, such as wastewater treatment (WWT).

METHOD

The method applied in this study includes an identification of appropriate allocation and substitution approaches in LCA of PHAs generated in WWT, using inputs from earlier experiences reported in the literature. The importance of the choice of allocation/substitution method is illustrated using an example system of mixed-culture PHA production integrated with industrial WWT.

The functional unit for the example system was chosen to be ‘treatment of 500 kL WW inflow to the WWTP per day’. A gate-to-gate approach was used for the illustrative example, as the generation and collection of the WW and treatment of the residues after polymer recovery are not relevant for the studied allocation/substitution approaches in the illustrative example, nor are in focus in the technical development work in the ROUTES project.

Few LCA studies on PHA production are available in the scientific literature. For mixed-culture PHA production, only one study has been published (Gurieff and Lant, 2007), assessing only global warming potential (GWP). A summary of available literature on LCAs of PHA production can be found in Heimersson et al. (2013). Integrated WWT and PHA production was therefore based on the model system from Gurieff and Lant (2007) with production of inputs modelled for European conditions using Gabi 5 Professional database (PE International). Two alternative substitution products are modelled: (1) PHA-rich biomass from pure culture production from corn as modelled by Akiyama et al. (2003), with input data from Renouf et al. (2008) for monosaccharide production, both with production of inputs modelled for European conditions using Gabi 5 Professional database and (2) High-density polyethylene (HDPE) for German conditions from Gabi 5 Professional database. As the future main application area and actual function of PHA in relation to alternatives are unsure, 1 kg PHA is assumed to replace 1 kg HDPE in the illustrative example, to show the potential of replacing one possible oil-based polymer. Other polymers or PHA-containing products could also be eventually considered.

RESULTS AND DISCUSSION

The issue of multi-functionality in the studied system can be handled in two ways: substitution of additional functions by other means of providing the same function, or allocation of impacts between WWT and additional functions, based on e.g. physical or economic basis.

Substitution was applied by Gurieff and Lant (2007) in their LCA comparison of WWTPs producing either PHA or biogas. They assumed that the produced PHA replaced an equal amount of HDPE. In the study, the PHA recovery process was not modelled specially for mixed-culture PHA production, but instead it was based on simulated data produced for an economic analysis by Van Wegen et al. (1998). The lack of process data on PHA recovery modelled specially for mixed-culture applications adds uncertainty to the LCA.

A review by Heimersson et al. (2013) showed that almost all data on PHA recovery processes in published LCA studies refer directly or indirectly to (often about ten year-old) simulated data. Furthermore, in our study the likely application area for the PHA was not known, adding another level of uncertainty to the assessment. In the ROUTES case, PHA recovery could be placed either inside or outside of the system boundaries. If the recovery is placed inside the system boundaries, recovered PHA is leaving the system and could be assumed to replace another polymer, e.g. the marginal polymer in the studied area based on economic or environmental criteria, often a petrochemical-based polymer. But if the recovery is placed outside of the system boundaries it is the PHA-rich biomass that should be replaced. This could be a reasonable option since data availability on PHA recovery and the use phase of the PHA is low, although this limits the substitution possibilities to other PHA-rich biomass streams, i.e. pure culture production from grain.

Allocation made on a monetary basis should at this stage be avoided, due to the large uncertainty in terms of the value of PHA or PHA-rich biomass on the emerging PHA market. A physical allocation requires a common physical unit for the WWT function and the PHA-production function. No such unit is obvious, but an allocation between the functions of WWT and of production of PHA-rich biomass based on chemical oxygen demand (COD) removal by the processes has been suggested by Heimersson et al. (2013), for a study in which both PHA (main function, reflected in the functional unit) and WWT (by-function) is performed by the system. This way of allocating focuses on the WWT function and in particular the COD removal function of the process.

Figure 1 shows the influence on the results of different choices regarding the substitution or allocation methods. The figure contains just a few examples of possible substitutions; however, more options can be explored, for example PHA-rich streams from other feedstocks and other oil-based and renewable alternatives to PHA. Nevertheless, the results do show that the influence of choice of substitution/allocation approach on the overall result can be substantial. The net impact can even be negative if substitution is applied and the biopolymer recovery is left out of the studied system. In Figure 1, only GWP is shown. The substitution/allocation approach could potentially put focus on the assessment of different impact categories, e.g. as the replacement of a grain-based PHA-rich stream could increase the importance of assessing categories like eutrophication and toxicity that have shown to be significant when assessing agricultural products.

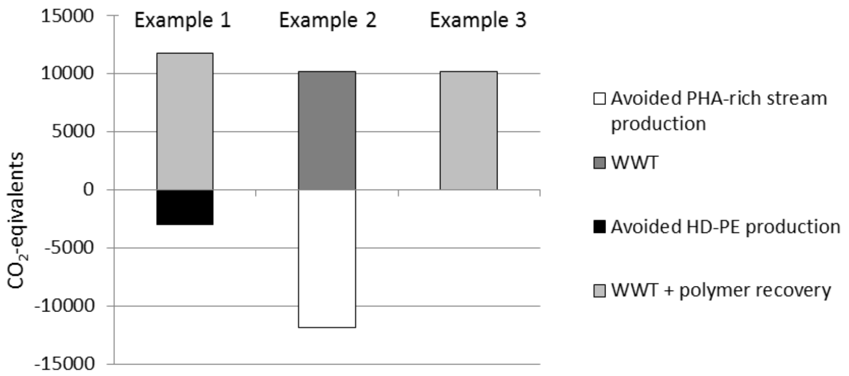


Figure 1. Three different ways of accounting for the additional PHA-producing function of the studied WWT system: (1) PHA substituting HDPE (with polymer recovery included in the system) (2) the PHA-rich biomass substituted by a similar stream from pure culture fermentation of corn (with polymer recovery excluded from the system) and (3) COD allocation with recovery included in the studied system.

CONCLUDING REMARKS

This paper has shown that selecting an accounting approach for additional functions is a delicate issue in the case of simultaneous PHA production and WWT. Accounting for the generated PHA by substitution by polymer or polymer-rich stream or even a COD removal based allocation is shown to be important for the overall results. The influence of the choice of approach should preferably be investigated in a quantitative sensitivity analysis.

ACKNOWLEDGEMENTS

This work was supported by the EU ROUTES project (Contract No 265156, FP7 2007-2013, THEME [ENV.2010.3.1.1-2] Innovative system solutions for municipal sludge treatment and management).

REFERENCES

Akiyama, M., Tsuge, T. & Doi, Y. 2003. Environmental life cycle comparison of polyhydroxyalkanoates produced from renewable carbon resources by bacterial fermentation. *Polymer Degradation and Stability,* 80**,** 183-194.

Braguglia, C., Gianico, A. & Mininni, G. 2012. ROUTES: innovative solutions for municipal sludge treatment and management. *Reviews in Environmental Science and Biotechnology,* 11**,** 11-17.

Chanprateep, S. 2010. Current trends in biodegradable polyhydroxyalkanoates. *Journal of Bioscience and Bioengineering,* 110**,** 621-632.

Gurieff, N. & Lant, P. 2007. Comparative life cycle assessment and financial analysis of mixed culture polyhydroxyalkanoate production. *Bioresource Technology,* 98**,** 3393-3403.

Heimersson, S., Morgan-Sagastume, F., Peters, G., Werker, A. & Svanström, M. 2013. Methodological issues in life cycle assessment of mixed-culture production of polyhydroxyalkanoates using wastes as feedstock. *Accepted for review in New Biotechnology*.

Renouf, M. A., Wegener, M. K. & Nielsen, L. K. 2008. An environmental life cycle assessment comparing Australian sugarcane with US corn and UK sugar beet as producers of sugars for fermentation. *Biomass and Bioenergy,* 32**,** 1144-1155.

Van Wegen, R. J., Ling, Y. & Middelberg, A. P. J. 1998. Industrial production of polyhydroxyalkanoates using escherichia coli: An economic analysis. *Chemical Engineering Research and Design,* 76**,** 417-426.

TOLERANCE OPTIMIZATION FOR ECONOMIC AND ECOLOGICAL SUSTAINABILITY USING RD&T

Steven Hoffenson, Andreas Dagman, Rikard Söderberg, Bengt Steen*

Chalmers University of Technology
**Hörsalsvägen 7A, 412 96 Göteborg, Sweden, stevenh@chalmers.se*

Keywords: tolerance specification; variation propagation; sustainability; life cycle assessment; multi-objective optimization.

ABSTRACT

Product developers choose tolerances to go along with every geometric dimension, and they typically do so based on how the tolerances influence variation in so-called “critical” dimensions of the final assembled product. A common decision-making approach is to minimize costs given some acceptable critical dimensional variation, but this strategy often conflicts with ecological sustainability objectives. This paper introduces a new approach to simultaneously considering the ecological and economic consequences of tolerances through a software tool that combines Robust Design and Tolerancing (RD&T) with Environmental Priority Strategies in product development (EPS). This allows designers to simultaneously assess the economic and ecological sustainability outcomes associated with geometry, material, and tolerance choices, and it is demonstrated through design optimization of an automotive part.

INTRODUCTION

Product designers are aware that manufacturing processes produce products with slight deviations from the designed dimensions, and they account for this by specifying dimensional tolerances. Tighter specified tolerances require more precise manufacturing methods and tools, which typically come at higher costs and thus raise an important design trade-off between low-cost manufacturing and high-quality manufactured products. For decades, researchers and practitioners have studied this problem and developed tools and software to aid in variation analysis and design decision-making. These solutions typically seek to minimize manufacturing costs while somehow accounting for quality losses.

Another product development consideration that is becoming increasingly important is ecological sustainability. Consumers want to buy sustainable products, businesses want to sell their products to those consumers, and governments want to encourage businesses and consumers to behave more sustainably. As a result, a number of methods have been developed for assessing the environmental impacts of products and actions, many of which consider the entire life of the product from the extraction of raw minerals to the end-of-life disposal; these are known as Life Cycle Assessment (LCA) tools.

Proponents of ecological sustainability and LCA tools advocate that designers should consider ecological impacts in all stages of product development, from the conceptual design phase through the design for disassembly and disposal. One part of the design process is the embodiment design phase, where tolerances and other decisions such as materials are chosen. This paper describes a tool that integrates an LCA method into tolerance analysis software, facilitating environmental considerations in this stage of design.

MATERIALS AND METHODS

The present work enhances an existing software package for measuring variation propagation, Robust Design & Tolerancing (RD&T), by integrating into it an established environmental impact assessment method, Environmental Priority Strategies in product development (EPS).

Robust Design & Tolerancing (RD&T)

RD&T is a computer-aided tolerancing (CAT) program used to analyze variation in a product based on assembly locating schemes and input dimensional tolerances (Söderberg & Lindkvist, 1999). The software is compatible with commercial computer aided design (CAD) programs, and it can import models and report sensitivity and robustness calculations based on Monte Carlo simulations of the tolerance distributions. Such a tool enables designers to understand a product’s geometric sensitivity and robustness prior to physical prototyping.

Environmental Priority Strategies in product development (EPS)

EPS is an LCA tool that follows the International Organization for Standardization (ISO) 14040 and 14044 standards on environmental impact assessment (Steen 1999). It is aimed to be used in product development and includes weighting by calculating environmental damage costs in Environmental Load Units (ELUs), defined to represent ecological damages in euros. All materials and processes have associated environmental costs, and an EPS assessment is made in a similar way to an economic calculation. This enables the designer to directly respond to an environmentally expensive material by either choosing another or assuring efficient recycling. It also allows trade-offs against other issues expressed in economic terms.

RESULTS

The result of the study is an updated version of RD&T with a built-in environmental impact assessment tool. This section describes the software and functionality, as well as the use of the tool when performing multi-objective design optimization of an automotive part.

Integrated tool: RD&T with EPS

The software integration is based on an interface designed in the existing RD&T program, which communicates with an external database file containing EPS information as process flows and ELU values. This enables an efficient assessment of the total environmental load for the product life cycle, including production, use, and end-of-life phases, using geometric data from the simulation model itself. Prior to analysis, the users should define system boundaries such as a functional unit and the lifecycle phases to account for. For the production phase, materials are assigned to each part, and the manufacturing processes and amounts of production waste are defined. The use phase calculation relies on an estimate of the lifespan of the product as well as the quantities of energy and material inputs that are required for operation. For the final, end-of-life, phase, the user defines disposal or recycling scenarios in different fractions. Once these inputs are set, the software can report the lifecycle environmental load in ELUs alongside the results of the RD&T variation analysis.

Case study: Design optimization of a sustainable automotive part

The software implementation is demonstrated for the design of the d-pillar of a first-generation Volvo XC90, shown in Figure 1. The d-pillar is the part on each side of the vehicle connecting the roof to the lower frame, between the rear-side window and the rear windshield. This particular model is comprised of two stamped sheet metal components that are welded together, and the prescribed tolerances are located at the mating surface of the parts (t_1) and at the support points (t_2). The critical dimensions are the coordinates of the top-left corner of the part, which should be flush with the other roof supports and the side window.

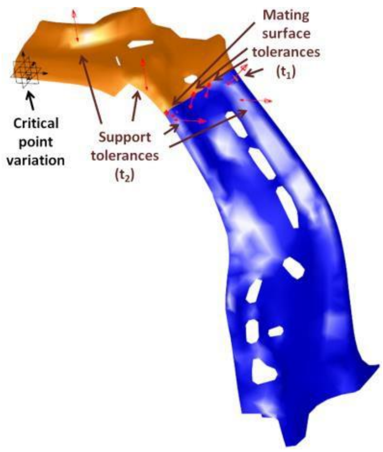


Figure 1. Model of left-side d-pillar

The model was analyzed for variation propagation 3,600 times with different input tolerance values using an exhaustive full-factorial sample, each analysis consisting of a 5,000-point Monte Carlo simulation to determine the distribution of output critical dimension variation. With the allowed variation set to 1 millimeter, the output is interpreted as a percentage of faulty parts, φ, as a function of the inputs, t_1 and t_2. For input values between the sampled points, spline interpolation was used to form φ into a continuous function of the tolerances.

The value of φ influences both economic costs C as well as ecological impacts E, due either to making replacement parts or manual re-work. C is also a function of tolerances t_1 and t_2, as higher precision is associated with higher manufacturing costs. Multi-objective optimization was conducted with four material options following the optimization formulation in Equation (1), where C is in Euros, E is in ELUs, and E_{max} is a varying upper limit on E. Solving with a number of E_{max} values yields a Pareto, or trade-off, curve for each material (Deb 2001).

$$\begin{aligned} \min_t \quad & C\,(t_1, t_2, \varphi(t_1, t_2)) \\ \text{subject to} \quad & E(\varphi(t_1, t_2)) \leq E_{max} \end{aligned} \tag{1}$$

Figure 2 shows these Pareto sets under two strategies for managing faulty parts, where the length and height of the boxes reflect the optimal values of t_1 and t_2, respectively; i.e., a larger box corresponds to a wider tolerance. The optimal solutions for when the objective is the simple sum of C and E are highlighted in yellow. Here, the system boundaries are different for the economic and environmental assessment, as the economic cost only covers production while the environmental impact spans the full lifecycle.

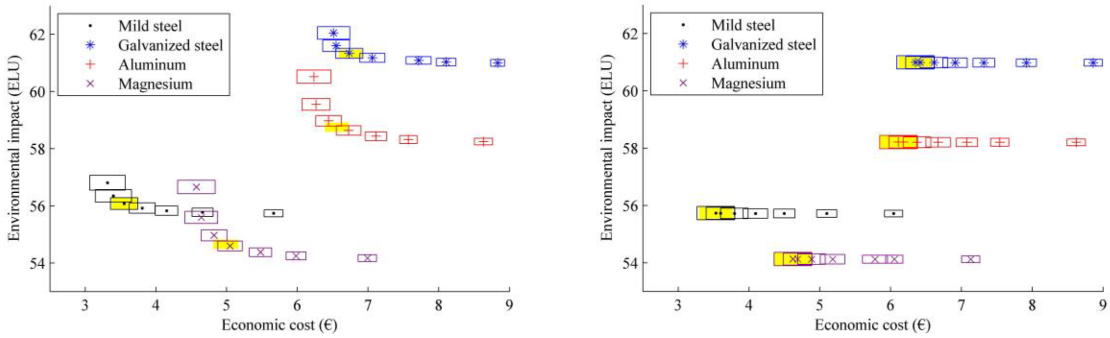


Figure 2. Trade-off curves, *(left)* discarding faulty parts and *(right)* re-working faulty parts

DISCUSSION AND CONCLUSIONS

The example shows simultaneous analysis and design optimization accounting for variation propagation and ecological impacts. The d-pillar scenario in which faulty parts are discarded shows a significant trade-off, where lower ecological impacts can only be achieved at higher economic costs, shown on the left of Figure 2. In this case, mild steel is the lowest-cost material alternative, but if the manufacturer places enough value on environmental impacts, magnesium may be better. This trade-offs within material options are much less evident in the scenario where faulty parts are re-worked, shown on the right of Figure 2, as the ecological impacts of faulty parts are much lower in this case; however, re-working defective parts may not be implemented in companies since it requires labor that is not always available.

This new tool and approach can facilitate sustainability-focused design by making designers more aware of ecological consequences with minimal extra investment in LCA. Since tolerances have been shown to influence aesthetic quality, functionality, and product life, this work provides a new user-friendly way to manage and understand the interrelations between variation and ecological impacts. Such a capability is of benefit to designers and strategists for making knowledgeable decisions toward sustainable product development.

REFERENCES

Deb, K. (2001). *Multi-Objective Optimization Using Evolutionary Algorithms*. Chichester, England: John Wiley & Sons.

Steen,B (1999) *A Systematic Approach to Environmental Priority Strategies in In Product Development (EPS). Version 2000 – General System Characteristics* (CPM 1999:4). Gothenburg, Sweden: Chalmers University of Technology, Centre for Environmental Assessment of Products and Material Systems.

Söderberg, R., Lindkvist, L. (1999). Computer Aided Assembly Robustness Evaluation. *Journal of Engineering Design*, vol. 10, no. 2, pp. 165-181.

USING ECO-EFFICIENCY TO IMPROVE SUSTAINABILITY IN THE LARGE-SCALE MINING INDUSTRY

Pia Wiche, Carolina Scarinci, Claudia Peña. Chilean Network of Life Cycle Assessment (Red ACV Chile). *Corresponding author: Pasaje Proyectada 1144, Quilpue, Region de Valparaiso, Chile. Pia.wiche@gmail.com.*

Keywords: eco-efficiency; mining; solar heating; copper; sustainability.

ABSTRACT

Eco-efficiency is used to analyze the convenience of installing a solar-based water heating system for a large-scale mining operation in Chile. The solar-based system will be used as primary source of heat, complemented with the currently in-use diesel-based system. Eco-efficiency is defined as the ratio between comparative savings from business as usual and GWP 100. Use scenarios are fixed to 25 years, with variations depending on annual energy demand and technology used. Eco-efficiency increases when the solar-based system is used for both energy scenarios. We find that incorporating the solar-based system makes the heating process more resilient, hence improving the overall performance of the whole system.

INTRODUCTION

Eco-efficiency first appeared as a concept in 1991 (WBCSD, 2000) and due to increased popularity and application it earned its own ISO norm in 2012. In the norm, eco-efficiency is defined as a relation between the environmental value of a product and the value of the product system (ISO 14045, 2012). Being a flexible indicator, eco-efficiency must comply with two basic rules: i) To equal product system value and better environmental performance, the eco-efficiency indicator must be greater; ii) To equal environmental performance and higher product system value, the eco-efficiency indicator must be greater (ISO 14045, 2012). A typical eco-indicator can be defined as: Eco-efficiency = value / impact.

Eco-efficiency has been increasingly used by companies, which have developed their own methods, tools, certifications and even labels for calculating this quantity (BASF, 2012). In the mining sector this concept has been used for over a decade, but its use has not been massive (Guerin, 2009; van Berkel, 2007). Zaldivar Mining (ZM) is a large-scale mining industry that produces 133,500 ton/y of copper cathodes. Its production process includes electro-winning (EW), for which large amounts of hot water are needed. The current technology used for water heating is diesel-powered water heaters. ZM looks forward to reducing the cost of heating water while improving its relationship with the environment. For that, a solar-powered alternative has been considered to serve as the primary heating system, leaving the older diesel-based technology as a back-up system. ZM also wants to reduce its hot water consumption in the long run (25 years horizon). But, how to aid decision making in economic and environmental terms?

We propose eco-efficiency as a suitable indicator to aid the decision-making process to meet the requirements defined by ZM. This work aims to provide relevant information and to show how eco-efficiency can be used to guide sustainability for a large-scale electro-winning copper refining process in Chile.

METHODS

We use eco-efficiency as defined in ISO 14045, and frame our study following the consequential approach. Four scenarios are analyzed for a period of 25 years, namely:

- Constant energy requirement with diesel heating;
- Constant energy requirement with solar heating complemented with diesel heating;
- Decreasing energy requirement with diesel heating;
- Decreasing energy requirement with solar heating complemented with diesel heating.

Diesel heaters are the business as usual case, and are used as the base line for comparison in the two energy demand cases studied (constant and decreasing energy demand in the next 25 years). The product system value indicator is defined as the savings arising from the use of the "solar with diesel" heating system versus the "diesel-only" system for a particular energy demand case. The environmental value is defined as the carbon footprint of the heating system in the energy demand case defined. Hence, the eco-indicator is defined as savings divided by carbon footprint for each scenario. For both energy demand cases (constant and decreasing), it is assumed that "diesel only" scenarios caused no savings (base line case). In order to calculate costs and savings for each case, the cost of diesel, solar system installation and maintenance are calculated using data provided by ZM. All costs are corrected to present value and aggregated for comparison.

The energy demand of year 2011 is taken as base for the calculation. In the "constant energy" cases, it is assumed that the annual energy demand for all years would be equal to that of 2011. In the case of "decreasing energy" scenarios, it is assumed that the energy demand of the first 10 years would equal to that of 2011 and that for the following 15 years energy demand decreased in approximately 1% per year.

The carbon footprint is calculated using SimaPro with the GWP100 method. Use of diesel as well as the construction and maintenance of the solar-based system are considered. The construction of the diesel-based heaters is not taken into account because they will continue operating, though at a lower rate.

RESULTS

Results are unambiguous both for savings and carbon footprint, showing that for all cases, the addition of the solar-based heating system increases savings in the long run while reducing the carbon footprint of water heating. These results can be seen in Table 1.

Table 1. Economic and environmental values and eco-efficiency scores for the four scenarios analysed.

Value	At constant energy demand		At decreasing energy demand	
	Diesel	**Diesel & Solar**	**Diesel**	**Diesel & Solar**
Savings [US$]	0	15,219,108.33	0	14,278,671.61
GWP 100 [ton CO_{2eq}]	237.803,69	117.645,59	186.822,86	93.955,90
Eco-efficiency	**0**	**129.36**	**0**	**151.97**

From the table it can be seen that for both economic and environmental values, the process choice with solar complementation is better, resulting in higher eco-efficiency results.

For both constant and decreasing energy demand in the next 25 years, the addition of the solar-based system resulted in a reduction of approximately 30.5% in costs and 50% in the life cycle carbon footprint. This makes it very clear that incorporating the solar technology is convenient for business and also for the environment.

DISCUSSION

This study offers some limitations. The effect of transport of the solar system was not taken into account, and neither was the effect of maintenance of the diesel system. The authors cannot estimate the effect of shipping the solar panels over a 25 year period, but we assume it is small compared to the savings in diesel combustion. Regarding maintenance, ZM estimates that the maintenance and part replacement for the diesel boilers will be reduced when the solar system starts operating, so we understand the effect over the eco-efficiency indicator should be positive. Additionally, maintenance of the solar system is minimal.

This work makes a good example for eco-efficiency at the process design level (van Berkel et al., 2007), but it does not respond to the principle of resource efficiency, since it brings in more materials and, instead of substituting a system, it complements it with a renewables-based one. Moreover, it also presents a good example of how eco-efficiency can aid into making systems more resilient. The addition of the solar-based heaters complemented by the older diesel-based heaters makes the water heating process more resilient as in the definition of Korhonen (2008). The system will be more *diverse* since it has two energy sources, which brings in greater *adaptability* of the system to accidents, changes in climate and reparations. As well, it becomes more *flexible* to changes in the copper process conditions, and finally, increases the *reserve* capacity of heat. In addition, the system becomes more independent of fossil fuels, decreasing supply risks caused by political, infrastructural or production issues and freeing resources for investment in other areas of the mining industry.

Overall, results do not show compromise between the economic benefit of the solar system and the environmental performance of this heating process. The authors strongly believe that case studies like the one presented here will aid in introducing eco-efficiency as an everyday tool for use in decision making and process design in industry.

CONCLUSIONS

We conclude that the addition of a solar-based heating system is convenient for the water heating process for electro-winning at ZM. The addition of this system will result in both an increase of savings and a decrease of the carbon footprint, thus leading to a two-way increase of the eco-efficiency of the process. In addition, the implementation of the solar heater may increase the resilience of the process by making it more adaptable, diverse and flexible. Therefore, it is recommended the implementation of the solar heater for Zaldivar Mining.

REFERENCES

BASF, 2012. Eco-efficiency analysis. In: www.basf.com. Accessed: December 20, 2012. Full URL: http://www.basf.com/group/corporate/en/sustainability/eco-efficiency-analysis/eco-efficiency-analysis.

Guerin, T. 2009. Applications of Stakeholder engagement and Eco-Efficiency as enablers of Corporate responsibility in the Australian mining and minerals processing industry. In: Mining, Society and a Sustainable World. Richards, J. (Ed.). Springer-Verlag:Berlin. DOI:10.1007/978-3-642-01103-0.

ISO 14045. Environmental management — Eco- efficiency assessment of product systems — Principles, requirements and guidelines.

Korhonen, J. and Seager T. P. 2008. Beyond Eco-efficiency: a Resilience Perspective. Editorial article, *Bus. Strat. Env.* 17, 411–419.

Van Berkel, R. 2007. Eco-efficiency in the Australian minerals processing sector. *Journal of Cleaner Production* 15, 772-781.

WBCSD, 2000. Eco-efficiency creating more value with less impact. Online publication. Switzerland. Full URL: http://www.wbcsd.org/web/publications/eco_efficiency_creating_more_value.pdf

EXPLORING CHALLENGES AND OPPORTUNITIES OF LCM AND LCA FOR THE INDUSTRY: PANEL

Wednesday, Aug 28: 10:30 am - 12:00 pm

Session chairs: Martina Prox, ifu Hamburg GmbH, Germany
Mieke Klein, ifu Hamburg GmbH, Germany

A PRODUCT CHAIN ORGANISATION STUDY OF CERTIFIED COCOA SUPPLY

Afrane, George (1); Arvidsson, Rickard (2); Baumann, Henrikke (2,3); Borg, Josefin (2); Keller, Emma (4); Milà í Canals, Llorenç (4); Selmer, Julie K (2)*

1: University of Ghana, Ghana; 2: Chalmers University of Technology, Sweden; 3: Erasmus University Rotterdam, the Netherlands; 4: Unilever R&D – SEAC, UK

Keywords: supply chains, sustainable sourcing, Ghana, cocoa farming, GHG

ABSTRACT

Cocoa supplies may become limited in the future. Demands for sustainable cocoa sparked an exploration of the product chain organisation of conventional and certified cocoa from Ghana. The comparison shows that transparency requirements have led to a more complex product chain. Even so, certification has yielded important productivity increases resulting in environmental benefits (e.g. reduced greenhouse gas emissions) and improved livelihoods for smallholder farmers.

INTRODUCTION

Interest in organisational issues of LCM prompted the development of *product chain organisation* study (Baumann, 2012) to improve understanding of how, for example, supply chains can be organised. With increased interest in certification comes a growing need to know where and how ingredients are sourced. A case in point is the supply of certified cocoa, and a PCO study of cocoa sourcing was made, from farmers to a consumer goods company, Unilever. Whilst this study refers to a specific case, the insights gained are more general.

In 2010, as part of its wider Sustainable Living Plan, Unilever committed to source all cocoa sustainably (www.unilever.com/sustainable-living/sustainablesourcing/cocoa-sugar/). To realise the plan to only have certified cocoa sources for Magnum ice creams by 2015, Unilever partnered with Rainforest Alliance (www.mymagnum.co.uk/article/beantobite/). Currently Unilever procures its chocolate from wholesalers and has thus little or no direct contact with farmers at the beginning of the supply chain. Certification provides a means of assurance that farmers adhere to a number of good agricultural practices, and with Rainforest Alliance they also receive education and training as part of the certification process.

The introduction of new actors to Unilever's supply chain lets us 1/ describe the structure of conventional and certified cocoa supply chains and 2/ explore whether differences in greenhouse gas impacts can be observed.

MATERIALS AND METHODS

For practical reasons, the study was geographically limited to cocoa grown in Ghana, the world's second largest producer of cocoa. Actors in the supply chains were identified through multiple sources, i.e. Unilever contacts, a Ghanaian LCA study of chocolate production (Ntiamoah & Afrane, 2008) and on-site in Ghana. Interviewing included traders, representatives for wholesaler Barry Callebaut, Rainforest Alliance, local non-governmental organisations (NGOs), as well as the national cocoa research institute and authority, the COCOBOD. Farmers were interviewed in groups. The interviews covered the actors' roles and relationships and thus enabled the mapping out of the PCOs. Additionally, interviews explored the actors' views and perspectives on sustainability and certification in order to understand premises for communication and sustainability management along the chain. Visits to three farming regions provided a diverse sample of both certified and non-certified cocoa farms for the comparison of their greenhouse gas impacts. A free excel-based GHG calculator, the Cool Farm Tool (Hillier *et al*., 2011), was used for this. Table 1 summarises the empirical material. A more detailed report is given by Borg & Selmer (2012).

Number of farms studied	Number of interviews	Interview topics
6 conventional, non-certified 8 with sustainability training prior to certification 4 certified without prior sustainability training	In total, more than 30 people Interviewees found in 15 types of organisations (*i.e.* local and international NGOs, producers, traders, sector organisations, research institutes, governmental bodies, multinational companies, educational institutions)	• role in cocoa industry • perceived sustainability challenges • reasons for sustainability management • on-going sustainability work • views on certification schemes

RESULTS

The cocoa industry involves a diverse range of actors. The described situation is specific to Ghana, where governmental bodies regulate the national cocoa market.

Conventional and certified cocoa chains

The two analysed product chains are organised with a large multi-national manufacturing company, Unilever in this case, at one end of the chain and numerous smallholder farmers at the other. These are two very different types of actors. Smallholder farmers typically operate on approximately 1 ha of land, are often very poor, most workers illiterate and production is often a family effort.

In a conventional cocoa chain, the manufacturing company and farmers generally have no contact. With certification, Rainforest Alliance becomes a link between the manufacturing company, farmers and nearly all other actors in the chain.

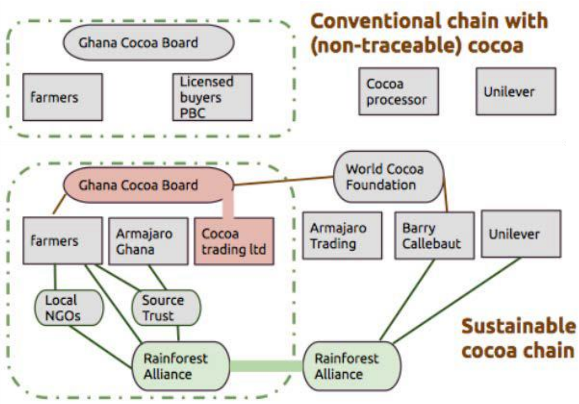


Figure 1. Product chains of conventional cocoa (top) and certified cocoa (bottom), based on Borg & Selmer (2012). Inside green line: in Ghana.

Views on sustainability along the chain

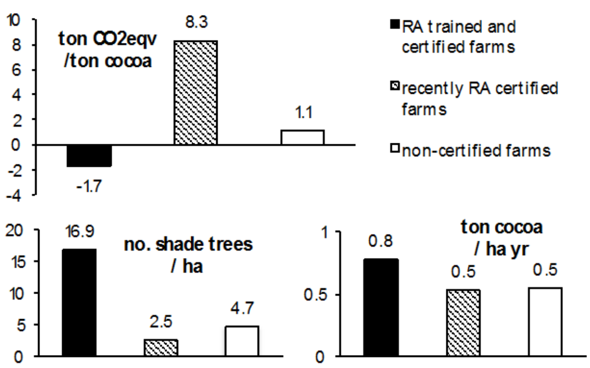
The understanding of sustainability issues in cocoa chains is not uniform. Also agreement on the importance of sustainability issues differs. There is strong agreement amongst nearly all actors on several issues concerning the farmers, particularly the need for socio-economic development. The COCOBOD state that farmers' economic situation should be improved ahead of other issues. For most supply chain actors, environmental issues were secondary The exception here were the farmers who realise the reality of climate change and its adverse impact on cocoa farming, and Rainforest Alliance who has strong views on deforestation and.

biodiversity as well as improving farmer income and strengthening community development. Table 2 gives an overview issues reported by Borg & Selmer (2012). Whilst governmental bodies maintain that socio-economic development is the key issue for the future, business-oriented actors will look to certified cocoa to address both these issues as well as other environmental concerns.

Strong agreement among chain actors	**Views expressed by only certain chain actors**	**Conflicting views among chain actors**
Deforestation Soil Depletion Farmer Income Productivity Community Development Lack of knowledge and education	Climate change. Only farmers bring this up as the major environmental problem. Landowner system and conflict of land. Only Ghanaian governmental bodies bring this up. Illegal logging, illegal mining, slash and burn. Several Ghanaian actors bring up these problems.	Food safety issues – some actors see this as an important concern while others believe it has been tackled well. Child labour concerns – some farmers and other supply chain actors believe child labour and trafficking has been addressed and is being eliminated through certification. Others believe it is still a problem for the cocoa sector in some cases.

Comparison of GHG emissions from conventional and certified cocoa farming
Rainforest Alliance certification was assessed with regard to annual farm greenhouse gas emissions using the Cool Farm Tool. Calculations include general crop data, production area, yield, climate data, soil quality information, crop residues management, use of fertilisers and pesticides, land use changes the past 20 years, biomass sequestration (e.g. in shade trees), livestock, energy use, farm-level processing and transports. Still, simplifications were made, e.g. same climate and soil composition for all farms. Results are presented per group of farms given their certification status.

Annual cocoa production in Ghana averages 0.4 ton/ha. In comparison, all surveyed farms had better than average productivity. Certified farms that also had received training clearly outperform other farms here in GHG performance. This was largely due to shade tree quantity, absence of land-use change over the past 20 years and having had time to establish sustainable agricultural practices. These farms first received training in 2008 and were certified in 2010. More, they also fulfilled national recommendations of 15-18 shade trees/ha.



Shade trees are important since they store CO_2. The relatively high CO_{2eqv} levels for the recently certified farms can be explained by land-use changes, i.e. deforestation, having taken place in the past 20 years. Additionally, delayed delivery of shade trees led to many not surviving plantation, thus increasing GHG levels as less CO_2 could be stored.

Attitudes to certification
RA certified farmers expressed positive attitudes towards certification. Stated benefits include: improved soil quality, reduced disease incidence, increased biodiversity and species return as well as productivity gains that result in increased profitability and livelihood gains. Other actors, however, were not always as positive towards certification and there remains confusion between several competing schemes (e.g. RA, UTZ and Fairtrade) and resistance to entailing administrative burdens. Some actors also stress that certification alone will not make

the cocoa industry sustainable. The COCOBOD suggests that it could improve sustainability without certification and instead organise sustainability efforts through broad collaborations. It therefore seems more efforts are needed if certification is to become a more universally beneficial mechanism towards sustainable supply chains.

DISCUSSION

The development of a sustainable product chain organisation described here differs from other reported cases. Sustainability goals can sought through a 'domino effect' by placing demands on suppliers (e.g. Gullbring et al., 2010) or by building a new sustainable product chain 'from scratch' (Kogg, 2003). Here, sustainability is attempted through adding a 'sustainability brace' onto an ordinary product chain. The 'brace' provides sustainability support to virtually all actors in the chain, resulting in numerous new collaborations. Rainforest Alliance forms a link between the manufacturing company and Ghanaian farmers in collaboration with local NGOs, local traders and international wholesalers to make the sustainability efforts effective. However, further collaboration is needed. As a regulating body, the COCOBOD is key to sustainability of the Ghanaian cocoa industry since all farmer projects must go through it. Yet, it questions current certification trends, calls for harmonisation and asks what its role will be in the future.

CONCLUSIONS

Transition from conventional to traceable, certified cocoa changes the structure of the cocoa industry in Ghana. It also introduces a new set of issues concerning competing certification schemes and alternative routes to sustainability. Potentially more important than certification *per se* seems to be the education and training the local RA initiatives provide, since these increase farm productivity and thereby lower GHG levels and raise incomes and livelihoods for farmers. Aligning sustainability efforts in cocoa chains will however require further discussion and development of collaborations.

REFERENCES

Baumann, H. (2012). Using the life cycle approach for structuring organizational studies of product chains. *18th Greening of Industry Network conference*, 22-24 Oct 2012, Linköping, Sweden.

Borg, J. & Selmer, J.K. (2012). *From Ghana to Magnum Ice Cream: Tracking Down the Organisation of Sustainable Cocoa Product Chains*. ESA report 2012:14, Environmental Systems Analysis, Chalmers, Göteborg.

Gullbring, A., Nilsson, H. & Baumann, H. (2010). Environmental management in a diaper product chain. *10th EURAM conference*, Rome, Italy, June 2010

Hillier, J., Walter, C., Malin, D., Garcia-Suarez, T., Mila-i-Canals, L., & Smith, P. (2011). A farm-focused calculator for emissions from crop and livestock production. *Environmental Modelling & Software*, *26*(9), 1070-1078.

Kogg, B. (2003). Greening a cotton-textile supply chain: a case study of the transition towards organic production without a powerful focal company. *Greener Management International*, 43:53-64.

Ntiamoah, A., & Afrane, G. (2008). Environmental impacts of cocoa production and processing in Ghana: life cycle assessment approach. *Journal of Cleaner Production*, 16(16), 1735-1740.

.

LCA METHODOLOGY FROM ANALYSIS TO ACTIONS: EXAMPLES OF BARILLA'S IMPROVEMENT PROJECTS

Luca Ruini[1], Laura Marchelli[1], Assunta Filareto[2,]*

[1] Barilla G. R. Fratelli S.p.A

[2] Life Cycle Engineering

**Corresponding author. Tel. +39 (0) 11 22 57 311; Fax +39 (0) 11 22 57 319. E–mail address: filareto@studiolce.it. Postal address: Life Cycle Engineering c/o Environment Park – 60,via Livorno, I–10144 Torino (TO).*

Keywords: Life cycle assessment; durum wheat semolina pasta; improvement actions; environmental performance; cropping system project.

ABSTRACT

The life cycle approach is implemented by Barilla in the decision making process to identify processes requiring improvement in order to meet in-line sustainable business strategies. This work illustrated the main improvement projects that Barilla performed in its analyses of Life Cycle Assessment results relevant to dry durum wheat semolina pasta. Projects were undertaken for each phase, including in system boundaries (dry durum wheat pasta, milling, pasta production, packaging production, product transport and household cooking). Results obtained from each phase shall be used to improve processes management along the product chain. An example of improvement action concerns the updating of crop guidelines in relevance to the need of greater sustainability of durum wheat cultivation.

INTRODUCTION

Barilla's development policy strongly pursues the research of business strategy closely linked to sustainability, measuring continual improvements in the areas of environmental footprinting, energy efficiency and water management by means of Key Performance Indicators (KPI).

Environmental related issues are examined through Life Cycle Assessment (LCA) methodology to evaluate each activity along the product chain.

These analyses have two aims: on one hand the identification of hot spots along the product chain with consequential improvement projects, on the other hand the integration of communication policies with reliable environmental information.

MATERIALS AND/OR METHODS

One of the first analyses performed by Barilla focused on the evaluation of durum wheat pasta (see Figure 1); and delved deeply into every phase of the entire chain (durum wheat cultivation, milling, pasta production, packaging production, product transport and household cooking).

A specific analysis was launched for each phase to identify actions able to improve activity management along the chain.

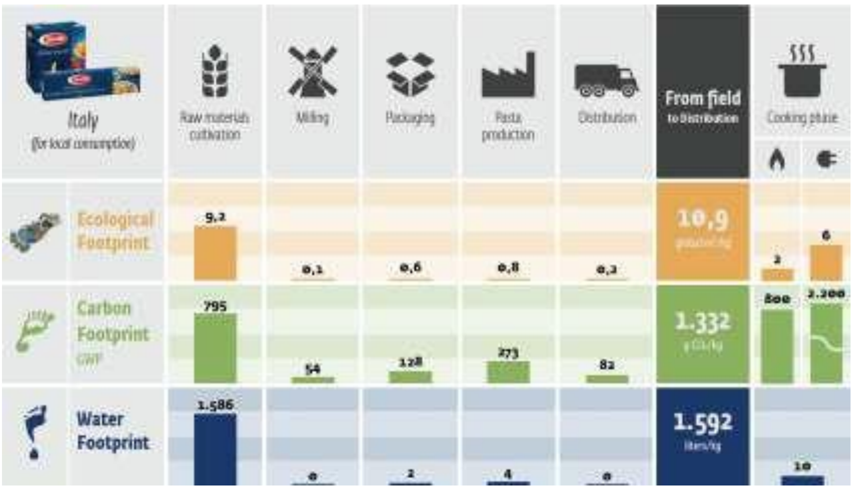


Fig.1: Ecological, carbon and water footprint of 1 kg of dry durum wheat semolina pasta, produced and distributed in Italy

RESULTS

Durum wheat cultivation is one of the phases that most contributes to pasta environmental performances. As a result, Barilla has launched a specific project for the implementation of more sustainable cropping systems for the production of the most important raw material in pats production: durum wheat. The aim was to analyse and compare different cropping systems for durum wheat cultivation. The study demonstrates that “sustainability” is a feasible concept that finds solid application in the agricultural sector: the best durum wheat crop systems identified demonstrate that agronomic improvements (a favourable crop rotation, the right choice of seeding rate and date, an efficient utilization of fertilizers and pesticides) can lead to environmental improvements and an increase in a farmers' income.

The milling and pasta production phases lend minor contributions to environmental performance when compared to durum wheat cultivation. Despite this fact, a series of energy saving projects have been performed (electronic control system for the boilers, installation of Oil Free variable rate compressor, the partial replacement with high efficiency motors).

Aside from the projects mentioned above, two of the three Italian pasta plants have adopted cogeneration/trigeneration power generation. Pedrignano cogeneration plant began full-capacity operation in February 2009; and construction of the trigeneration plant in the Caserta factory was completed in July 2009. The cogeneration plant gave rise to a 13% reduction compared to 2008 in GWP emissions per unit of finished product at the Pedrignano factory.

Environmental performance of packaging production does not have a strong impact along the whole pasta chain. Regardless of this fact, the LCA approach was also applied to packaging materials in order to first check their environmental performance and then compare alternatives on an equi-functional basis. According to the huge amount of information available over years, Barilla's focus shifted from ex-post analyses to further focus on a dynamic approach which allowed preliminary comparison of packaging alternatives. The general concept revolved around the availability of a restricted set of LCA indicators for each material and process at issue in order to preliminarily pinpoint the environmental benefits of innovative solutions, which will later be fully illustrated through specific data collection and LCA. Results are based on a cradle-to-gate approach; and comparison is made in relation to the quantity of material necessary for 1 kg of packaged pasta. System boundaries account for: primary packaging material production, tertiary packaging material production, shaping process for tertiary material and ancillary materials. In pursuit of the goal, a first LCA calculation tool was developed in 2004 and then refined and enhanced with more specific data as it became available (continuously collected). Packaging materials data is available with a set of predefined processes for shaping and coupling in order to best define the current system, which also includes supply transport. A specific feature also allows an ad hoc analysis of the benefits related to more efficient storage procedures on board delivery vehicles.

A project was also launched to evaluate the environmental performances of the logistic network. Its goals were to identify and analyse a series of Key Performance Indicators (KPI) related to transport activities and to warehouse used for the product storage before its transport to final customer to evaluate logistic improvement projects performed from 2006 to now from an environmental point of view.

Results coming from the project are summarized hereby:

1. Transport emissions have decreased since 2008 thanks to the annual replacement of old vehicles;
2. Emissions per kilogram of product transported have decreased since 2008 thanks to an increase in transport efficiency (e.g. optimization of vehicle saturation);
3. Projects for the improvement of the logistic network have contributed to reduce emissions of carbon dioxide equivalent; an example of such project implemented for a specific route has saved 800 tons of carbon dioxide equivalent.

Household cooking phase also contributes to environmental performances. This fact has prompted Barilla to carry out a project aimed at reducing the amount of water required to cook pasta, while keeping quality standards untouched. LCA indicator monitored in this type of projects is carbon dioxide equivalent emissions (Global Warming Potential - GWP_{100}).

Main hypotheses considered are listed below:

- household cooking could adopt gas or electrical ranges; in the case of power, the GWP varies per country producing site-specific results (see figure 2);
- quantity of water recommended per 100 grams of pasta: 1 litre;
- evaluation of necessary energy is made independent from energy required to heat a specific pot.

Preliminary results (figure 2) reveal that using less water prevents a certain quantity of carbon dioxide equivalent; for example, using 0.5 litres of water (instead of 1 litre) per 100 grams of pasta prevents about 30 grams of carbon dioxide equivalent

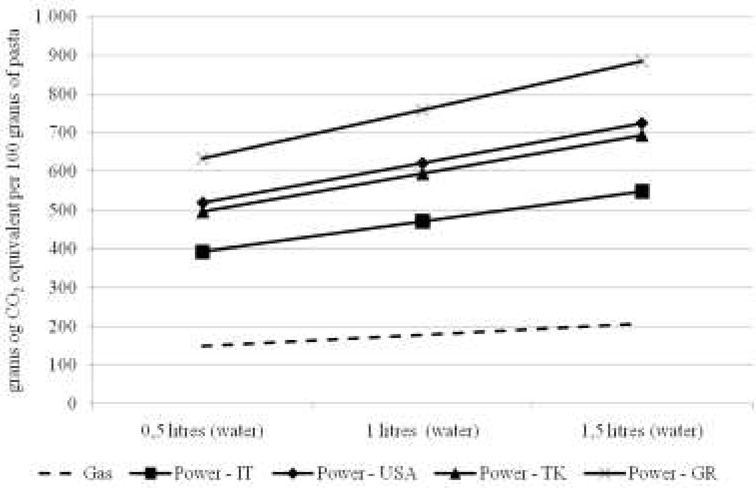


Fig.2: GWP_{100} of 100 grams of pasta cooked at home with different quantities of water (0.5 - 1 - 1.5 litres) using different types of energy mix

CONCLUSION

In its definition of improvement programs, Barilla also accounts for results of LCA evaluation. The company aims to improve both process management and environmental performances of the whole chain. The next update of the crop guidelines, suggested by Barilla, shall also implement the qualitative results of the cropping system project, given that these findings should be tested and confirmed through in-field experimentations. Cogeneration plants and energy saving projects allow Barilla to improve its environmental performance and cut expenses. The use of a calculation tool to determine the environmental performances of packaging materials permits the preliminary identification of environmental benefits linked to innovative solutions, which shall undergo extensive analysis for future implementation. The project concerning product transport will help optimize the logistic network through the use of specific KPI. Lastly, the household cooking phase is not directly controlled by Barilla, rather it depends on consumer behaviour. Barilla could provide cooking recommendations that exploit project results through informative campaigns.

REFERENCES

Barilla, Environmental Product Declaration of dry durum wheat semolina pasta, 10/03/2011.

International EPD Consortium, General Program Instructions (EPD), ver.1 of 29/02/2008.

Luca Ruini, Paolo Cabrini, Roberto Ranieri, Fabrizio Boeri, Marco Montani, Pierluigi Meriggi, Economic, Agronomic and Environmental integrated analysis of durum wheat cultivation cropping system, LCA food 2010 proceedings, Volume 1.

Barilla, Environmental Product Declaration of durum wheat semolina dried pasta (brand Barilla), available at http://www.environdec.com/en/Detail/?Epd=7699, 10/03/2011.

LIFE CYCLE MANAGEMENT THROUGH BUSINESS DRIVEN SUSTAINABILITY MANAGEMENT SYSTEMS OPPORTUNITIES AND LIMITATIONS

Lennart Swanström[1], Michail Pagounis[2], Richard Almgren[3]
1) ABB AB, Corporate Research, SE-72178 Västerås, Sweden 2) ABB Asea Brown Boveri Ltd
*3) Linköping University * lennart.swanstrom@se.abb.com*

Keywords: life cycle management; value chain; model; management systems; sustainability.

ABSTRACT

This paper is based on a study of the current sustainability management system landscape within the ABB Group and discusses the limitations and opportunities related to these systems and belonging tools. It also suggests a sustainability management model which covers both the "vertical" and "horizontal" directions along the value chain. The model describes how current management systems and tools can be better linked to the business strategy and decision situations to enable sustainable growth and profit while contributing to a "better world". The main conclusions are that LCM needs to be explored further through the lenses of each company's specific organization. Finally the role of a continual improvement procedure is considered the cornerstone for "true" life cycle implementation.

INTRODUCTION

ABB in brief

ABB is a global leader in power and automation technologies. Based in Zurich, Switzerland, the company employs 145,000 people and operates in approximately 100 countries. ABB's business is comprised of five divisions organized in relation to the customers and industries that ABB serves. The company in its current form was created in 1988, but its history spans over 120 years. ABB's success has been driven particularly by a strong focus on technology and innovation.

The role of corporate sustainability in ABB

The demands and expectations from customers and other stakeholders on corporate handling of sustainability issues have increased substantially during the last decades. As a result, ABB and other companies see sustainability today as a strategic issue with large impact on the business. Various types of sustainability management tools have been implemented over the years, like sustainability reporting, management systems according to ISO14001, OHSAS18001, product related LCA and Eco Design tools. ABB has operations across the world and implementation of management systems in the majority of manufacturing facilities helped establishing continual improvement mechanisms and ensured a safe working environment, environmental stewardship and high quality standards. This large base of experiences gained since mid-1990s in the application of management systems and product-related LCA and Eco Design tools was the basis for conducting a case study on the current management systems landscape at ABB. This resulted into better understanding the opportunities lying ahead but also the limitations ABB has to overcome towards more efficient management systems and life cycle management.

A previous experience is that a gap was observed in the implementation of management systems and between life cycle tools on one hand and business strategy and decisions on the other hand. There are also gaps between management systems and tools themselves, e.g. between ISO 14001 and product related LCA tools. These are examples of challenges that need to be addressed enabling the full utilization of life cycle management within ABB to achieve a truly business driven sustainability management process from Group level to local business units.

METHODOLOGY

This paper is based on a case study including literature review and more than 30 individual in-depth interviews covering a number of internal stakeholders from different regions, countries and businesses. The aspects examined for the two investigated areas are summarized below:

Sustainability governance

- Mapping of sustainability governance documentation (policies, instructions, guidelines)
- Building understanding about the architecture of documentation from Group perspective to local business units. (Top-down approach)
- Identification of the level of integration of the governance documentation in the local management systems
- Optimization possibilities of the overall architecture for the controlling documents

Management Systems

- Mapping management systems throughout the Group and identify the level of integration of management systems
- Review Group sustainability objectives & target setting processes
- Level of commitment to continuous improvement and performance monitoring

RESULTS

The role of management systems in ABB operations has been very important as they are being seen as the driving force behind continual improvement. In this case study, it was recognized that corporate sustainability governance documentation (policies, directives and instructions) should be properly cascaded to Management Systems, through Group Sustainability Objectives. This also helps with the implementation of the sustainability strategy too. In order to enable performance monitoring, Key Performance Indicators (KPIs) should be an integral part of the process. Ultimately the use of Group Objectives and KPIs can result in an efficient and effective sustainability governance system as shown in figure 1.

The first element, corporate sustainability governance ensures the proper implementation of the sustainability strategy through Group Sustainability Objectives in all local operations, the foundations of ABB. The second element, the local ABB operations, is paired with management systems maintaining and improving the sustainability performance in almost all manufacturing sites across the world.

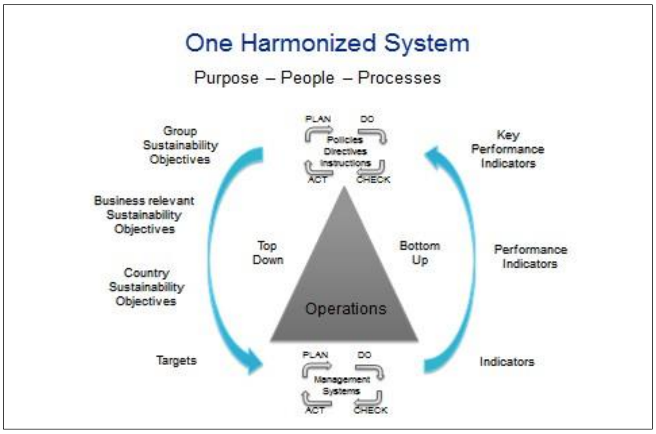


Figure 1 Operations and the role of management systems as driving forces

Linking the distance between Group and the local ABB Operations is thus being achieved through the use of the Group Sustainability Objectives. The objectives ensure that the sustainability strategy implementation will reach the local operations by cascading properly these objectives though all different organizational levels (regions, countries, local business units). However, this process comes along with great challenges due to the size and global presence of ABB. Well designed, continuously maintained and business relevant Group Sustainability Objectives can thus be seen as the primary communication tool and "common denominator" to drive continual improvement and increase the control of sustainability impacts.

The final element which closes the loop of corporate sustainability governance is Key Performance Indicators (KPIs). KPIs create the basis for measuring performance of operations through management systems. It is of vital importance to monitor the efficiency of the sustainability governance process, the management systems and maximize the benefit for ABB's business as well as the overarching social objective to reach a more sustainable society.

The intention now is to shift focus into exploring how these past experiences and knowledge can be utilized to enable a transition from the current system boundaries (ABB operations) to the whole value chain through the use of Group Sustainability Objectives and KPIs. The aspiration is to identify the driving forces behind each activity of the value chain and apply a framework similar to the way management systems are used in operations. The purpose is to establish continual improvement processes facilitated by the use of applied tools linked to specific objectives and KPIs rather than using these tools as ad-hoc solutions.

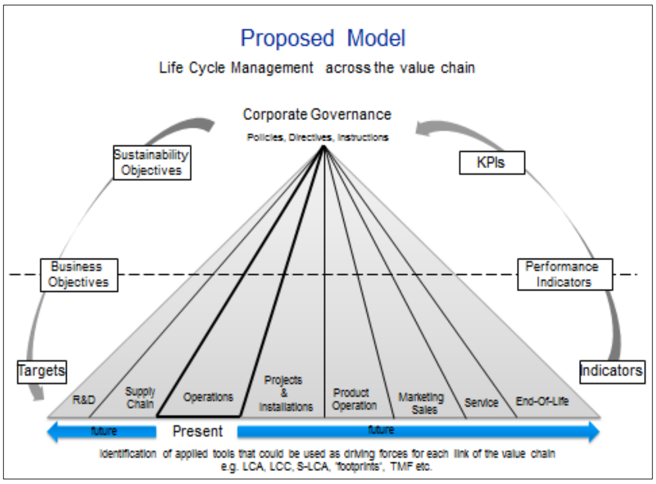


Figure 2 Model: LCM and value chain

Identification of the driving forces behind each activity of the value chain need to be explored through the evaluation of existing applied tools (e.g. LCA, S-LCA, LCC, TMF etc.) and best practices from industry. The overall objective will be to recognize the tools that can be used as catalysts towards the implementation of a Strategic LCM model incorporating all elements of the value chain and facilitating integration of sustainability into business. The schematic visualization of the model presented in this study is summarized in figure 2 above.

DISCUSSION

Corporate Life Cycle Management – A Proposed Model

Taking the decision to extend focus from own operations to the whole value chain is a decision not any more accompanied by the question "why" but rather "how" as integration of sustainability into business is an imperative. The larger and more complex an organization is, the more difficult it becomes. However taking the decision to extend the scope from operations to other value chain activities can find a company overwhelmed by the size and number of challenges without having a well thought-out plan.

To trigger this transition we propose a model which links corporate governance, operations, available applied tools and identifying synergies between value chain activities in a seamless way. The overall purpose of the model presented is to show how LCM can be the forward looking strategic tool to drive change for the years to come. LCM could be used as the vehicle for change however the implementation process differs for each organization. Each organization has first to appraise the current sustainability governance structure together with the sustainability relevant processes that exist in each activity of the value chain. Only then synergies between activities can be identified and selection of suitable tools to support LCM implementation.

CONCLUSIONS

The main conclusions from this paper are summarized below:

- Life cycle management should be seen from a continual improvement perspective - impregnation of sustainability governance, corporate objectives, management systems and KPIs with a continual improvement process is the cornerstone for the long term establishment of LCM.
- Applied life cycle tools can be used as the facilitators towards implementation of LCM rather than the driving force.
- There is no single approach towards LCM implementation – Every organization must explore LCM individually and tailor it to its own needs.

REFERENCES

Henrik Ny, Jamie P. Mac Donald, Göran Broman, Ryoichi Yamamoto, Karl-Henrik Robèrt, 2006. Sustainability Constraints as System Boundaries. Journal of Industrial Ecology 10(1-2):61-77

Jørgensen TH., 2008. Towards more sustainable management systems: through life cycle management and integration. Journal of Cleaner Production 16:1071-1080

Michail Pagounis., 2013. Overview of the current GF-SA Documentation and Management Systems landscape at ABB, GFSA strategy project 2015+, 2013 (internal report: 9ADB003049-32)

Robèrt, K.-H., et al. 2002. Strategic sustainable development—Selection, design and synergies of applied tools. Journal of Cleaner Production 10(3): 197–214.

THE BENEFITS OF APPLYING PROJECT MANAGEMENT TOOLS TO LIFE CYCLE ASSESSMENTS

Susanne Veith[1], Carina Maria Alles[2], Ivo Mersiowsky[3], Steve Barr[4], Debbra Johnson[5]*

[1] DuPont Engineering & Research Technology, Brussels, Belgium;
[2] DuPont International Operations Sarl, Geneva, Switzerland
[3] DEKRA Consulting GmbH, Stuttgart, Germany
[4] DuPont Engineering & Research Technology, Wilmington, USA
[5] DuPont Sustainable Solutions, Wilmington, USA

** Avenue des Arts 44, 1040 Brussels, Belgium; Susanne.r.veith@dupont.com*

Keywords: Project Management, RACI chart, Gantt charts, LCA Flexography and Gravure Printing

ABSTRACT

Life Cycle Assessments (LCAs) that encompass complex value chains can be challenging to manage since data is needed from different value chain partners and information needs to flow between different players in the value chain. However, good project planning and the application of time-tested project management tools can help practitioners to overcome obstacles and successfully navigate the team through the study.

Project management provides a very useful tool box to LCA. For example, RACI charts help to clearly assign roles and responsibilities within a project team. To guarantee the appropriate timing of individual tasks, Gantt charts can be helpful to manage the timing and the sequence of individual activities. In this presentation, we use a case study from industry to demonstrate how the effective integration of such project management methods can help to successfully manage even complex value chain LCA projects.

INTRODUCTION

Life Cycle Assessment (LCA), while complex and sometimes complicated, becomes quite feasible, if good project management practices are applied. As with many other involved tasks, careful project design and planning go a long way towards avoiding pitfalls down the road. It is really about deciding who does what, until when, and with which resources.

The RACI chart for assigning team responsibilities and the Gantt chart for determining timeline and sequence of work items are two key techniques of project management. In the following, a case study will demonstrate how these two tools were successfully applied to a comparative LCA that involved a broad range of value chain partners.

METHODS

LCA System Boundary and Functional Unit Definition:

The first objective of this study is to compare the environmental performance of solvent-based and thermal flexographic plate imaging technology. The second objective is to benchmark the environmental performance of flexographic versus rotogravure printing including print form manufacture, imaging of the print form and printing of the film for the flexible packaging and tag & label markets. The results of these comparisons shall educate the value chain and support downstream customers in sustainable decision making.

The functional unit to compare imaged plates made by alternative image setting techniques (analog, digital, solvent, thermal) is area of imaged plate. The final functional unit for the study is area of printed substrate.

The value chains of imaging and printing processes are quite complex. For flexography the following steps are included in the LCA:

- Manufacture of the photopolymer plates
- Plate imaging or image setting steps (analog versus digital, solvent versus thermal)
- Flexographic printing of the packaging film

For the alternative gravure printing technology, the corresponding steps are:

- Facing and re-facing of the printing forms /cylinders
- Printing form imaging
- Gravure printing of the packaging film

Consequently, data was collected from a variety of value chain partners, including trade shops and printers serving the flexible packaging and tag & label markets. Stakeholders identified cradle-to-gate non-renewable energy and GHG emissions as the key environmental indicators. The LCA was concluded with a critical peer review.

Project Management Tools: RACI Chart

One key aspect of good project planning is to have the right team in place to solve the task at hand, and to assign and communicate the responsibilities in a clear and transparent manner. RACI stands for:

- **R= Responsible** person who owns the problem and performs the work. In an LCA analysis this is often the LCA practitioner or individual business people, who help collect input data for a life cycle analysis.
- **A = Approver**: Person, to whom “R” and the team is accountable and who is often the commissioner of the study.
- **C=** person to be **consulted**: often a technical subject matter expert or value chain partners, who have specific knowledge needed in certain parts of the project.
- **I** = person who needs to **be informed**: often a business manager who will use the results of an LCA to make the appropriate business decisions.

Project Management Tools: Gantt Chart

Gantt charts support managers to make sure that all activities are accounted for, their order of performance is logical and appropriate, and that completion times for each individual activity as well as for the whole project are determined. To create a Gantt chart, the project has to be broken down into individual tasks, which then need to be put into the appropriate sequence. Tasks that can be worked on in parallel need to be identified. The longest time path through the network of connected tasks (*critical path*) determines whether project deadlines can be met. The project manager then needs to give special attention to the activities on the critical path, and may consider increasing resources and financial support in those bottle-neck activities to support in-time completion of the overall project.

LCA guidance documents like the ISO 14040 standards (ISO, 2006) and the ILCD handbook (JRC, 2010) provide useful frameworks to identify resources and work streams that are relevant within the goal and scope of a given LCA project. Software tools like Microsoft Project are available to support the planning process and to help build Gantt charts. In this project, Gantt charts were established as Microsoft Excel spreadsheets to facilitate the exchange of information among the practitioners involved.

RESULTS

At the very beginning of the project, the project team developed layered RACI to manage resource responsibilities. The below RACI chart shows data collection activities on the highest level. More detailed RACI charts described the individual tasks at hand.

	LCA Practitioner	Internal Process Expert	Value Chain Partners	Comissioner	Subject matter expert	Internal/External Reviewer	Business Mananger
Goal and scope definition	R	C	C	I, A	C	C	I
Data collection	R	R	R	I, A	C		
Development of LCA Model	R				C		
Discussion of Results	R	C	I, C	I, A	C	C	
Interpretation / Business Guidance	R	C	I, C	I, A	C	C	I

Figure 1. RACI Chart for LCA

Due to the complex value chain, the study relied on the input from multiple contributors along the value chain, with the objectives to include knowledgeable internal and external experts on the considered technologies and value chains, and to gather input from customers and other stakeholders to determine the relevant issues early on in the process. The individuals involved came from diverse functional and educational backgrounds, e.g. marketing, R&D, business functions, trade shop customers, converter customers, and process technology.

Since the goal and scope definition is critical for the whole project, value chain partner and customer feedback was solicited as early as the goal and scoping process. Some of the data collection activities were performed internally, and some by value chain partners. In some cases, internal data was validated by real life operations at customers.

Given the interdependent relationship of its components, this LCA project deviated from its predefined, sequential path. Several iterations) were encountered during the project, such as realignment of scope, changes in data collection strategy, inclusion of additional resources. However, due to proper project management, the team was able to anticipate changes early on. Gantt charts like the one below were instrumental to realign timelines and resources in an iterative fashion and to manage the complexities of the project, so that in the end, the project goal to complete the project within the given timeline could be attained.

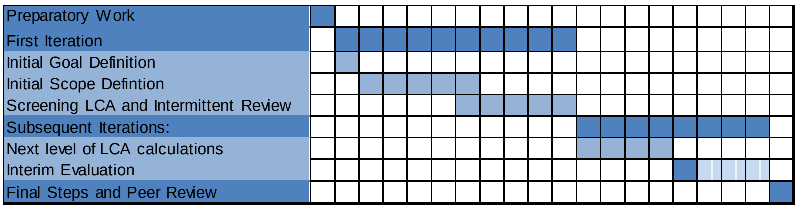


Figure 2. High-level Gantt Chart for LCA

All LCA case scenarios conducted support the general conclusion that flexographic printing is more sustainable with respect to non-renewable energy consumption and greenhouse gas emissions in the flexible packaging and tag & label industry compared to rotogravure printing (see Fig. 3 for illustration of exemplary results). Comparing thermal and solvent plate imaging processes, it can be seen that the environmental performance of the different imaging techniques is dependent on solvent recycle practices, the choice of equipment configuration, the selection of the trade shop electricity grid, and the choice of the fiberweb material. For more detailed results, please refer to the underlying publication (Veith & Barr, 2008).

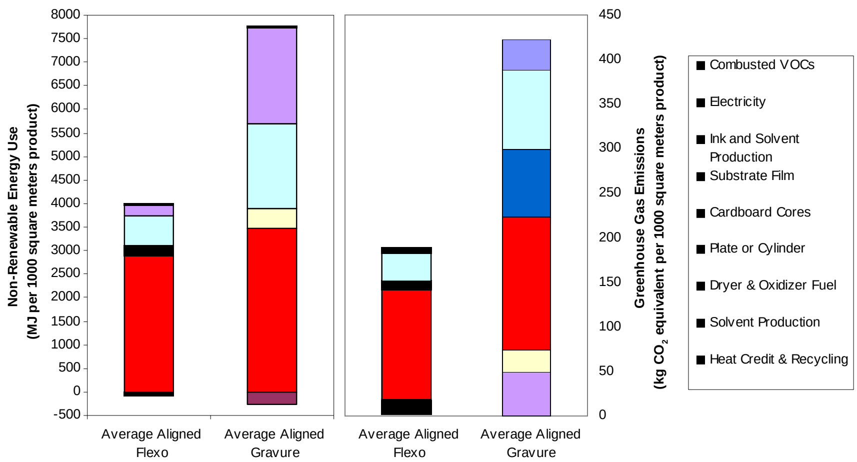


Figure 3. Flexography/Gravure Comparison of Cradle-to-Gate Impact Contribution

DISCUSSION / CONCLUSIONS

The successful management and timely completion of this exemplary LCA study clearly demonstrate that traditional project management tools like RACI and Gantt charts can indeed be very helpful to execute LCA projects within complex value chains.

REFERENCES

Veith, S.R., Barr, S. (2008). *Life Cycle Assessment: Flexographic and Rotogravure Printing Comparison & Flexographic Plate Imaging Technologies*. Retrieved from http://www2.dupont.com/Packaging_Graphics/en_US/sustainability/sustainability_LCA.html

Joint Research Center (2010). *ILCD Handbook - General Guide for Life Cycle Assessment* (First edition).

International Organization for Standardization (2006). *ISO 14040 and ISO 14044 Environmental Management Life Cycle Assessment Package*.

THE E-MISSION

ELECTRIC MOBILITY AS A DRIVER FOR LIFE CYCLE MANAGEMENT

Sebastian Schmidt, Benjamin Boßdorf-Zimmer, Dr. Stephan Krinke,*
**Letterbox 011/1774 38436 Wolfsburg; sebastian.enrico.schmidt@volkswagen.de.*

Keywords: Electric Mobility; Life Cycle Assessment; Life Cycle Management

ABSTRACT

Electric mobility will change the car as we know it, the way it is used and the way it is manufactured. The emerging electric mobility further increases the necessity for life cycle management. The massive implications of electric mobility not only on the automotive industry but also on its supply chain, the customers, energy market and the recycling industry require a detailed and well-structured management instrument. The life cycle assessment methodology is used as a starting point to master the complex challenges in the field of electric mobility. This detailed holistic environmental stocktaking on electric mobility gives a detailed status-quo analysis. Challenges and opportunities associated with the electric car become apparent and therefore manageable. Future areas of activity can therefore be derived and justified.

INTRODUCTION

Electric mobility holds the key to long-term sustainable transportation. It will, however, change the car as we know it, the way it is manufactured and the way it is it is used. New resources and materials are required, from lithium for the batteries to neodymium for the electric motors. Production systems have to be restructured and employees have to be trained to work with new electric technology and components. The implications of electric mobility, not only on the automotive industry, but also on its supply chain, the customers, energy market and the recycling industry require a detailed and well-structured life cycle management instrument. Since environmental protection and corporate social responsibility have a long tradition in the Volkswagen Group and are central to the company‘s long-term policy it is even more important to apply life cycle management for electric vehicles at its best. life cycle assessment for environmentally sustainable product development is firmly anchored in our corporate principles and in the following the Volkswagen approach of managing the life cycle of a vehicle is shown using the electric vehicle as an example.

METHODOLOGY

The life cycle assessment methodology is used to master the complex challenges in the field of electric mobility at the Volkswagen Group. In order to enable an effective life cycle management each of the life cycle phases is subject to extensive research. In the following selected examples of Volkswagen´s challenges and solutions for each phase of the life cycle of an electric vehicle are presented.

Manufacturing

Growth in e-mobility will lead to increased demand for a variety of raw materials used in vehicles, which could potentially create market shortages. “Raw Materials Analysis” is a tool used by Volkswagen to assess the risks to its raw materials supplies. This early warning system helps to select the most appropriate technologies and safeguard long-term supplies. In order to obtain an early indication of corruption risks that could affect resource supplies, Volkswagen takes part in regular discussions and exchanges with the extractive industries transparency initiative (EITI). Additionally, Volkswagen installed environmental standards for suppliers. Our suppliers undertake to comply with VW standard 01155, VW standard 99000 and the Standard Components Specifications. Volkswagen requires its partners all over the world to deliver impeccable quality while also respecting environmental and social standards.

Our efforts to increase sustainability on the supply side are completed by our measures to continuously improve our Volkswagen Group sites. The goal for new factories of the future is clear: they must be resource-efficient and low-emission operations. But existing factories offer huge opportunities for reducing emissions, too. They are converted step by step to operate at similar levels of efficiency as a new factory. Of course, emissions reductions on this scale can only be achieved by adopting a holistic approach. The Volkswagen Group is aiming to make its production operations 25% more eco-friendly by 2018. In concrete terms, these cuts relate to energy and water consumption, emissions and waste.

In order to ensure a continuous improvement in production-related environmental protection environmental management systems are in operation at Volkswagen plants for many years. These systems are audited in line with the ISO 14001 (ISO 2009) standard and virtually all Volkswagen Group sites are certified using this standard. Since 1995, some of the European Volkswagen plants take part in the European Union‘s eco-management and audit scheme (EMAS) (European Commission 2009). In many respects the requirements for EMAS certification go even further than those for ISO 14001.

At the current state of the art, each electric car has generated 74 g CO_2/km when leaving the manufacturing site (Volkswagen Group 2012). With our green factory concept, we are aiming to reduce CO_2 emissions at our factories by 25% for every vehicle produced. And by collaborating with our partners in the supply chain, we can extend this goal to all stages of the production process.

Use Phase

For Volkswagen it is clear that the goal is to charge electric cars solely from regenerative sources. VW Kraftwerk GmbH made green power available for the German fleet trials of the electric Golf in 2011/2012. This 100% renewable electricity is sourced for example from hydroelectric power plants in the Alps. The Volkswagen now group offers special green electricity contracts for final customers. The green electricity is generated by waterpower plants in Germany, Austria and Switzerland and certified by TÜV Nord and labelled with the “ok power” eco-seal.

Based on the European generation mix, the carbon footprint of an electric vehicle is at an average of 88 g CO_2/km (Volkswagen Group 2012). With renewable electricity we can reduce this to 1 g CO_2/km (Volkswagen Group 2012).

End-of-Life

Electric vehicles are too valuable to be simply scrapped at the end of their useful life. Not only the battery but the rest of the vehicle as well is a source of raw materials which must be put to good use. Consequently, recycling techniques are a focus of ongoing development work at Volkswagen. One such technique is the Volkswagen SiCon process, which is used to recover raw materials from end-of-life vehicle shredder residues. With the aid of this multi-award-winning process, a 95% recovery rate can be achieved for end-of-life vehicles. Once the battery has been removed, the process is suitable for recycling e-cars too. Growth in electric mobility will result in increasing numbers of end-of-life lithium-ion batteries. Fortunately, high recycling rates are already achievable for the lithium, cobalt and other metals contained in these batteries. The feasibility of such recycling including a life cycle assessment (Buchert 2011) has been demonstrated by the LithoRec project, in which Volkswagen is a partner. Tests have shown that around 90% of the battery‘s raw materials can be recovered with the LithoRec processes – thereby helping to reduce dependence on imports of raw materials and ensure security of supply. The main focus for appropriate recycling is on systematic recycling of valuable metals. In the life cycle Assessment, recycling is offset against total life cycle emissions in the form of a recycling credit. Recycling of the lithium-ion battery according to our calculations brings an overall recycling credit of 10 g CO_2/km (Volkswagen Group 2012).

RESULTS

This holistic environmental stocktaking on electric mobility gives a detailed status-quo analysis. Challenges and opportunities associated with the electric car become apparent and therefore manageable. Future areas of activity can therefore be derived and justified. Over a life cycle of an electric car currently 162 g CO_2/km are emitted. By identifying hotspots and taking the measures described above these CO_2 emissions can be reduced to 56 g CO_2/km. This is an important step towards a true zero-emission vehicle.

CONCLUSIONS

Electric mobility can play an important role in the transition to sustainable transportation. In order to achieve the full potential towards sustainable mobility life cycle management is essential. In order to build cars as resource-efficiently as possible, it is crucial to analyse resource pathways in depth, to closely collaborate with suppliers and to train employees. With the aim of running cars in a sustainable way, electricity from renewable sources must be used. For the end-of life advanced recycling solutions for electric components need to be developed. Only by successfully applying life cycle management these vital steps toward sustainability can be identified and successfully implement.

REFERENCES

Buchert, Matthias et al (2011). Ökobilanz zum „Recycling von Lithium-Ionen-Batterien“ (LithoRec). Darmstadt: Ökoinstitut.

European Commission. (2009). Regulation (EC) No 1221/2009 of the European Parliament and of the Council of 25 November 2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS), repealing Regulation (EC) No 761/2001 and Commission Decisions 2001/681/EC and 2006/193/EC. Brussels: Official Journal of the European Union

ISO 14001:2004/Cor 1:2009 (2009). Environmental management systems -- Requirements with guidance for use. Geneva: ISO

Volkswagen Group (2012). The e-Mission: Electric mobility and the environment. Wolfsburg: Volkswagen Group

USING WATER FOOTPRINTING ON A REGULAR BASIS - PROBLEMS AND CURRENT DEVELOPMENTS FROM AN INDUSTRY PERSPECTIVE

Andreas Uihlein & Ellen Riise*
SCA Hygiene Products GmbH
**Sandhofer Straße 176, 68305 Mannheim, Email: andreas.uihlein@sca.com*

Keywords: water footprint; water inventory; supply chain; product portfolio

ABSTRACT

Water footprinting is still in its infancy. So far, an accepted general framework and various water footprint impact assessment methods have been developed. SCA performed a case study to evaluate the usefulness and applicability of water footprinting in industry. For water footprinting becoming a useful tool for decision making there are several problems: data is lacking and of poor quality. In addition, some impact assessment methods are not operational yet. Different operational impact assessment methods might lead to different conclusions because of different pathways or endpoints modelled or different characterisation factors. On-going improvements will solve some of those problems and will hopefully allow to use water footprinting as a robust basis for decision making in industry.

INTRODUCTION

SCA performed a case study on water footprinting for four selected tissue products. The main focus of the project was the identification and analysis of existing and proposed water footprint methods and their possible application in industry. The results of the study will be used internally to identify hotspots and possible future improvement areas in terms of water use as well as for educational purposes within the company. The study will also be used to identify the advantages and challenges of water footprinting and the appropriateness and applicability of the various methods related to SCA's product portfolio.

MATERIALS AND METHODS

A screening of existing water footprint methods has been performed. The methods found in literature range from simple indexes to sophisticated endpoint methods. While only the most recent simpler methods have been selected, all midpoint and endpoint methods have been applied in the case study.

Simple indexes can be based on water scarcity or vulnerability. The index methods applied in this study are the water stress index (Pfister et al., 2009) and the water impact index (Veolia water, 2010). Going beyond indexes, midpoint and endpoint methods for water footprinting exist. As midpoint methods, we have chosen the WFN scarcity method (Hoekstra et al., 2009), the ecological scarcity method (Frischknecht et al., 2009), and the methods according to Milà i Canals et al. (2009), Bayart et al. (2010), and Boulay et al. (2011). As endpoint methods we have selected: Pfister et al. (2009), Bayart et al. (2010), Boulay et al. (2011), Verones et al. (2010), Van Zelm et al. (2011), Bösch et al. (2007), and Motoshita et al. (2008, 2009).

RESULTS

Water flows and water balance

A water balance including water inputs and outputs of each process of the life cycle of the products was compiled. Typically, many different databases and data sources are used in LCAs performed by industry and are mixed in a life cycle model (e.g. Ecoinvent database, ILCD/ELCD database, data from industry associations, primary data). Nomenclature and the way of how water is modelled vary between databases. Sometimes, only water withdrawals are accounted for while water returns are documented only sometimes. Incorporation into products and evaporation are usually not reported.

Often, water inputs and water outputs are not balanced in datasets with generic data. In addition, some water flows are not specified (e.g. an input flow is just named 'water') which makes the calculation of impacts impossible if we go beyond water volume accounting. In the case study, for every individual process, an in-depth investigation had to be performed to complete the water balance involving many assumptions and estimations. To perform a water footprint assessment, it is also necessary to identify the location of water use for every process. This is especially difficult for aggregated and generic datasets from databases that are usually used for upstream data (e.g. "Diesel mix at refinery, EU-27").

Water footprint assessment results

The results for the four products of the different water footprint methods have been compared by establishing a ranking. Interestingly, all methods that are operational come to the same conclusions regarding the ranking of the products. We also analysed the contribution of each life cycle step to the results for each method applied (Figure 1). The results differ between the methods. Most methods show highest impacts for raw material supply, followed by the production process. For some methods, the water footprint is dominated by raw material supply, for example the WFN scarcity (Hoekstra et al., 2009), Pfister (Pfister et al., 2009) and Boulay endpoint (Boulay et al., 2011) methods. Those 'outlier' methods have very high characterization factors for those countries where some of processes for raw material supply are located.

DISCUSSION

Data gaps and data quality

Data gaps exist for primary data but also in databases for secondary or generic data. Data collection systems on water use upstream the supply chain are usually not in place. For secondary data from databases, water inventories are not complete and not transparent. A typical data gap is that only water withdrawals or water inputs are accounted for while information on the fate of water is missing. Incorporation into products and evaporation are usually not reported. Another problem of secondary data is that often the geographic location of water flows are not known.

Data quality for water flows from existing databases is not very good. Data quality of primary data collected by industry for own operations and from suppliers is better, however, in some cases, questions on water flows cannot be answered since there are no measurements done. Compared to energy there are fewer water meters installed, for example, split between production lines cannot be done. So, there are many assumptions and estimates needed to get a dataset as complete as possible. In addition, data quality for evaporation from industrial processes also has to be improved.

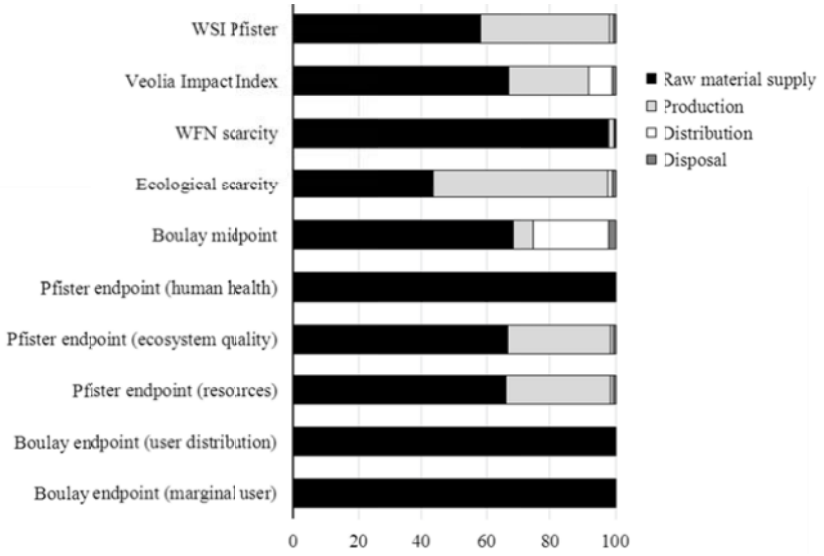


Figure 1. Percentage of life cycle steps of total water footprint according to selected methods

Impact assessment

Concerning the water footprint methods, many midpoint and endpoint methods are not operational yet but only propose a framework (e.g. Bayart et al., 2010). Some authors like Verones et al. (2010) or Van Zelm et al. (2011) only provide characterisation factors for selected case studies (e.g. selected watersheds or countries).

When looking at the methods that were applied in this case study, the following conclusions can be drawn: the WSI according to Pfister et al. (2009) is an index that is very easy to understand. It can be used as a first screening indicator as also proposed by the authors. The Boulay midpoint indicator (Boulay et al., 2011) is very easy to use. The ecological scarcity method (Frischknecht et al., 2009) can be easily applied but is probably best to use when water footprint is integrated into a full LCA with also the other impact categories being calculated using the ecological scarcity method. The endpoint methods that have been proven to be most operational are the Pfister et al. (2009) and Boulay et al. (2011) endpoint methods.

CONCLUSIONS

Several conclusions can be drawn from this case study. The first findings indicate that data quality for water flows from secondary data is not very good. Many data gaps exist. For primary data, usually, data quality is better, however, data quality should be improved by installing water metering systems or improving them (e.g. allowing for disaggregated measurements).

We expect that the accounting of water flows will be improved in secondary databases soon and some progress can be seen already now. If we want to improve data quality and to close data gaps, it is important to consider that demands on data differ for various impact assessment methods. It is thus often difficult to decide what data to collect. What we would need is an agreement on what data to collect (e.g. what types of water, what information on location and water quality, which temporal disaggregation to use). We hope that the ISO standard 14046 on water footprinting will help in defining what should be the minimum requirements regarding data collection.

Concerning the impact assessment methods, many midpoint and endpoint methods are not operational yet but only propose a framework while others provide characterisation factors for selected case studies. In addition, the case study has shown that different operational impact assessment methods might lead to different conclusions.

From our case study, we have seen that water footprinting is possible, however, not at all straightforward. A lot of manual data handling, assumptions and estimates are needed that all have to be done on a case-by-case level. This will hinder water footprinting to be applied (or added to more traditional impact categories) in industry for larger product portfolios, or for regular performance tracking on assortment level. Data quality issues and the differences between IA methods make it extremely difficult to use water footprinting as a robust basis for decision making in industry.

REFERENCES

Bayart, J.B., Bulle, C., Deschênes, L., Margni, M., Pfister, S., Vince, F., Koehler, A. (2010). A framework for assessing off-stream freshwater use in LCA. *The International Journal of Life Cycle Assessment*, *15*, 439-453

Bösch, M.E., Hellweg, S., Huijbregts, M.A.J., Frischknecht, R. (2007). Applying Cumulative Exergy Demand (CExD) Indicators to the ecoinvent Database. *The International Journal of Life Cycle Assessment*, *12*, 181-190

Boulay, A.M., Bulle, C., Bayart, J.B., Deschênes, L., Margni, M. (2011b). Regional Characterization of Freshwater Use in LCA: Modeling Direct Impacts on Human Health. *Environmental Science & Technology*, *20*, 8948-8957

Frischknecht, R., Steiner, R., Jungbluth, N. (2009). The Ecological Scarcity Method Eco-Factors 2006. Bern, Switzerland: Federal Office for the Environment

Hoekstra, A.Y., Chapagain, A.K., Aldaya, M.M., Mekonnen, M.M. (2009). Water Footprint Manual. State of the Art 2009. Enschede, The Netherlands: Water Footprint Network

Milà i Canals, L., Chenoweth, J., Chapagain, A., Orr, S., Antón, A., Clift, R. (2009). Assessing freshwater use impacts in LCA: Part I - inventory modelling and characterisation factors for the main impact pathways. *The International Journal of Life Cycle Assessment*, *14*, 28-42

Motoshita, M., Itsubo, N., Inaba, A. (2008). Development of impact assessment method on health damages of undernourishment related to agricultural water scarcity. P*roceedings of the* 8^{th} *International Conference on EcoBalance*, Tokyo, 10 -12 December

Motoshita, M., Itsubo, N., Inaba, A. (2009). Development of damage assessment model for infectious diseases arising from domestic water consumption. *Proceedings of the SETAC Europe 19th Annual Meeting*, Gothenburg, 31 May - 4 June

Pfister, S., Köhler, A., Hellweg, S. (2009). Assessing the Environmental Impacts of Freshwater Consumption in LCA. *Environmental Science & Technology*, *43*, 4098-4104

Van Zelm, R., Schipper, A.M., Rombouts, M., Snepvangers, J., Huijbregts, M.A.J. (2011). Implementing groundwater extraction in life cycle impact assessment: characterization factors based on plant species richness. *Environmental Science and Technology*, *45*, 629-635

Veolia Water (2010). The Water Impact Index and the First Carbon-Water Analysis of a Major Metropolitan Water Cycle. Veolia Water

Verones, F., Hanafiah, M.M., Pfister, S., Huijbregts, M.A.J., Pelletier, G.J., Koehler, A. (2010). Characterization Factors for Thermal Pollution in Freshwater Aquatic Environments. *Environmental Science & Technology*, *44*, 9364-9369

FOOD WASTE IN A VALUE CHAIN PERSPECTIVE 1

Wednesday, Aug 28: 10:30 am - 12:00 pm

Session chairs: Ole Jørgen Hanssen, Ostfold Research, Norway
Clementine O'Connor, BIO Intelligence Service, France

CAUSES OF AND STRATEGIES FOR REDUCING FOOD WASTE IN POST FARM SUPPLY CHAINS

Ingela Lindbom, Jenny Gustavsson, Joakim Forsman and Karin Östergren*

SIK - the Swedish Institute for Food and Biotechnology

**P:O Box 5401, SE-402 29,Göteborg, Sweden, e-mail Ingela.Lindbom@sik.se*

Keywords: food waste, food supply chain, root cause analysis

ABSTRACT

About 1/3 of food produced for human consumption is lost and wasted. Considering resource efficiency and environmental impacts, the need for reducing food waste levels is urgent. This case study illustrates the potential and great possibilities to deal with the food waste challenge by proper root cause analysis and the methodology of Lean Six Sigma. A production line of a dough-based product was targeted, and the practical work resulted in a 50% reduction of waste.

INTRODUCTION

Every actor in the different parts of the food chain needs to reduce their amount of waste due to environmental consequences and pressure from politicians and authorities to contribute to the reduction of the environmental impact from the food chain. Preventing waste is one option that contributes to cost reduction as well as increasing profits.

However, waste reduction is a complex objective which demands time and involvement of staff at different levels of the managerial hierarchy, from the production line to the top managerial level. Root causes of waste may vary significantly, based on physical and human resources and technical solutions and are highly dependent on how the whole process is designed and managed. In many cases, there may be a combined effect from a number of driving influences which make the improvement more difficult (Carlos and Oznur, 2011) since the food supply chain is complex.

A very important part of waste reduction work is the diagnosis, a correct identification of the causes that can be considered as drivers of the major waste quantities in the system studied and to which the measures taken should be addressed. However, this identification process is very complex since there can be hundreds of ideas on possible causes for a single production line at the start of the identification work. The question is how to find the needle in the haystack.

The aim of this case study was to adapt a stepwise method inspired by Lean Six Sigma (George, 2002) to deal with the reduction of food waste. Within the Lean Six Sigma methodology, Pareto charts are often used to illustrate which factors influence a given outcome the most (George, 2002). The Pareto Principle is also known as the "80/20 Rule". If valid and applied to food waste in a given system, about 20% of the causes would generate

80% of the waste. The Lean Six Sigma methodology has earlier been applied to identify waste generating-causes in two different Swedish food industries, and the results indicated that a major part of the waste in these food production systems was generated by quite few causes (Gunnerfalk, 2006; Svenberg and Torgå, 2007). Inspired by this methodology, a method for mapping waste within a specified system, identifying the major causes of the waste and root cause identification of the major drivers of waste has been adapted to a case study carried out on a production line of a dough-based product manufactured in Sweden The process is continuous, with a number of sub-process steps from mixing of ingredients to palletizing of the final product, for example dough mixing, baking, cooling, packing and palletizing. All sub-processes have potential to generate waste if not efficiently run.

METHODS

The first step of the method is to map the product flow in detail throughout the chain and measure the waste quantities at different points along the chain studied. The points where the major waste quantities are detected are thereafter identified as the waste hotspots in the system, but it does not show the cause(s) of that waste.

The second step in a mapping method is to investigate the hotspots in greater detail to identify possible causes to the waste detected here. In the third step, a root causes analysis is performed to yield the detailed information needed to identify actions suitable for eliminating the root cause.

In some cases, root causes may be associated with activities in other management zones of the production line aside from the hotspot of waste occurrence. Therefore it is of importance to be open-minded to a very high degree of complexity in the analysis and avoid pre-assumptions that waste is necessarily caused at the site of its occurrence. For example machinery stoppage can be a cause of waste in a bakery production line. It can result in a cascade effect where machine stoppage at one specific point of the process line will generate cascades of waste occurring at several points of the line. Therefore interviews and gathering of facts from the staff that are running the process daily are of major importance to understand the detailed complexity since it is these persons who have the best knowledge of what incidents frequently occur at the same time as waste is generated at the hotspots in the actual process line.

RESULTS

Based on the method explained above, the amount of waste throughout the production line had been measured for a couple of months. The highest amount of waste was detected in the sub-process of baking in the oven, leading to the conclusion that the oven was the hotspot for waste on this process line.

For the deeper study of possible causes to the waste detected in the baking step, the oven was thoroughly studied under production conditions to gather information directly from the center of coincidences that actually resulted in waste. In addition, the oven operator was interviewed to identify critical information about waste generation in the sub-process of baking. The result was that waste generation often could be associated with the dough properties; especially, the occurrence of stickiness was regarded as a parameter related to waste generation. It was also concluded that the dough properties were determined in one or more sub-processes from the oven and upstream to the very beginning of the process line. Based on these findings, the focus was shifted to the dough making sub-processes in order to find the root cause(s) for stickiness of the dough.

Possible causes of the dough's stickiness were the subject of a brainstorming session held with experienced production staff where a large number of ideas on possible causes of stickiness were identified. Thereafter, available options in the different sub-processes on how to control these different causes (factors) were identified. The analysis of information from the brainstorming session highlighted a few factors, as being more likely to affect the stickiness of the dough and also possible to control.

Due to practical reasons, sets of at most three factors could be investigated. The three factors assessed as more likely to cause major quantities of waste were selected. In full scale trials, it was statistically validated that one of these factors, the resting time of the dough, significantly affected the stickiness and that a longer resting time was correlated to less stickiness.

To validate the result that a longer resting time of the dough would decrease the waste amounts from the actual process line, the process parameter settings were changed during a test period of 6 weeks out of 18 weeks project time. Waste generation before and after the changed settings and implemented improvement was monitored.

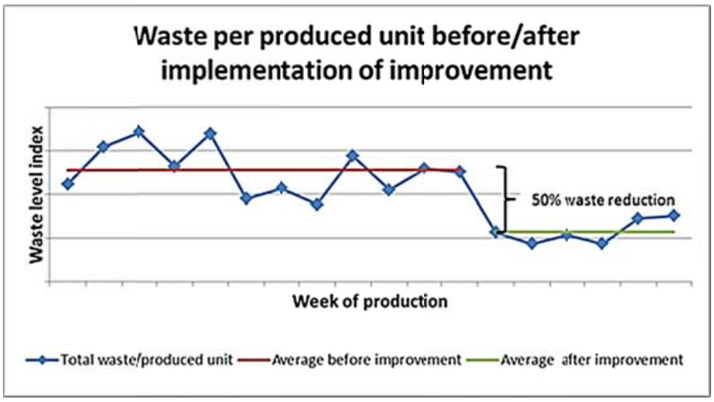


Figure 1. Waste per produced unit before/after implementation of improvement

During the test period, the average waste generation of the process line was reduced by 50% as shown by Figure 1. It was concluded that the root cause for 50% of the waste in the actual line had been properly identified and also that it was possible to control this factor over a longer time period. It was furthermore concluded that the correct identification of this major root cause simultaneously enabled not only a lower environmental impact from waste but also cost reduction.

DISCUSSION

In accordance with previous studies (George, 2002; Zhen, 2011; Gunnerfalk, 2006; Svenberg and Torgå, 2007), this case study indicates that the 20/80 rule m ay be roughly applied to food waste issues.

Improvement activities for increasing efficiency require the i vestment of human resources and management to adjust their activities to the best practices. By a correct identification of quite few root causes and implementing actions towards these, the waste reduction potential may even exceed 50% for a specific line. In this specific case, a 50% reduction of waste from the actual process line could be achieved by taking one single action.

Nonetheless, this is not the end point of waste reduction as there are still causes with lesser effects which can be dealt with, respective to their priority. The cost reduction gained by actions that result in waste reduction can be proactively used as an investment in continuous improvements aiming for further waste reduction activities.

The results achieved in this case study cannot be generalized and validated for all bakeries as the root cause of waste may vary between production lines, even when the lines are producing quite similar products. This is due to differences in the ingredients and actual machinery used but also based on how physical and human resources work separately and together and depending on how the whole process is managed.

The root cause of waste can vary significantly case by case, therefore setting standards by generalizing for the whole of the food industry or even the bakery industry may be too much simplification. However, a guideline may be defined on how to map waste to identify the hotspots along the part of the food chain studied and the root cause(s) associated with the hotspots. Based on this type of analysis, effective waste prevention activities for food chains can be identified.

CONCLUSIONS

A mapping methodology for reducing food waste has been adapted and successfully applied to a dough-based product line. The case study illustrates that the potential and great possibilities to deal with the food waste challenge can be exploited through proper root cause analysis and adaption of the methodology of Lean Six Sigma. As such, the result of this study is not merely about a better use of a technology it also shows the importance of maintaining the gained knowledge within the company to achieve long lasting effects of the waste prevention work. This highlights the influence of management on food waste levels at each specific food production plant.

REFERENCES

Carlos, M., B., A., & Oznur, Y. (2011). The causes of food waste in the supplier–retailer interface: Evidences from the UK and Spain. Resources, Conservation & Recycling, 55(Environmental Supply Chain Management), 648-658. doi:10.1016/j.resconrec.2010.09.006.

George, M. O. (2002). Lean six sigma. (1st ed.). New York: McGraw-Hill.

Gunnerfalk, F. (2006). Sex Sigma vid. Coca-Cola Drycker Sverige AB. Ett. DMAIC-projekt för att minska svinnet av dryck i produktionsprocessen. Institutionen för industriell ekonomi och samhällsvetenskap. Avdelning för kvalitets-och miljöledning. ISNN: 1402-1617.

Svenberg, S., Torgå, K. (2007). Analys av svinn: en tillämpning av DMAIC-metodiken vid Lantmännen Axa, Luleå tekniska universitet/Industriell ekonomi och samhällsvetenskap/Kvalitets- & miljöledning, Svenska. Examensarbete / Luleå tekniska universitet, Civilingenjörsprogrammet, 1402-1617

Zhen, Y. (2011). Food safety and Lean Six Sigma model, An abstract of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the Department of Safety Science University of Central Missouri.

CLOSING THE LOOP: FEASIBILITY OF INDUSTRIAL SYMBIOSIS FROM FOOD PROCESSING WASTE

Nadia Mirabella[1], Valentina Castellani[1], Serenella Sala[2].*

[1]*Department of Earth and Environmental Sciences, Piazza della Scienza 1, 20126 Milano, Italy.* nadia.mirabella@unimib.it .

[2] *European Commission, Joint Research Centre, Institute for Environment and Sustainbaility, Sustainability Assessment Unit , Via E. Fermi 2749, 21027 Ispra, Italy*

Keywords: food waste; industrial symbiosis; closed loops; bioeconomy; biorefinery.

ABSTRACT

Closed systems are the basis of so-called industrial symbiosis, in which the goal is to use wastes from one sector as an input for other sectors. In the context of bio-economy, the food industry generates a large amount of residues. Many of these, however, have the potential to be reused into other production systems, trough e.g. biorefineries. The present study, based on extensive literature review, presents feasibility and constraints of applying industrial symbiosis in recovering waste from food processing. Generally, food waste is not used as it is, but only after a transformation that allows to extract active ingredients with high added value. Mainstream sectors of application of functional ingredients derived from this transformation are the nutraceutical and pharmaceutical industry.

INTRODUCTION

In Europe, integrated product policy (EC, 2003), resource efficiency flagship initiative (EC, 2011) and the bio-economy communication (EC, 2012) are promoting the prevention of food waste (FW) in all the life stages. The production of FW covers all the food life cycle: from agriculture phase, up to industrial manufacturing and processing, retail and household. Up to 42% of FW is produced by households, 38% losses occur in the food manufacturing industry, and 20% is distributed along the whole food chain (agricultural food loss is not included in this estimation) (EC, 2010). In addition, FW is expected to rise to about 126 Mt by 2020 if additional prevention policy or activities are not undertaken (EC, 2010).

The large amount of waste produced by the food industry, in addition to being a great loss of valuable materials, also raises serious management problems, both from the economic and environmental point of view. Many of these residues, however, have the potential to be reused into other production systems, trough e.g. bio-refineries.

There are several studies in the literature which deal with the bio-refinery concept, i.e. with the use of biomass feedstock in substitution of fossil ones. Due to the well-known problem of land competition between food and biomass feedstock dedicated crops, a growing number of studies investigate specifically the use of residues as a secondary source of energy or raw material (see, for instance, Ghatak, 2011; B. Kamm and M. Kamm, 2004 and Mahro and Timm, 2007). In fact, closed systems are the basis of so-called industrial symbiosis, in which the goal is to use wastes from one sector as an input for other sectors.

In order to systematize most recent research on the topic, the present study focus on the potential use of food waste coming from food manufacturing (FWm). The aim of this study is twofold:

- Reviewing the literature concerning the possible use of FWm for producing new products, reducing burden on virgin raw materials
- Assessing main constraints and limitation in a large scale implementation of FWm reuse/ recycling

The authors performed an extensive review of possible use of FWm in order to transform food waste in resource for production of new products, applying industrial ecology and eco-innovative approaches.

METHODOLOGY

Several keywords were chosen to obtain a large range of existing studies to be analysed. The keywords selected were: food waste; industrial ecology food; byproducts food waste; byproducts food industry; food processing waste; meat processing byproduct; biorefinery food waste; meat waste byproduct; dairy waste byproduct. No geographical restrictions were applied, and the search was limited to papers published from 2000 to 2012. The keywords were introduced with boolean operator “and” into the most important databases of scientific journals, such as Scopus, Cilea and SciDirect. Titles and abstracts from more than 1500 publications were screened and examined, and then relevant papers were selected based on a number of criteria and were used for this review.

Papers coming from fifty scientific journals were finally selected, plus two conference proceedings and one PhD thesis, for a total number of 107 papers reviewed. The journals mainly belong to food research, biotechnology, chemistry and waste management field. The 107 articles selected were classified into the following categories: fruits and vegetables; dairy products; meat and derivatives. Within the first category, the following subcategories were defined: apples; berries; citrus fruits; exotic fruits; potatoes; tomatoes; olives; other vegetables; and miscellaneous.

RESULTS

The literature review allowed identifying, for each of the food processing industries considered (fruit and vegetables, meat and meat products, dairy products) which are the most significant possibilities of FWm reuse. Table 1 illustrates the correspondence between the processing chains and waste potentially reusable in the fruit and vegetable sector. For more detailed results see Mirabella et al (2013).

The most promising sources of valuable compounds from fruits and vegetables are: olives, exotic fruits and tomatoes, which can provide several valuable compounds. According to the results of this review, researches mainly focus on antioxidants, fiber, phenols, polyphenols and carotenoids extraction, due to their high possibilities of application and potentials.

Concerning meat and derivatives, proteins are the most extracted substances, while lactic acid, proteins and peptides from dairy by-products are mainly obtained.

Table 1. Summary of the correspondences between manufacturing chains and reusable wastes in the fruit and vegetable sector.

	Apple	Berries	Citrus Fruits	Exotic fruits	Potatoes	Tomatoes	Olives	Other vegetables	Miscellaneous
Lactic acid								X	
Food additives				X					
Heavy metals adsorber									X
Functional Food				X				X	
Antimicrobials				X					X
Antioxidants	X			X	X	X	X	X	X
Carotene						X			
Carotenoids						X			
Cellulose			X						
Bioactive compounds				X				X	
Herbicide			X				X		
Phenols	X						X		X
Fibers	X	X						X	X
Rubber filler				X					
Phytochemicals	X								
Flavonoids	X	X						X	
Lipids							X		
Lycopene						X			
Animal feed			X		X				X
Pectins				X					X
Polyphenols		X					X		
Carbon adsorber							X		
Substrate				X				X	X
Carbohydrates							X		
Sugar syrup			X						
Various		X	X	X			X		X

DISCUSSION

The literature review about FWm recovery and industrial symbiosis in the food industry showed that the majority of the studies focus on restricted examples and pilot-scale laboratory experiences, while only few cases contain data about economic and technical feasibility on existing full-scale studies. In general, there is a lack of specific studies related to logistic aspects of industrial symbiosis, e.g. case studies with the characteristics and the quantity of food wastes produced by a company, the geographical distribution of other companies that could benefit from that wastes etc.

Furthermore, it was observed that the FWm are not used as they are, but they need further processing steps. This transformation implies high costs of capital investments in research and development; hence, it is essential to obtain valuable and high added-value products in order to justify the investment.

In this regard, an investigation to identify the type and amount of wastes, the potential for exploitation, the geographical location of producers, intermediaries (e.g. laboratories which could be involved in the transformation and valorization of wastes) and finally, the potential end-users will be necessary.

CONCLUSIONS

In order to promote an industrial symbiosis in the food manufacturing industry, feasibility studies are essential to classify the type and amount of wastes and to identify which industrial sector/activity might transform and use them. According to most of the reviewed studies, the functional compounds extracted from FW can be used as high value added ingredients in the pharmaceutical and cosmetic industry.

Nevertheless, since most of the recovery options involves deep transformation processes before the reuse of the extracted component, it is necessary to assess also the sustainability of the whole recovery process proposed, to avoid the risk of burdens shifting from an environmental compartment to another. For instance, some of the extraction procedures of compounds presented in this review may involve the use of potential polluting chemicals, such as solvents or additives. The benefits of recovery should not be undermined by environmental impacts caused by new production processes. Hence, it is preferable to promote direct reuse/recovery practices (i.e. the replacement of a virgin raw material) without the intermediation of manipulations and extraction from the waste product or to evaluate the processes for the bio-refinement adopting environmental assessment methodologies encompassing the entire life cycle of the by product (e.g. Life Cycle Assessment).

REFERENCES

European Commission. (2003). *Integrated Product Policy. Building on Environmental Life-Cycle Thinking. COM(2003) 302final.*

European Commission. (2010). *Preparatory study on food waste across EU 27, Technical Report - 2010 – 054.*

European Commission. (2011). *Roadmap to Resource Efficient Europe. COM (2011) 571final.*

European Commission. (2012). *Innovating for Sustainable Growth: A Bioeconomy for Europe. COM (212) 60final.*

Ghatak, H.R. (2011). *Biorefineries from the perspective of sustainability: Feedstocks, products, and processes. Renew Sust Energ Rev 15, 4042–4052.*

Kamm, B., Kamm, M. (2004). *Principles of biorefineries. Appl Microbiol Biot 64, 137–45.*

Mahro, B., Timm, M. (2007). *Potential of Biowaste from the Food Industry as a Biomass Resource. EngLife Sci 7, 457–468.*

Mirabella N., Castellani, V., Sala S. (2013) *Current options for the valorization of food manufacturing waste: a review.* Submitted to Journal of Cleaner Production.

ECOLOGICAL FOOD WASTE – COMPARING SMALL AND LARGE FOOD RETAILERS

Birgit Brunklaus[1]*, *Johanna Berlin*[2].

[1]**Environmental Systems Analysis, Chalmers University of Technology, S-41296 Gothenburg, Sweden. Email: birgitb@chalmers.se.*

[2]*SP Technical Research Institute of Sweden*

Keywords: Food waste; retailer, ecological food products, actor analysis, collaboration.

ABSTRACT

.

Green efforts and collaboration in the food chain vary as well as how retailers handle ecological products. The ongoing study shows that small retailers care for their products and inform consumers specifically about each individual product: the season, the quality and how to handle each individual product, to reduce waste. Large retailers inform the consumer generally on products and how the retailer is handling waste e.g. food to needy. The question is: does the "caring" handling and communicating of ecological food products lead to less waste and environmental impacts? Further observational studies on waste and handling of food products at retailers will be made and combined with an environmental assessment, LCA. This new interdisciplinary methodology is called actor based LCA.

INTRODUCTION

Previous studies of organic food show that agriculture dominates the environmental impact in the life cycle (~ 90% for animal origin, both conventional and ecological (Carlson et al 2009), and ~ 35% for vegetables such as tomatoes (Högberg 2010)). Notable is that farming and transport matters for vegetables such as imported tomatoes contribute more than three times than local ones (Högberg 2010). However, environmental impacts related to agriculture may be reduced not only by farmers. But also by actors further down-stream, the food industry, retailers and consumers, each of them through reducing the wastage of food. Recent studies on wastage showed that food producers and distributors are contributing 1/3 due to lack of coordination, as well as retailers and consumers are contributing 1/3 each due to inefficient purchasing and meal planning (Gustavsson 2010, Sonesson et al 2010).

The results of this paper lies within the project "Actor-based Life Cycle Assessment – towards green food chains for eco-products" within Formas Organic Production Program 2010-2012 (Brunklaus 2011, Brunklaus & Berlin 2010). This paper describes and compares small and large organic product chains. The organic food chains have been described with its main actors: agricultural actor, industrial actor, retailer and consumer. Following questions are answered within the study:

- What kind of green efforts are made by actors in the organic food chains?
- What characterises small product chains of organic food in Sweden?
- What characterises large product chains of organic food in Sweden?
- What are the impacts on waste and environmental impacts?

METHODS

When describing actors and actions in the product chains the distinction of companies' environmental efforts and effects have been used based on environmental management perspective. In order to describe green efforts, a short review of existing literature was performed in 2010 (Floren et al 2005, Carlson et al 2009, Gustavsson 2010, Sonesson et al 2010, Högberg 2010). In order to identify and characterise small and large product chains, general literature on the retailing sector was complemented with specific information on retailers, including annual reports, websites and telephone communications during 2010 and 2012 (Table 1).

Table1: actor and source of information in organic food chains

Actor in the food chain	**Green efforts**	**Source of information**
Agricultural actors	Fuel consumption and use of nitrogen fertilisers.	Environmental studies (Högberg 2010, Gustavsson 2010, Sonesson et al 2010)
Industrial actors	Effective production, distribution and transports, such as green lean production	Food industrial sector organisation, webpage 2010 Environmental studies (Gustavsson 2010, Sonesson et al 2010)
Retailers	Transport, such as "green cargo", and energy for storing, such as fridge/freezer/lightning	Retailer "COOP" sustainability report and telephone communication 2010, webpage 2012. Retailer "Arstiderna" and "Ekoladan" webpage 2010/2012, email 2010. Retail sector organisation "Svensk Dagligvaruhandel", webpage 2010.
Consumers	Purchasing local and ecological products	Newspaper "Camino" consumer association 2009. Region Western Sweden (Floren et al 2005)

RESULTS

The results of the study on green efforts and actors in the food chain are presented in table 1, (Brunklaus 2011). Agricultural challenge and efforts lie within fuel consumption and use of nitrogen fertilisers (Sonesson et al 2010). The food industries green efforts lie within effective production, distribution and transports, such as green lean production, to reduce energy and climate change (Li 2010). Retailers green efforts lie within transport, such as "green cargo", and energy for storing, such as fridge/freezer/lightning and the environmental challenge is still food waste reduction (Coop 2010, Gustavsson 2010, Sonesson et al 2010), and storing (Coop 2010, Carlsson and Sonesson 2001). According to the branch organisation (Svensk Dagligvaruhandel 2010), retailers have solved their climate challenge with logistics. Consumers green efforts lie within purchasing local and ecological products (Floren et al 2005) and the environmental challenge is still food purchasing, planning, storage and waste (Sonesson et al 2010, Camino 2009).

Within the organic food project small and large food chains have been described. For the small, the demand is rising, and the challenge lies in keeping the good contact, logistics and quality (Li 2010). Interesting small food chains are the new organisational trends of "organic food boxes transported directly to the consumers". These organisations have good local contact with consumers and farmers, they have good logistics, especially for vegetables and fruits (Arstiderna 2010, Ekoladan 2010). Both retailers care for the quality of food products and inform the consumer about best storing behaviour (Arstiderna 2012, Ekoladan 2012). For the large, the challenge lies in the complexity of chains, and the consumers contact is low (Li 2010). Interesting are the large food chains, such as the retailer COOP, which has the broadest variety of ecological food products, but less information to consumers on storing and quality (COOP, 2012).

DISCUSSION

When describing actors and actions in the product chains the distinction of companies' environmental efforts based on environmental management perspective have been useful. The description of organic product chains with help of retailers' way of communicating with consumers has been useful as well. More important information can be gained in the link between farmer, retailer, and consumer, like in a similar study on environmental information and practice in the food supply chain (Soler et al 2010).

The ongoing study shows that small retailers care for their products and inform consumers specifically about each individual product: the season, the quality and how to handle each individual product, to reduce waste. Large retailers inform the consumer generally on products and how the retailer is handling waste e.g. food to needy. The question is: does the "caring" handling and communicating of ecological food products lead to less waste and environmental impacts? To answer that questions further observational studies on waste and handling of food products at retailers will be made and combined with an environmental assessment, LCA. This new interdisciplinary methodology is called actor based LCA.

CONCLUSIONS

Comparing the green efforts within the food chain shows that actors have solved the production and transport issues, while the food waste is still a challenge.

Comparing the small and the large product chains of organic food in Sweden indicates that organising of short and local chains might not only reduce transport, but also reduce waste due to the caring handling of vegetables within the chains. This means less environmental impacts overall.

So far initial work has been performed (literature review, webpage, telephone and mail contact). The next step will be study visits with observations and interviews with the above organic food retailers. Observations will focus on describing and comparing collaboration and logistics between actors in the chain, and how these can be improved. Observations will especially focus on routines for storing, transport and waste for both organic and non organic products and how these routines effect the environmental. Environmental impacts will be calculated according to LCA methodology. Suggestions for improvements will be made, as in the previous actor-based food study on dairy products (Berlin et al 2008), which led to actions regarding waste reduction within industry.

Future studies will be on global organic food chains for examples handling of fruits, where the actor methodology helps to describe responsible product chains. Results will be strategies for retailers and consumers on how to handle products such as fruits.

REFERENCES

Arstiderna (2010 and 2012). Webpages and mail contact, www.arstiderna.se

Berlin, Johanna; Sonesson Ulf; Tillman AnneMarie (2008). Product Chain Actors Potential for greening the product life cycle: The case of Post-farm Milk Chain. Journal of Industrial Ecology Vol 12, Nr 1 , p 95-110.

Brunklaus, B. (2011). Actor's behavior matter – organizing green product chains. Poster presented at the ISE conferences, 7-10th of June 2011, University of Berkley, San Francisco, USA.

Brunklaus, B. & Berlin, J. (2010). Actor Based Life Cycle Assessment - towards green food chains for eco-products. Research project within ORAGNIC PRODUCTION 2010-2013 FORMAS.

Camino (2009). Seminarium om restmat av konsumentföreningen Stockholm, Camino nr 9, 2/2009, Göteborg, Sweden.

Carlsson and Sonesson (2001). Livscykelinventering av butiker – data and metoder för att beräkna butiker med LCA av livsmedel. SIK report SR 676, Göteborg, Sweden.

Coop (2010 and 2012). Hallbarhetsredovisning, webpages and and telephone contact, www.coop.se

Davis, J., Wallman, M., Sund, V., Emanuelsson, A., Cederberg, C. & Sonesson, U. (2011). Emissions of Greenhouse Gases from Production of Horticultural Products - Analysis of 17 products cultivated in Sweden. Göteborg: SIK.

Ekoladan (2010 and 2012). Webpages and mail contact, www.ekoladan.se

Floren, Davis and Cederberg (2005). Kartläggning av konsumption av livsmedel i Västra Göaland, SIK report SR 733, Göteborg, Sweden.

Gustavsson (2010). The climate change impact of retail waste from horticultural products. Master thesis GU. SIK report SR 801, Göteborg, Sewden.

Högberg (2010). European Tomatoes – comparing global warming potential, energy use and water consumption from growing tomatoes in Sweden, the Netherlands and the Canarias

Li (2010). Livsmedels företagens bransch organization – branschfrågor-miljö. www.li.se

Raab, M. & Brunklaus, B. (2012). Carbon Footprint of organic Spanish compared to conventional Austrian/Swedish cucumbers. Gothenburg: Chalmers University of Technology.

Soler, Bergström, Shanahan (2010). Green Supply chains and the missing link between environmental information and practice. Business strategy and the environment 19, 14-25.

Sonesson, , Davis, and Ziegler (2010). Food production and emissions of greenhouse gases. SIK report 802, Göteborg, Sweden.

FOOD WASTE IN THE SUPPLY CHAIN – IMPACTS ON THE PRODUCT CARBON FOOTPRINT

Eveli Soode, Paul Lampert, Gabriele Weber-Blaschke. *Munich Wood Research Institute, Winzererstraße 45, 80797 München, Germany, soode@wzw.tum.de*

Keywords: product carbon footprint, asparagus.

ABSTRACT

Product carbon footprint (PCF) of food products does not directly reflect the amount of produced food ending as waste. Current research aims to determine the impact of the food waste in the asparagus supply chain on the PCF. Data on asparagus cultivation in a conventional production system was collected. Up to 40% of the harvested asparagus is sorted out at the production site and up to 15% of the vegetable is disposed of by the consumer, leaving 45% of the harvested vegetable for consumption. If customers accept asparagus with visually lower quality, reduce energy for shopping trips and cooking, the waste occurring in the asparagus supply chain can be reduced as well as the total PCF.

INTRODUCTION

One-third of food produced for human consumption is lost or wasted globally (van Jenny Gustavsson, 2011). This means that huge amounts of the resources used in food production and the greenhouse gas emissions caused by the production are in vain (van Jenny Gustavsson, 2011). In medium- and high-income countries significant amounts of food waste occurs at the consumption stage and early in the food supply chains (van Jenny Gustavsson, 2011).

In the recent years customers have become more aware of the environmental problems and have shown interest in the environmental impact of food products. This has initiated the more frequent use of a simplified life cycle analysis methodology in a form of carbon, water or environmental footprint. PCF has risen as one of the most common tools to be used due to its clear connection to the climate harmful greenhouse gases and a clear numeric result. PCF is the sum of GHG emissions and removals in a product system, expressed as carbon dioxide equivalent (CO_2e) and based on a life cycle assessment (Draft International Standard 14067). The obvious limitation of using PCF is that it does not reflect the wide spectrum of influence on the environment caused by the production and consumption of the product. Another limitation is that the PCF does not directly reflect the amount of food products which do not reach customer because of inefficient production system, product quality requirements and losses during the transport. Also, only little information is available about the use phase PCF of products.

In Germany, asparagus was the most widely cultivated vegetable in 2012, covering 20% of the total land used for growing vegetables (Statistisches Bundesamt, 2013). Also, it is a vegetable which is to a great extent being sold directly at the farm shop (Dirksmeyer, 2009) or at the sales stalls within the neighbourhood of the farm. In Germany, the asparagus season starts in April and ends on the 24th of June. Asparagus is first and foremost enjoyed freshly cooked within a few days after the harvest.

With using asparagus as a case study the aim of the research is to determine

1) the impact of the customer on the PCF;
2) the impact of the amount of food wasted in the supply chain on the PCF.

METHODS

To achieve the goal of the study life cycle, inventory was gathered about each life cycle stage of the product. It includes transporting the seedlings to the farm, planting the seedlings, yearly soil cultivation, application of agricultural chemicals, harvesting, sorting and packaging, supply chain from the farm to the marketer, centre of distribution and supermarket, customer shopping trip, product preparation at customer's home, and waste occurring at the customer life cycle stage.

Data about the asparagus seedlings, cultivation and transport to the marketer was gathered during an interview in a conventional asparagus farm in Germany for the cultivation in 2010-2012. The asparagus is grown on a field under a thermo-foil with no additional heating. Except for harvesting, all other operations in the field are done with agricultural machines. Since the fields have been in use for agricultural land for a long time no impacts caused by land use change were taken into account.

The marketer prodived data about further transportation of asparagus until the arrival at the central distribution storage. Since no primary data was available for the processes at the central distribution storage or supermarket these stages were modelled as scenario.

User phase data was gathered as a panel questioning during three month. In total 168 customers sent back 420 questionnaires with data about their spargel shopping trip and cooking. After eliminating the extreme values, an average value for each data point was used for the user phase PCF calculations.

Throughout the study, the manufacture and construction of all buildings and infrastructures were omitted. Since no data was available for specific agricultural chemicals, generic data sets for herbicides, pesticides and insecticides were used. For asparagus transport in all stages a truck use was calulated although occasionally asparagus was transported to the marketer by a transporter bus.

The functional unit was defined as 1 kg of product at the point of sale. The PCF was calculated with life cycle assessment calculation programme GaBi 6 as total greenhouse gas emissions 100-year global warming potential.

RESULTS

The results are summarised in Table 1. According to the asparagus producer, only approximately 60% of the asparagus harvested from the field is transported further for sale.

The 40% loss occurs mainly during sorting, where the asparagus stems are cut to the same length, and crooked, stained and purple stems are excluded. The customers estimated that on average at least 10% of purchased asparagus is disposed of as peelings and cuttings of the dried stem ends. However, a few customers who actually weighted the peels and stem ends reported about values up to 25%. If losses in the supply chain are kept below 5%, then only between 43% and 54% of the asparagus harvested from the field gets consumed as food. If no asparagus would be wasted throughout the production and supply chain, the total PCF could be reduced up to 47%.

Table 1. PCF results and the impact of waste on the final PCF*

Life cycle stage	kg CO2 e	Relative contribution	Occurring asparagus waste	Left of harvested asparagus	Effect on the total PCF
Pre-farm and farm	0.24	33.3%	40%	60%	up to -40%
From farm “gate” to the point of sale	0.11	15.2%	0-3%	57-60%	0 to -0.8%
From the customer shopping trip to the end-of-life	0.36	51.5%	6-15%	43-54%	-2.6 to - 6.3%
Total	0.71	100%	-	43-54%	-42.6 to -47.1%

*At the moment of writing current paper the results have not been verified and adjustments in the future may occur.

In the farm stage the asparagus waste occurs just before the end of that life cycle stage, i.e. before asparagus is transported to the marketer. From the farm gate to the point of sale the waste can occur at the distribution storage while repacking the asparagus. In both stages the total amount of greenhouse gas emissions could be divided by more kilograms of asparagus if no waste occurred. In the customer phase the difference in the amount of asparagus waste would only affect the emissions at the end-of-life stage, in the current case study when the asparagus peels and stem ends are composted.

DISCUSSION

The asparagus waste mainly occurs in the sorting and packaging process at the farm and at the customer stage. This waste cannot be completely avoided because in case of natural products there are always some asparagus stems which cannot be sold because of insufficient quality. In case of asparagus also visual signs have an imporant impact: when asparagus stems have “rost” stains or purple heads the vegetable cannot be delivered to the supermarket due to unsufficient quality. When the producer assesses also the potential price he could receive at the local sales stall too low, the stems will be excluded from further sale completely and regarded as waste. These visual flaws do not affect the taste and the asparagus with purple heads have even higher nutritional value in contrast to white ones.

Waste cannot be avoided at the customer stage. Each asparagus stem must be peeled and if they are not kept cold and moist the stems dry up in a few hours and must be shortened up to a few centimetres. Short storing time and proper storing conditions help to avoid drying and reduce the waste. Thereby, the PCF can be reduced only minimally. Since the customer stage sums up to a half of the total PCF, customer shopping trip, storing, asparagus cooking and dish washing have higher potential to reduce the total PCF. Similarly, Schäfer and Blanke (2012) emphasise that the largest PCF reduction potential is the customer responsibility.

CONCLUSIONS

The study revealed that asparagus waste cannot be avoided, but if customers would accept asparagus stems with minor visual flaws the amount of asparagus waste at the farm stage could be reduced. Waste at the customer stage can be reduced minimally. The farm stage waste reduction would theoretically reduce the PCF up to 40%. The customer stage waste minimisation only up to 6%. Neither of these theoretical reduction potentials are realistic. Since the customer stage contributes half of total PCF it entails a relevant greenhouse gas reduction potential through more energy efficient shopping trips and cooking practices.

REFERENCES

Dirksmeyer, W. (2009). *Status quo und Perspektiven des deutschen Produktionsgartenbaus*. Retrieved from http://www.bfafh.de/bibl/lbf-pdf/landbauforschung-sh/lbf_sh330.pdf

Draft International Standard 14067 (2012). Geneva: International Organization for Standardization.

Schäfer, F., & Blanke, M. (2012). Farming and marketing system affects carbon and water footprint – a case study using Hokaido pumpkin. *Journal of Cleaner Production*, *28*, 113–119. doi:10.1016/j.jclepro.2011.08.019

Statistisches Bundesamt. (2013). *Wirtschaftsbereiche - Obst, Gemüse, Gartenbau - Spargel das am häufigsten angebaute Gemüse 2012*. Retrieved from https://www.destatis.de/DE/ZahlenFakten/Wirtschaftsbereiche/LandForstwirtschaftFischerei/ObstGemueseGartenbau/AktuellGemuese.html

van Jenny Gustavsson, C. C. U. S. R. O. A. M. (2011). *Global food losses and food waste*. Retrieved from http://www.fao.org/docrep/014/mb060e/mb060e00.pdf

FOOD WASTE PREVENTION: THE CHALLENGE OF MAKING APPROPRIATE DEFINITIONAL AND METHODOLOGICAL CHOICES FOR QUANTIFYING FOOD WASTE LEVELS

Karin Östergren[1], Gina Anderson[2], Sophie Easteal[3], Jenny Gustavsson[1], Ole Jørgen Hanssen[4], Graham Moates[5], Hanne Møller[4], Alessandro Politano[6], Tom Quested[3], Barbara Redlingshöfer[7], Felicitas Schneider[8], Kirsi Silvennoinen[9], Åsa Stenmarck[10], Han Soethoudt[11], Keith W. Waldron[5]*

[1]SIK- Institutet för Livsmedel och Bioteknik, Sweden; [2]BIO Intelligence Service, France; [3]WRAP Waste & Resources Action Programme, UK; [4]Østfoldforskning, Norway; [5]Institute of Food Research, UK; [6]University of Bologna, Italy; [7]INRA Institute National de la Recherche Agronomique, France; [8]BOKU Universität für Bodenkultur Wien, Austria; [9] MTT Agrifood Research, Finland; [10]IVL - Swedish Environmental Institute, Sweden; [11]Wageningen UR, The Netherlands

** Ideon, SE-223 70 Lund, Sweden, e-mail: karin.ostergren@sik.se*

Keywords: Food waste; Resource efficiency; waste prevention

ABSTRACT

To establish reliable food waste statistics, which can be produced continuously over time, it is necessary to produce data within a robust methodological framework based on consistent definitions of food waste, and its components, and consistent system boundari s of the food supply chain. In this work, carried out within the FP7-project FUSIONS, a literature review has been carried out to understand what definitions of food waste; system boundaries of the food supply chain and methodological approaches are commonly used in studies quantifying food waste. Based on the critique a systematic concept on how to address food waste has been suggested.

INTRODUCTION

Estimates suggest that food waste account for about 1/3 of the global food production (FAO, 2011). Preventing and reducing food waste is thus vitally important in the context of both food security and resource efficiency (e.g. Stuart T, 2009). To be able to monitor and compare the effect of different food waste prevention activities, strategies and policy decisions; a consistent definition is needed. To date, no consistent definition exists.

The objectives for the FUSIONS project is to contribute significantly to the harmonization of food waste monitoring, show the feasibility of social innovative measures for optimized food use in the food supply chain and to give policy recommendations in the development of a Common Food Waste Policy for EU27 aiming at delivering a 50% reduction in food waste and a 20% reduction in the food supply chains resource inputs by 2020. Given this, a concept on how to address food waste in a consistent way has been developed.

METHODS

The work has been carried out systematically and progressively. First a critique of literature concerning food waste focusing on the definitions and system boundaries applied at each step of the food supply chain, including summarizing the environmental and economic & socio-economic aspects of food waste was performed. In the next step a criteria document to serve as a methodological reference point for the main definitional choices was developed though an experts' workshop. Finally a concept on how to address food waste in a consistent way was developed.

RESULTS

Literature review

The full review is reported in by Gustavsson et al, 2013. An overview on the number of papers reviewed for each segment is provided in Figure 1. From Figure 1 it can be concluded that most of the relevant studies relate to household wastes. Relevant studies were found on all segments apart from open markets. The different segments of the food supply chain were examined with respects to definitions used and boundary conditions applied. An analysis was then performed with respect to the critical issues regarding definitions and boundary issued.

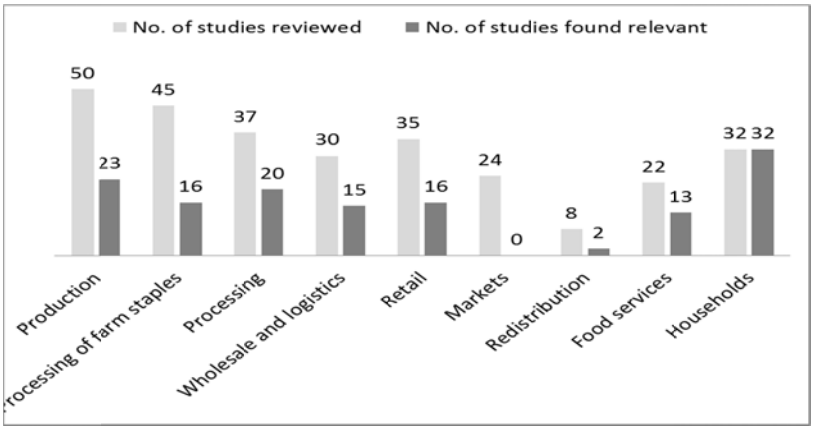


Figure 1. Scope of the literature review (Gustavsson et al, 2013)

One of the major results from the literature review is that the same terms are often used but defined differently. Commonly used terms are "food waste", "food loss", "avoidable food waste", "unavoidable food waste", "potentially avoidable food waste" etc. but these terms are *not* always defined in the same way. Some terms and definitions are very specific for the supply chain step to which they refer and for the context in which they are used. Differences were also found regarding the basis of different definitions. Most definitions are based on a mass, which means that the primary measure of food waste is weight. A few definitions take an economical perspective meaning that the primary measure of food waste is loss in revenue. Some definitions include also nutritional loss from food waste. One of the major questions which were highlighted in the literature review was which system should be conceded. That is, should the whole agricultural system be considered, the food production system or only the food supply chain? This was in particular highlighted in the review of the primary production system (Gustavsson et al., 2013).

Methodological reference points

A criteria document was developed to act as a reference point for all discussions. The purpose was to create a consistent methodological framework to enable, encourage, engage and support key actors across to reduce the amount of edible food waste and resource in puts in the food supply chains. Bearing this aim of FUSIONS in mind, a concept for addressing food waste explicitly for the food supply chain was targeted.

Considering definitional choices, the criteria document states that the definition should be unambiguous, applicable to all types of food and across all parts of the food supply chain. Furthermore, the definition should support the practical work on quantification, evaluation & monitoring of food waste; understanding different drivers of f od waste on different parts of the food supply chain; and be framed in the context of a mass balance approach. Considering the boundary issues the definition should provide a definite starting- and end-point of the food supply chain.

The concept approach to address food waste was built up progressively by first defining “food” and then the “food supply chain” and the fractions being wasted. The definition of “food” is suggested to follow the existing European defintion of food (EU, 2002) stating that food is “any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be eaten by humans” The food supply chain is defined as “the connected series of activities used to produce, process and distribute food to the end consumer, from farm to fork”. Principal starting points of the food supply chain are for grown crops and bred animals when crops are mature for harvest and animals ready for slaughter and for wild crops and animals when crops are harvested and animals are caught/killed. The end point of the food supply chain is defined by when food is a) c nsumed b) removed from the food supply chain.

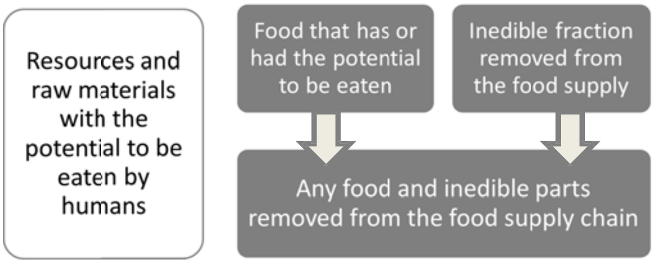


Figure 2. Wasted resources in the system for food production. The shaded boxes refer to streams leaving the “food supply chain”.

Figure 2 provides an overview of a set of well-defined fractions leaving the food chain to be accounted for from a resource efficiency perspective. Resources and raw materials with the potential to be eaten by humans are separated out. This refers to the fraction that is discarded, which is part of the economic and technical system for food production, but which is currently not intended for human consumption and are thus not included as a part of the food supply chain, e.g. male chickens and laying hens, as well as material intended for human consumption but which has not reached the stage to be defined as food.

DISCUSSION

The concept developed address a mainly post farm activates. This will facilitate the aim of FUSIONS. However, it can easily be fitted into larger systems considering overall resource efficiency and environmental impact of food wasted in relation to the food production system as a whole including primary production and feed production or other bio based systems. By using mass as a base the resource use and the environmental impact from food waste, as well as other indicators relating to economy and nutritional value, can be calculated.

The presented concept may serve as a base for urther work on an explicit defintion of terminologies to be used and methodologies for monitoring food waste. Although FUSIONS is limited to food waste prevention in the food supply chain it should be stressed that from a resource perspective the impact from all fractions defined in Figure 2 needs to be considered. The environmental, economic and social life-cycle thinking needs to be considered as well in order not to sub-optimize prevention strategies with regards to resource efficiency. It should also be recognized that food waste not currently being treated can be a valuable resource for further valorization; to produce new food products or bio-energy. The waste hierarchy presented in the Waste Framework Directive (EU, 2008) states the priority order for waste management; being prevention, as the most-preferred option followed by preparing for re-use; recycling; other recovery and disposal as the least-favoured option. Better quantification of food waste at all stages of the food supply chain, will help us target waste to be moved up the waste hierarchy helping achieve our resource efficiency goals.

CONCLUSIONS

Based on a structured analysis of wasted resources in the food chain a concept for addressing food waste has been developed.

ACKNOWLEDEMENTS

This work was supported by the European Commission FP7 Grant agreement no. 311972.

REFERENCES

EU (2002). Regulation (EC) No 178/2002 of the European Parliament and of the Council laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety.

EU (2008). Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.

FAO (2011). Global Food Losses and Food Waste - extent, causes and prevention. Rome, Food and Agriculture Organization of the United Nations.

Gustavsson, J., Östergren, K., Soethoudt, H., Quested, T., Easteal, S., Politano, A., Bellettato C., Massimo Canali, M., Falasconi, L., Gaiani, S., Vittuari M., Anderson, G., O'Connor, C., Hansen, O.J., Møller, H., Schneider, F., Moates, G., & Redlingshöfer, B. (2013). *D1.1 Main definitional choices for the food and drink waste produced within Europe*., FUSIONS European Commission FP7 Grant agreement no. 311972.

Stuart, T. (2009). Waste - uncovering the global food scandal. London, Penguin books.

INFLUENCE OF AGRO-FOOD WASTE ON SUSTAINABLE FOOD CONSUMPTION

Gabriela Clemente, Macarena Pérez-Sánchez, Javier Ribal, Neus Sanjuán, Neus Escobar*

**ASPA Group (Analysis and Simulation of Agro-Food Processes). Food Technology Department. Universitat Politècnica de València. C/ Camino de Vera s/n, 46022 Valencia, Spain. E-mail: gclemen@tal.upv.es*

Keywords: carbon footprint; food chain; waste; consumer practices

ABSTRACT

Food waste is generated along the whole product life cycle. For this reason, when calculating the carbon footprint of food, waste must be taken into account. From the literature data about food waste along the food chain, the carbon footprint of two daily menus was calculated according to PAS 2050. The results highlight the environmental consequences of decreasing food waste along the food chain. Processing was the stage that generated more waste. The agricultural and post-harvest stages generated a lower amount of waste. The amount of waste during the consumption stage presented a high variability. Results show the influence of consumer practices on the reduction of global warming of food products.

INTRODUCTION

Food production is a basic activity because food provides energy and nutrients to humans. During its production, energy and resources are consumed, thus causing different impacts on the environment. In fact, food contributes with 20% to 30% to the environmental impact caused by European consumption (Stuart, 2011).

Food waste is generated along the whole product life cycle, thus the amount of food produced is higher than the amount of food finally consumed. According to the European Parliament Resolution 2011/2175(INI), every year a growing amount of edible food (some estimates say up to 50%) is lost along the entire food supply chain in Europe. The environmental relevance of food losses does not only depend on the amount, but also on the type of food, where in the food value chain it is lost, and how it is recycled or disposed of. Therefore, food losses should not only be quantified, but also evaluated by life cycle assessment or carbon footprint. This would allow more accurate quantification of the environmental benefits of reducing food waste and help us define fields of priority (Beretta et al., 2013).

The carbon footprint (CFP) is a tool for calculating the quantity of greenhouse gases released to the atmosphere along the life cycle of a product. It is expressed as kg CO_2 equivalent. Among the methodologies proposed to quantify CFP, the PAS 2050 (BSI, 2011) is one of the most used.

The goal of this work was to evaluate the contribution of waste along food chain to the CFP of two daily menus. To this aim, the CFP of the menus was calculated to highlight the environmental consequences of food waste and the importance of food choices in the CFP.

METHODS

The CFP was calculated according to PAS 2050. One of the menus corresponded to a Mediterranean consumption pattern and the other one to a Western style diet. The functional unit was a ready to eat daily menu for an adult person (table 1).

Table 1. Menus designed based on Mediterranean and Western diets.

MENU	BREAKFAST	SNACK	LUNCH	DINNER
Mediterranean	150 g milk 16 g sugar 20 g coffee 60 g white bread 5 g olive oil 30 g tomato	125 g raspberry yoghurt 500 g water 100 g whole grain bread	100 g lettuce 150 g carrot 25 g olive 20 g olive oil 5 g lemon juice 100 g pork 150 g corn 125 g apple 75 g rice 1000 g water	250 g broccoli 100 g cod 25 g olive oil 150 g oranges 100 g whole grain bread 90 g wine 500 g water
Western	250 g coffee 40 g sugar beet 50 g cheese 60 g whole grain bread	50 g coffee 8 g sugar 50 g pistachios	200 g veal 200 g potato chips 30 g ketchup 100 g corn 125 g ice cream 10 g walnut 500 g beer 75 g white bread 1000 g water	80 g pasta 75 g beef 75 g tomato sauce 75 g grinded cheese 30 g chocolate 500 g water

For both menus, it was taken into account that all the food was produced in Spain. For all food products, CFP data were obtained from literature. When necessary, CFP data were modified to include missing life cycle stages according to PAS 2050. To reach a geographical specificity where literature from other countries was used, the modular method for the extrapolation of crop LCA (MEXALCA, Roches et al., 2010) was applied.

Data about the percentage of waste along food chain were also obtained from literature (Grolleaud, 2002; Jones, 2006; Buzby et al., 2009; Lebersorger and Schneider, 2011; Gustavsson et al., 2011; Muth et al., 2011). According to these percentages, the quantities of food of the menus were increased in each stage of the food chain and the CFP was calculated considering the total amount of food.

RESULTS

For the Mediterranean menu, the CFP was 6.3 kg CO_2-eq, from this value 2.5 kg CO_2-eq corresponded to waste. For the Westernized menu the CFP was 16.4 kg CO_2-eq, from which 7.2 kg CO_2-eq corresponded to food waste.

As can be observed in Figure 1, waste generated at each stage along the food chain has a different contribution to CFP. For the two menus, the waste generated during the primary production and post-harvest stages contributed to CFP in a similar way. The contribution of the processing, distribution and consumption stages was different for each menu, being higher for the Western one.

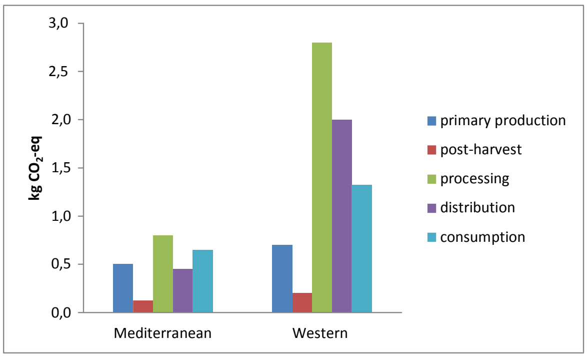


Figure 1. Contribution to CFP of waste generated at each stage considered along food chain

Although some of the waste cannot be avoided, it is very important to implement practices to decrease the avoidable fraction. Regarding to the consumption stage, consumer awareness, good planning, and correct storage of food could cause a 67% and 75% decrease of the CFP for the Mediterranean and the Westernized menu, respectively.

DISCUSSION

Waste contributed to more than 50% to the CFP of both menus. These results highlight the importance of food waste in the CFP of food products. The CFP of the proposed Western was more than twice higher than the Mediterranean one. In the Western menu, processed food and animal products are responsible of most of the global warming emissions.

Processing was the stage that generated more waste, although by-products are included in this fraction, which can be used as raw material in other processes. The agricultural and post-harvest stages generated a lower amount of waste. These residues are generally unavoidable and difficult to diminish. Nevertheless, they could be reduced by changing food quality requirements, usually related to size and shape of products.

The amount of waste generated during food distribution is variable. This waste is higher for fresh products than for processed products with a long shelf life. A suitable storage and transport would allow decreasing this waste. It is also important to adapt the production of fresh products to the demand to decease the spoilage during distribution (Beretta et al., 2013).

Consumer practices, that is, the choice of food products and their management (storage and cooking) have a great influence on the CFP. Thus consumers, through a responsible behavior towards food, can contribute to decrease the contribution to global warming of food products.

CONCLUSIONS

Food waste has a great contribution to the CFP of food products. For that reason, food waste should be decreased along food chain to improve the environmental impact of food products. The results also show the influence of consumer practices on the reduction of the CFP of food products. Consumers can diminish it through the choice of a diet, because each food has a different CFP and generates a different amount of waste. The management of food (storage and cooking) at home is also important. To carry out awareness campaigns addressed to consumers would be a useful tool.

Due to data lack about food waste in Spain, data from other countries have been used. Nevertheless, disparities in food habits across countries stress the need of specific data for Spain.

ACKNOWLEDGEMENTS

The authors acknowledge the financial support from "Ministerio de Ciencia e Innovación" (CTM2010-18118) and "Generalitat Valenciana" (PROMETEO/2010/062).

REFERENCES

Beretta, C., Stoessel, F., Baier, U., Hellweg, S. (2013). Quantifying food losses and the potential reduction in Switzerlaand. *Waste Management 33,* 764-773.

Buzby, J. C., Wells, H. F., Axtman, B., Mickey, J. (2009). Supermarket loss estimates for fresh fruit, vegetables, meat, poultry and seafood and their use in the ERS Loss Adjusted food availability data. USDA, Economic Research Service, Economic Information Bulletin, 44.

BSI (2011). British Standards Institution. PAS 2050. Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. ISBN: 978-0-580-71382-8. Retrieved from http://www.bsigroup.com/ (10th of May, 2013).

European Parliament Resolution 2011/2175(INI) (2012). European Parliament Resolution of 19 January 2012 on how to avoid food wastage: strategies for a more efficient food chain in the EU. Retrieved from http://www.europarl.europa.eu/ (10th of May, 2013).

Grolleaud, M. (2002). Inventario y análisis de las pérdidas post-cosecha. Pérdidas post-cosecha: un concepto mal definido o mal utilizado. Food and Agriculture Organization of the United Nations (FAO). Retrieved from http://www.fao.org/docrep/004/AC301S/ac301s04.htm (10th of May, 2013).

Gustavsson, J., Cederberg, C., Sonesson, U., Otterdijk, R., Meybeck, A. (2011). Global food losses and food waste. Food and Agriculture Organization of the United Nations (FAO). Retrieved from http://www.fao.org/fileadmin/user_upload/suistainability/pdf/Global_Food_Losses_and_Food_Waste.pdf (20th of May, 2013).

Jones, T. W. (2006). Using contemporary archaeology and applied anthropology to understand food loss in the American food system. Carnegie Mellon University, Pittsburgh, USA. Retrieved from http://www.ce.cmu.edu/~gdrg/readings/2006/12/19/Jones_UsingContemporaryArchaeologyAndAppliedAnthropologyToUnderstandFoodLossInAmericanFoodSystem.pdf (22th of May, 2013).

Lebersorger, S., Schneider, F. (2011). Discussion on the methodology for determining food waste in household waste composition studies. *Waste Management, 31,* 1924-1933.

Muth, M. K., Karns, S. A., Nielsen, S. J., Buzby, J. C., Wells, H. F. (2011). Consumer level food loss estimates and their use in the ERS loss adjusted food availability data. United States Department of Agriculture, Technical bulletin 1927. Retrieved from http://www.ers.usda.gov/media/134674/tb1927.pdf (22th of May, 2013).

Roches, A., Nemecek, T., Gaillard, G., Plassmann, K., Sim, S., King, H. and Milà i Canals, Ll. (2010). MEXALCA: a modular method for the extrapolation of crop LCA (and supporting information). *International Journal Life Cycle Assessment 15,* 842-854.

Stuart, T. (2011). Waste. Uncovering the global food scandal. London, England: Penguin Group.

PACKAGING - FROM SINNER TO SAINT … IN JUST 20 YEARS

Graham Houlder, European Aluminium Foil Association, Flexible Packaging Europe

Am Bonneshof 5, 40474 Düsseldorf, Germany

houlder@flexpack-europe.org

Keywords: food-waste, packaging, LCA, sustainable

ABSTRACT

Packaging - From Sinner to Saint … in just 20 years: A resource efficiency story about the absolution of packaging as it is increasingly recognized for the role it plays in helping society to manage the resources it uses more efficiently. The poster presentation uses 3 food packaging LCA studies (wine, goulasch soup, coffee) packed in either alufoil, flexible packaging or both to illustrate where the real environmental impacts are. Also, how a greater awareness and understanding of the role played by the pack is contributing to it's absolution as "the sinner" and being increasingly seen as part of the solution to reducing food waste – enter the "saint".

PACKAGING – A BRIEF HISTORY OF RECENT EVENTS PRE 1990

In the latter half of the 20^{th} century consumer attention was increasingly focused on the "mountains" of packaging waste either being buried in landfills or burned, potentially releasing harmful substances. The realization that Europe was running out of landfill capacity combined with the potential risks/issues from uncontrolled burning of waste which included packaging, resulted in the demonizing of packaging as the "Sinner of the 20^{th} century". Positively, it also resulted in the German Packaging Ordinance (implemented as the DSD) in 1990 and the EU's Packaging & Packaging Waste Directive in 1994.

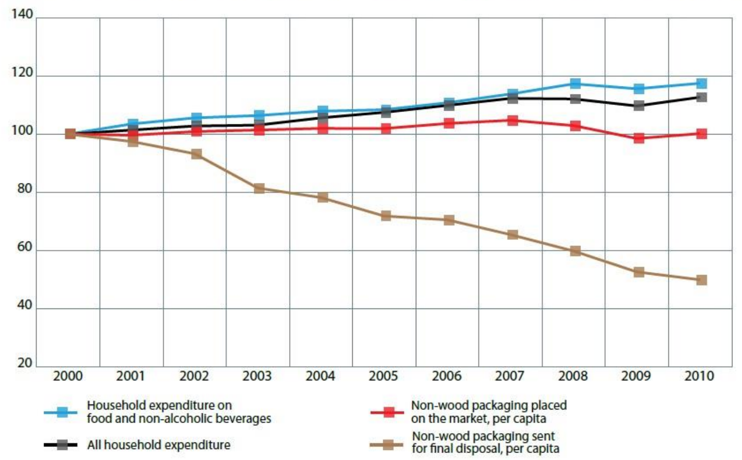
20 YEARS LATER …AND A LOT OF PROGRESS!

From this "pit of public opinion", all parts of the packaging and related industries have worked to progressively and collaboratively decouple packaging waste from economic growth; by lowering pack weights and by developing increasingly sophisticated packaging collection, sorting and recycling systems for all packaging materials.

The establishment of reliable LCI data for all packaging materials combined with the coming of age of Life Cycle Assessment (LCA) has gradually enabled a better understanding of the full lifecycle impacts of products hereby making the value added by the pack more visible. The phenomenal development in packaging waste management technologies has demonstrated that realizing the Cradle to Cradle dream, so key to a resource efficient society, is not only possible but is gradually being realized by several materials including aluminium.

The 2013 EUROPEN publication (see Figure 1), based on Eurostat data reported by the Member States, clearly shows not only the decoupling of packaging waste from household expenditure, but also that 65% of the packaging placed onto the market in the EU-15 was collected and recycled when compared with a 2000 baseline…. let alone using 1990 as the baseline!

Figure 1: Trends in household expenditure, packaging consumption and packaging disposal in EU-15, indexed to 2000

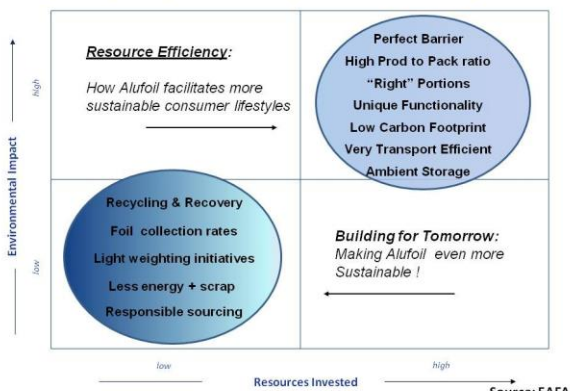


- **The amount of used packaging sent for final disposal is declining rapidly, as recovery rates – and particularly recycling rates – continue to increase. In 2010, 65% of the packaging placed on the market in EU-15, and 47% of the packaging placed on the market in the newer Member States, was recycled.**

RESOURCE EFFICIENCY

Recently, increased collection and recycling of packaging has gradually evolved into a focus on resource efficiency as society recognizes the need to live more sustainably; resource efficiency not only of packaging materials but also of the product it protects – especially food. The use of LCA to quantify the environmental impact of different resources is leading to a better understanding of the role of packaging and the value it adds in helping consumers to live more sustainable lifestyles.

Figure 2: Supporting Resource Efficiency – The Alufoil Sustainability Framework



Source: EAFA

EAFA, the European Aluminium Foil Association and FPE, the European Flexible Packaging Association have carried out a number of LCA studies done by credible external LCA agencies with the objective of further building the understanding the role of aluminium and flexible packaging in facilitating greater resource efficiency e.g. through better protection of the product.

Figure 2 shows schematically the conclusions of those studies; namely that a relatively small investment in aluminium foil or flexible packaging protects a far larger resource investment in the product and reduces the risk of potentially increasing the overall environmental impact if the packaging was not effective.

GOULASCH SOUP

To illustrate the relative investment in packaging to product, EAFA/FPE had a study done by ESU Services to quantify the relative environmental impacts of a goulasch soup packed in a multilayer stand-up pouch. Using a disposal scenario typical in a European situation (51% incineration with energy recovery, 42% recycling, 7% landfill) the study showed the ingredients to contribute 63% of the systems Cumulative Energy Demand (CED) whilst the packaging CED was only 12%! (distribution 6%, transport 11%, preparation 8%). This difference was even greater for the other LCA midpoint indicators such as Climate change 73%/8%, Ozone depletion 69%/8%, Terrestrial acidification 92%/3%, fresh water Eutrophication 86%/4%.

Another way of looking at it is that the 12% (CED) investment in packaging ensured the 63% invested in the goulasch soup ingredients was able to be eaten as intended avoiding food waste!

REDUCING COFFEE WASTE THROUGH BETTER PACKAGING

Another LCA study done by ESU services for FPE on two types of coffee packaging showed that, in some usage occasions, increasing the amount of packaging material actually reduced the amount of coffee that was wasted and consequently gave a lower overall environmental impact!

The study compared a 500g pouch of filter coffee where the packaging represented just 1.5% of the carbon footprint per cup of coffee with an equivalent “stick pack” of instant coffee where the packaging represented 8% of the carbon footprint per cup.

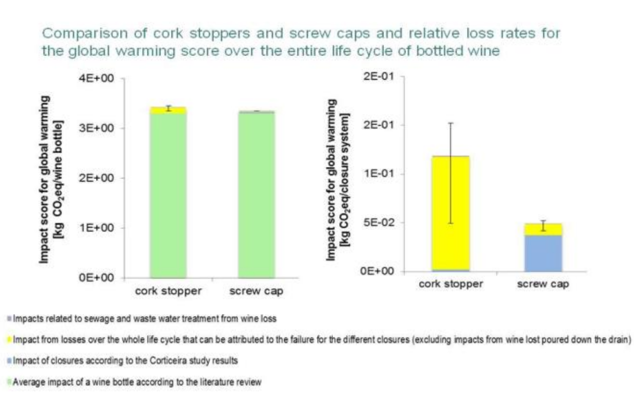
When the study factored in that in a typical meeting situation on average c.a. 30% of the filter coffee brewed was never consumed, the stick pack carbon footprint and overall environmental impact was considerably lower than the “pouch pack” despite having more packaging.

This study clearly demonstrates both the need to take the usage situation into account and the packs ability to effectively portion to reduce food waste and lower the overall environmental impact…. even though this may require more packaging.

IMPROVED WINE PROTECTION LEADS TO A LOWER ENVIRONMENTAL IMPACT.

Another EAFA study compared the performance of cork and aluminium screw caps for wine. It is estimated by wine experts that between 2% and 5% of all wine packed in glass bottles sealed with cork does not meet quality expectations due to it’s so called “corked taste”. Most often this failure

Figure 3: Influence of wine loss rate on the overall environmental performance



of the closure system results in the wine not being consumed and disposed of.

In Figure 3 the study done by Quantis comparing this impact with the recorded lower “wastage” level of aluminium screw caps (0.2% - 0.5%) shows that the wines packed with an aluminium screw cap have a lower overall environmental impact for most of the LCA mid-point indicators despite the higher impact of the aluminium screw cap relative to a cork equivalent.

DISCUSSION

These 3 examples show that 1) packaging contributes a relatively minor part of the overall environmental impact when the whole product system is considered and 2) that this small investment in packaging actually saves resources by effectively protecting the product so that it can be consumed as intended.

The studies also demonstrate that the packaging system needed to protect the product is situation dependent and that the relative differences in product/food that will be wasted in these situations needs to be included when specifying the pack.

CONCLUSIONS

Over the last 20 years, the huge progress made in collection, recycling and recovery rates together with improved recognition for role the pack plays in conserving resources (and minimizing the impacts of our consumption) is evidence that packaging has come a long way from being the “Sinner of the 20th Century”.

However, whilst packaging has not yet formally been proclaimed the “Saint of the 21st Century”, we argue that it is well on it’s way provided this impressive progress is continued. The Aluminium Foil and Flexible Packaging industries realize that there is still work to do make packaging even more sustainable and are actively working to further improve the resource efficiency of the packaging materials and systems they develop.

The pack’s sustainability journey is not over yet! And probably never will be!

REFERENCES

Büsser, Jungbluth, ESU Services GmbH. February 2011, LCA of Ready to Serve Goulasch soup in Stand-up Pouches. http://www.alufoil.org/tl_files/sustainability/ESU%20-%20Goulash%20(2011)%20Exec%20Sum.pdf

EUROPEN. January 2013. Packaging and Packaging Waste Statistics 1998-2010. http://www.europen.be/europen/files/File//Key%20Topics/Packaging%20&%20Packaging%20Waste%20Statistics%201998-2010.pdf

Humbert, Loerincik, Rossi, Margni, Jolliet, Ecointesys – life cycle systems sárl. September 2009. Lifecycle assessment of spray dried soluble coffee and comparison with alternatives (drip filter and capsule expresso). www.elsevier.com/locate/jclepro

Tatti, Pfister, Humbert, Loerincik, Quantis SA. July 2010. The influence of wine loss rates on the LCA results for (bottled) wine. http://www.alufoil.org/tl_files/sustainability/Quantis_-_Wine_2010_-_Exec_Sum.pdf

THE BEAUTY AND THE BEAST – HOW QUALITY MANAGEMENT CRITERIA AT SUPERMARKETS CREATE FOOD WASTE

Dominik Frieling*[1], Verena Stricks[1], Martin Wildenberg[1], Felicitas Schneider[2].
[1] GLOBAL 2000 / Friends of the Earth Austria
[2] BOKU-University of Natural Resources and Life Sciences, Institute of Waste Management, Vienna.
* Corresponding Author: Neustiftgasse 36, 1070 Vienna, Austria,
email: dominik.frieling@global2000.at;

Keywords: visual quality criteria; fruit and vegetables; food loss; food waste; quality management.

ABSTRACT

The issue of food waste at farm and supplier level due to high visual quality criteria defined by retailers is an important issue for many Austrian producers and suppliers of fruit and vegetables. In the framework of a sustainability program initiated by an Austrian retailer, the topic was discussed in several product-specific stakeholder workshops. Surveys with farmers and suppliers of fruit and vegetables for Austrian supermarkets gave some data on the share of losses at harvest and at supplier level.

INTRODUCTION

Worldwide, over 30 % of the food produced is lost at different stages of the value chain. The share of losses is especially high in fruit and vegetables. In industrialized countries, the most significant losses of fruit and vegetables occur at farm, distribution and consumer level, whereas losses due to storage and transport are less important (Gustavsson et al., 2011). The overall share of losses in fruit and vegetables in Europe is estimated at over 50 %. A rough estimation for Austria is that every year 175,000 t of edible fresh fruit and vegetable are lost at farm level; that is a share of about 25 % of the production (Leibetseder, 2012).

From a legal point of view, the EU marketing standards set out the quality standards that must be applied to the supply of fruit and vegetables in Europe in order to set a certain quality level in the market. On July 1st 2009, the European Union canceled specific marketing standards for 26 fruits and vegetables. Those products are now regulated by more general marketing standards focusing on hygienic and health related conditions. Another 10 specific marketing standards addressing 75 % of the inner European trade volume of fruits and vegetables (e.g. apples, strawberries, sweet pepper, kiwi fruit, tomato, salad) are still in force. In parallel to the EU standards retailers set their own specifications, which are often much more stringent.

The inspection or grading process, which checks if the products meet the standards is assumed to cause the most losses in agriculture (Gustavsson et al., 2011). Those fruits and vegetables, which do not fulfill the specifications may be downgraded or out-graded. Downgrading means that a product is classified into a lower class – e.g. apples marketed as class II. Down- or. Out-grading leads to wastage of the products if no alternative utilization is established. According to results published by WRAP (2011) the grading losses of nine fruit and vegetables types varies between 1 and 25 % within the UK. The highest share of grading losses are with apples (25 %), onions (20 %), potatoes (13 %) and avocados (30 %).

METHODS)

The Austrian environmental NGO GLOBAL 2000 cooperates with an Austrian supermarket chain and almost 400 Austrian producers and 40 associated suppliers of fruit and vegetables to achieve more sustainability in the value chain. In yearly product-specific stakeholder workshops farmers, suppliers, scientists, representatives from supermarkets, social and environmental NGOs discuss, which ecological and social hot spots have to be addressed in the value chain and how improvements can be made. In these workshops food waste due to high visual quality criteria is a frequently and emotionally discussed issue. Also part of the program is the calculation of the ecologic rucksack per kg of different products from field to supermarket shelves – based on data given by farmers, suppliers and supermarkets. GLOBAL 2000 determines resource and climate indicators (e.g. carbon emissions, resource use) and agricultural indicators (balances of humus, nitrogen and phosphorus, pesticide intensity, energy intensity). Harvest quotas (i.e. percentage of harvested produce) give an idea in which products lots of waste occurs at field level. Harvest quotas of around 1,500 harvested vegetable fields (between 2007 and 2011) have been analyzed. A survey on supplier level in spring 2013 included questions on food losses at this stage and alternative marketing strategies for products that do not correspond to retailer's quality criteria.

RESULTS

1. Discussion in stakeholder workshops

Farmers addressed the topic for the following products: potatoes, onions, cabbage, leek, spring onions, carrots, radish, apples. Visual quality standards of fruit and vegetables got ever stricter in the last decades. The abandonment of some legal standards of the EU in 2009 has not changed the situation since it is the retailers that call for these criteria. Farmers sometimes criticised that most supermarkets do not sell class II products today.

For all products detailed requirements concerning mass, size, shape and colour are made. High uniformity demands are difficult to fulfil and lead to food waste at farm level, e.g. in cabbage, salad, or leeks. Of course losses at field level do not only occur due to quality standards, but also due to fluctuating market conditions and low prices. For some products there is not only a conflict between "high external quality" and "little food waste", but these objectives have also to be traded off against "little use of pesticides" and "low pesticide residues". Good examples are moderate thrips damage in leek, or late infestation with scab (*Venturia inequalis*) on apples – two harmless external damages, which are not accepted by retailers and apparently consumers. Farmers want to avoid food waste not only because of economic reasons. Also on an emotional level they do not like to throw away good quality food just because it does not fulfill visual criteria. Nevertheless in some cases (e.g. for apples) the position of farmers is ambivalent, because some of them fear, that lower standards could put pressure on prices.

The situation for supermarkets is difficult: Supermarket managers admit, that consumers have been spoiled with ever “nicer” products and high gloss images in advertising. Now it is not easy for supermarkets to change the situation, because they fear negative consumer reactions. If one retailer lowers its external quality criteria, consumers could switch to the competing store. Or it could be accused to palm poor quality to consumers.

From an ecologic viewpoint wastage of fruit and vegetables is negative at first because more resources – including land, water, energy, nature – are consumed and more emissions occur. Furthermore for some vegetables (e.g. cabbage) low harvest quotas and underploughing of too much crop residues can cause high emissions of nitrate and nitrous oxide.

2. Data from survey

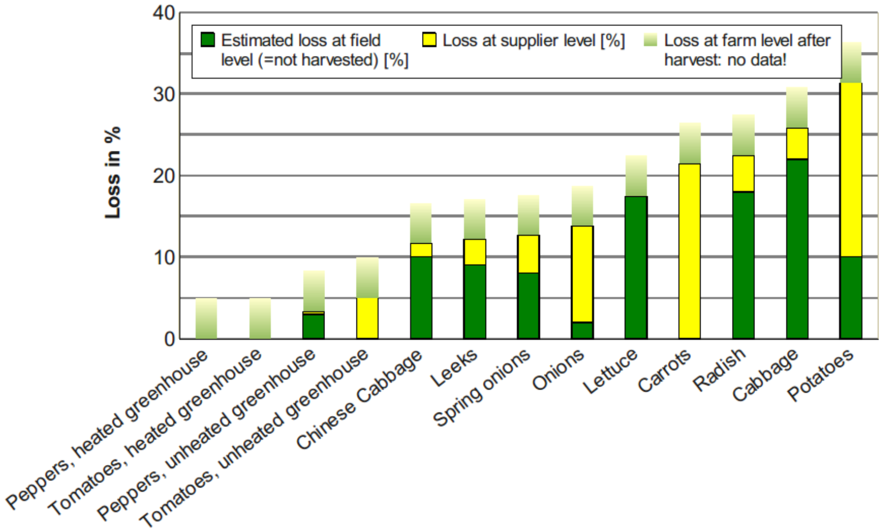


Figure 1: Estimated share of losses at the beginning of the value chain for different vegetables at field level and supplier level

Loss of fruit and vegetables at the beginning of the value chain can occur at different points (1) on the field (product not harvested), (2) at farm level after harvest (product not delivered to supplier), (3) at supplier level (product not delivered to retailer warehouses). Data on loss at farm level after harvest are lacking– probably it is less important than losses at field and supplier level, but certainly some losses occur as well. According to the results of the survey, losses at field level are especially high for salads (iceberg lettuce, butterhead lettuce), cabbage and radish. At supplier level high losses occur for carrots, potatoes and onions. Figure 1 shows estimated loss at field level and supplier level for different vegetables – further losses at farm level after harvest are not known and indicated with transparent columns.

As already applied measures to avoid food waste suppliers mentioned: export of class II products abroad (e.g. for apples), production of juice (apples), deliver products to social markets or food banks. Food waste at supplier level is sometimes used for fodder (carrots), but in most cases it is disposed in biogas plants or returned to farmers for composting. Our survey did not include losses at farm level after harvest. Therefore a direct comparison with data from literature is difficult. In some products 25 % loss – mentioned by Leibetseder (2012) for fruit and vegetables – is exceeded. In others – e.g. greenhouse products – losses seem to be lower.

CONCLUSIONS

A general problem is the lack of reliable data on product specific food losses at farm and supplier level for industrialised countries. To reduce losses of fruit and vegetables the whole production chain must be considered – including supermarkets and consumers. First ideas how supermarkets can help to reduce losses at farm and supplier level are: lowering visual specifications, improving the supply chain communication to avoid over-production, offering more class II products, selling products such as leek and cabbage per kg, not per piece to avoid the need for extreme uniformity. To be successful, a close cooperation between all stakeholders is necessary. Increasing awareness of food waste and food quality within society could support the implementation and acceptance of those measures in future. Thus, it is important to set initiatives to raise awareness and best practice know-how.

REFERENCES

Gustavsson, J., Cederberg, C., Sonesson, U., Van Otterdijk, R., Meybeck, A. (2011). Food losses and food waste: extent, causes and prevention. FAO, Rome.

Leibetseder, M. (2012). Lebensmittelabfälle in der landwirtschaftlichen Produktion - Abschätzung des Verlusts von Obst und Gemüse in der Landwirtschaft und während des Transportes zum Händler. Master thesis, BOKU-University Vienna (http://www.wau.boku.ac.at/fileadmin/_/H81/H813/IKS_Files/AktuelleForschungsthemen/Lebensmittel/Masterarbeit_Leibetseder_Miriam_Endfassung.pdf).

WRAP.(2011).Fruit and vegetable resource maps. *Final report, Bunbury, UK*.

THE FOOD WASTE PILOT PROJECT "SAA SYÖDÄ!" – "LICENSE TO EAT"

*Kirsi Silvennoinen *, Taija Sinkko, MTT Agrifood Research Finland*

** Latokartanonkaari 9, FI-00790 Helsinki, Finland, kirsi.silvennoinen@mtt.fi*

Keywords: food waste; food sharing; housing company; household

ABSTRACT

The aims of the project were to find out whether sharing food with other consumers could reduce food waste to a point where it could make a difference in terms of sustainability and to find out how much and what kind of food people are ready to share with their neighbors. This pilot experiment was conducted during winter 2012-2013 in Helsinki, Finland. During the experiment we found out that accepting other people's food was easy but sharing own food was more difficult.

INTRODUCTION

Food constitutes over a third of the environmental impact of Finnish overall consumption (Seppälä et al 2009). It is ecologically and economically unsustainable to waste edible food because the environmental impacts of producing the raw materials for food processing have been pointless.

In Finnish households, the annual amount of avoidable food waste is approximately 120-160 million kilos, worth around EUR 500 million (Silvennoinen et al 2012). The main reasons for disposing of food are spoilage, e.g. mould 29% and passing the "best before" date 19%. More than 40% of food is unspoiled when discarded. In the whole food chain, the households produce the largest amounts of food waste, about 20-30 kg per person per year, which means that there is significant potential for reducing it. The main discarded foodstuffs are vegetables, home cooked food, milk products, bakery and grains, and fruits and berries. (Silvennoinen et al 2012)

The aims of the project were to present people the value of food, to raise their awareness on the wasted food problems, and to help them pay attention to their food buying habits. Other aims was to find out whether sharing food with neighbours could reduce food waste in terms of sustainability and to find out how much and what kind of food people are ready to share. The aim of the pilot experiment was to get the food exchange system started and help people to share their extra edible food instead of discarding it.

MATERIALS AND METHODS

The pilot experiment was conducted from November 2012 to February 2013 in a housing company located in Roihuvuori, Helsinki, Finland. The housing company has about 200 occupants with different age range and backgrounds. The food sharing point was set up in the housing company`s cold storage cellar, where the occupants could bring fresh vegetables and fruits, unopened food packages that had not reached their "best before" or "last usage" date, and dishes that were prepared on the same day. All the occupants could take food home from the food sharing point. Information about the food left in the food sharing point was communicated through notebook, Facebook and the housing company`s own blog. Also the local retailer participated to the experiment by bringing aging food from his store to the food sharing point.

RESULTS

Occupants visited the food sharing point more than hundred times during the three-month-long experiment. There were at least 30 different occupants who took food from the food sharing point. Most of people visited the food sharing point more than once and took more than one item at the same time. Occupants brought food 19 times, mainly tea, pasta, chocolate, vegetables and fruits, but also home cooked meals. The retailer brought food six times, mainly vegetables, bread and milk products, but also meat and other meat products and ready meals. All the food brought to the food sharing point was taken away. Figure 1 represents the picking up times of different foods which changed hands during the three-month-long experiment. In addition to food, also candles changed hands through food sharing point.

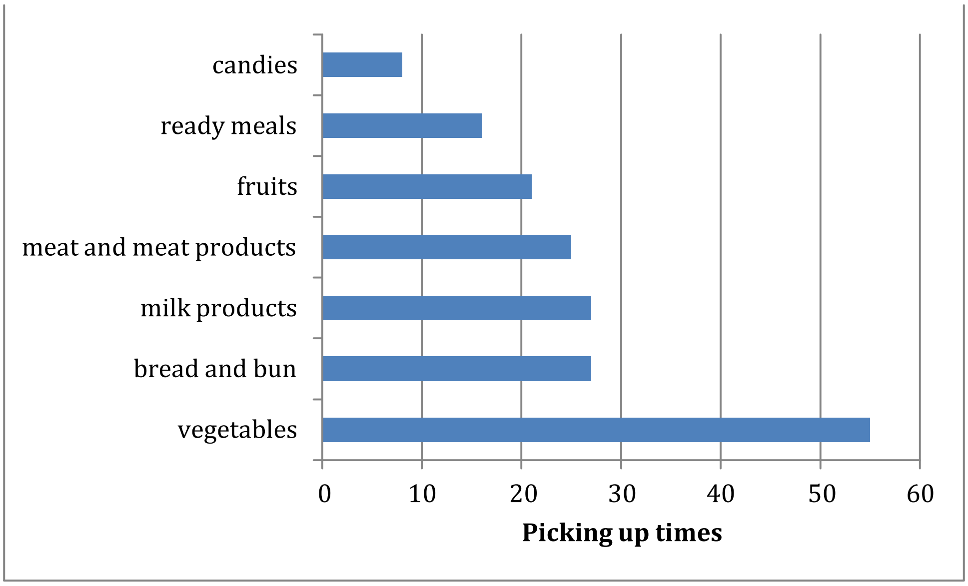


Figure 1. Picking up times of different foods during the three-month-long experiment.

As the result, contrasting with our presumption, the accepting of other people's food was easy but sharing one`s own food was more difficult. At the end, occupants were really enthusiastic about the experiment and they intend to continue food sharing in their housing company.

CONCLUSIONS

In this project we executed a pilot experiment where there was a food sharing point in the housing company`s cold storage cellar. The aim of the pilot experiment was to get the food exchange system going and help people to share their extra edible food instead of discarding it. More than 30 of 200 occupants participated in the experiment. Occupants were enthusiastic of the experiment and they intend to continue food sharing in their housing company.

The project named 'Saa syödä!' – 'License to Eat' was conducted by MTT Agrifood Research Finland, Motiva and the service design agency Palmu Inc. during winter 2012-2013. The project was funded by the Ministry of the Environment.

REFERENCES

Seppälä, J., Mäenpää, I., Koskela, S., Mattila, T., Nissinen, A., Katajajuuri, J-M., Härmä, T., Korhonen, M-R., Saarinen, M., Virtanen, Y. 2009. Suomen kansantalouden materiaalivirtojen ympäristövaikutusten arviointi ENVIMAT-mallilla (Assessment of the environmental impacts of material flows caused by the Finnish economy with the ENVIMAT model). *The Finnish Environment 20/2009 (In Finnish, abstract in English).* URL: www.ymparisto.fi/julkaisut

Silvennoinen, K., Koivupuro, H-K., Katajajuuri, J-M., Jalkanen, L., Reinikainen, A. 2012. Ruokahävikki suomalaisessa ruokaketjussa (Food Waste Volume and Composition in Finnish Food Chain). *MTT Report 41 (In Finnish, abstract in English)*. URL: www.mtt.fi/mttraportti/pdf/mttraportti41.pdf

VALORIZATION OF MEAT WASTE FROM RETAIL STORES

Ingrid Strid and Mattias Eriksson, Swedish University of Agricultural Sciences*

** Swedish University of Agricultural Sciences, Department of Energy and Technology, P.O. Box 7032, 750 07 UPPSALA, Sweden; ingrid.strid@slu.se*

Keywords: food wastage; freezing; prevention measure

ABSTRACT

The aim of this study was to test if, and how, a retail meat waste prevention measure could work in reality. A retail store cooperated, by selling meat that otherwise would be wasted, with a catering company that purchased and used the meat for cooking. Together they managed to save 35 kg meat during 8 weeks in May-June 2012. The measure proved to work in reality and was estimated to have a large potential to save meat, if fully implemented in the whole retail sector. Freezing of the meat was a key success factor, for logistic reasons. Not all types of meat can be saved this way, due to current authority regulations of the food sector.

INTRODUCTION

The Swedish University of Agricultural Sciences coordinated a three year research project "Reduced food wastage in retail stores - measures and their impact on economy and environment", where 6 stores from the retail chain Willys were studied. Results from this project indicated that an average store wasted ca. 3 tonnes of meat per year, during 2010-2012. Since meat has a high environmental burden (de Vries and de Boer, 2010) and represents a high economic and nutritional value, prevention of meat waste is an urgent matter. The aim of this sub-project was to test if, and how, a meat waste prevention measure could work in reality. How much meat could be saved? Were there any practical circumstances to take into account?

The meat waste prevention measure chosen was a possible future routine, where packages of fresh meat were saved from being discarded and instead sold to a cooking facility for food purposes. Making lunches in their own in-store kitchen of unsold retail food, close to its Best before day, is already a reality in a supermarket in southern Sweden (ICA, 2013). However, the Willys chain does not have any in-store kitchens, why an external solution is necessary.

The test thus takes a starting point by the involvement of a catering company as a possible receiver of the meat from the appointed Willys store. Since the catering company, Happy Food, has an ecofriendly profile (marketing organic and locally produced catering food), its manager Lena Hägg was willing to accept the offer to cooperate in this project. During the test period, May - June 2012, Happy Food would get access to cheaper meat, but also get more work due to extra transports and additional kitchen work. The catering company agreed to buy the meat at a favorable price and for environmental reasons. Happy Food was awarded the Environmental Award of the year at the Swedish Retail Gala 2012, for its environmental engagement and contributing to retail food waste prevention (Fri Köpenskap, 2013).

MATERIALS AND METHODS

Description of the set up procedure

Three stores were personally contacted; one agreed to take part of the test. Due to transport logistics in combination with low volumes, the first intention to pick up the meat twice a week was abandoned. Instead, a system with storage of meat in the store freezer for pick up once a month was developed. Due to legal restrictions, food marked with “expire day” is not allowed to be sold after that day, regardless of being frozen or not (Swedish national food agency, 2013). As regards to warm grilled chicken, this may not be sold after 4 hours of warming, and it is not allowed to be sold as a refrigerated good after that, since that would require a new label, which is not allowed. Happy Food prefers to buy organically produced meat, but agreed to also accept conventional Swedish meat. These constraints led to the conclusion that only Swedish meat cuts, marked with Best before day, could be included in the test.

Description of the participating retail store

The retail store orders and receives fresh meat several days per week. The monthly meat department turn-over for an average project store, calculated over 6 stores during three years (2010-2012), is about 19 tonnes, and the corresponding waste is about 250 kg. The test store is the only one selling warm grilled chicken, which makes that part of the results less general. The store is situated in the north-eastern perimeter of the city of Uppsala, Sweden.

Description of the participating catering company

Happy Food produces ca. 800 meals per day, most of which is sold as lunches to pre-schools and schools. They also do catering events as well as sell warm lunches and cold lunch boxes through their drive-in facility. The monthly purchases of meat, always of Swedish origin and often organically produced, is about 1800 kg, of which ca. 600 kg are cuts of pork or beef (Lena Hägg, pers. comm.). The catering company is situated in the south-eastern part of the city of Uppsala, Sweden; 6 km from the retail store. The company has its own pick-up cars, and delivers food all over Uppsala, on a daily basis.

Description of the tested meat saving routine

Meat packages that were about to reach their Best-before-day the next morning, were culled from the shelves on the evening before. The meat had otherwise been discarded on the next morning, before the store open. The packages were placed in the freezer of the store, after being noted on a list, keeping track of amount, normal price and reduced price. At two occasions, 25 May and 29 June, the catering company came and picked the meat up, whereas the list was sent to the researchers.

Description of the test evaluation

The amount of transferred meat, divided as pork and beef, was recorded and then compared with the retail store’s registered in-store waste for the same period. The latter data came from the wastage data base in the main project (www.slu.se/foodwastage). Telephone interviews were done with both managers to follow up their experiences.

RESULTS

The results of the test are illustrated in Figure 1. A total of 35 kg of meat, divided as 23 kg beef and 12 kg pork, was transferred from the retail store to the catering company during the 8 week test period. This corresponds to 27 % of the Swedish meat cuts wasted over the same period, i.e. the meat type available for the study, but only 10 % of the total wastage for the meat department. Note that all meat wastage was not possible to save; 44 % of the present store's wastage could not be taken care off, due to authority regulations. These applied to products marked with Expire day [minced meat, fresh chicken and intestinal food, etc.] and to grilled chicken sold in packages. The remaining 56 % was from a regulation aspect possible to sell. Thus, if this waste prevention measure would be applied to other kitchens in the future, not restricted to Swedish meat, the blue, red and green sectors of Figure 1, would be possible to save. This would give approximately 100 kg of meat cuts per month, divided roughly as 50% beef and 50% pork.

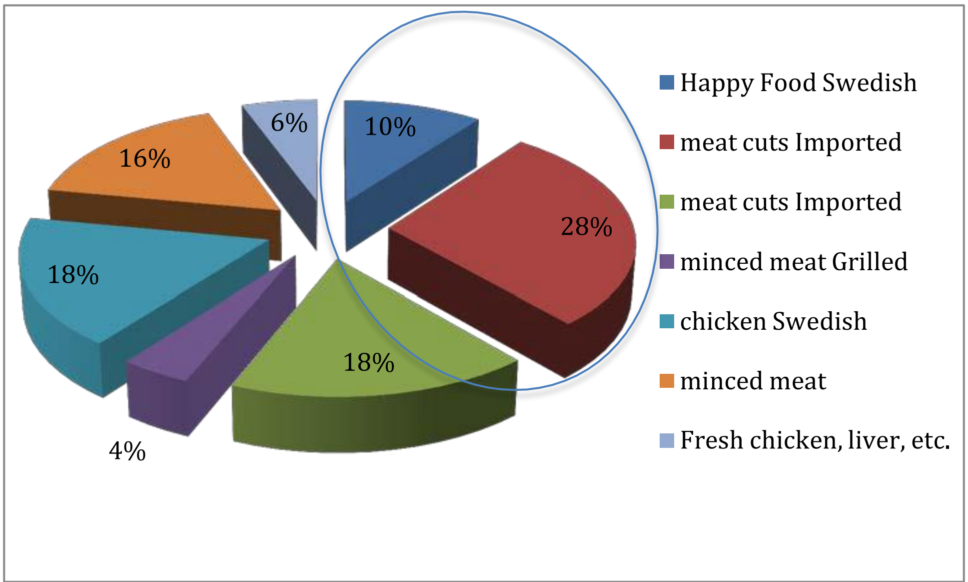


Figure 1. Total wastage from the meat department of the retail store during the test period, of which 10 % was sold to Happy Food. This amount corresponds to 27 % of the meat available for the test, visualized by the encircled sectors.

The manager of the meat department at the participating retail store, Marie Jansson, was in general satisfied with the experiment, referring to a "good feeling" and that this principally was a good idea. However, she also experienced some unclarities regarding the price agreement, giving rise to negative feelings, and did not appreciate the extra time required for administrative work. On the question, "Why did you not manage to save more of the meat [only 35 kg out of possible 130 kg]?", she answered that this was probably due to lack of communication with the rest of the staff. Other staff members were not informed properly or were not certain about the new routine.

The manager of the catering company, Lena Hägg, was also satisfied with the experiment as such. But, also she experienced problems related to the price agreement. The two pick-ups were done with separate transports, but she believed it would be possible to coordinate the pick-up transports with ordinary deliveries in the future. Another possible improvement would be to increase the amounts, since the present amounts were considered too small, leading to a possible solution where several retail stores cooperate with one cooking facility. She also concluded that if it was possible for the stores to sell frozen minced meat, this would be a perfect product for them to use in their cooking. What could be more troublesome, though, were some negative customer reactions, such as "Are you selling old food?" and "We want to buy this cheaper". However, Lena Hägg managed to answer these with correct information, taking some of the worries away, and she believes that these potential obstacles would be possible to overcome.

DISCUSSION

The tested waste prevention measure, selling meat close to its best before day to a nearby kitchen for use as food, proved to be realizable in all stages from idea to actual cooking. The logistic chain worked, but can be further improved. Ca. 18 kg meat per month was saved during the test period, however with a potential of 100 kg meat per month, if the measure becomes fully implemented. Based on data from the annual report of Axfood, the company group owning the retail chain, there were ca. 160 Willys stores (of the equivalent size) 2012, representing 11% of the Swedish food market (Axfood, 2013). Using these figures to scale up the results to the whole Swedish retail sector, give that the measure has the potential to save 1800 tonnes of meat from being discarded. Freezing of the meat appeared to be a key factor, since this made it possible to cut down transports to a realistic level. Also, customer attitudes will be a key factor to handle, in order to avoid negative reactions. The measure can however be regarded as an end-of-pipe solution to the meat waste problem, not targeting the root of the problem, which involves a mismatch of orders and sales, i.e. ordering more than what is possible to sell. As such it should strive for not taking the focus off the main problem, but instead be a measure limiting the damages while searching for solutions to the main problem.

CONCLUSIONS

The conclusion is that this retail meat waste prevention measure has the potential to work in reality and could potentially have a large effect on saved amounts of meat.

REFERENCES

Axfood, 2013. Annual report 2012. http://investor.axfood.se/files/axfood_ar_2012_en.pdf, accessed 2013-05-23.

de Vries, M., de Boer, I.J.M., 2010. Comparing environmental impacts for livestock products: A review of life cycle assessments. *Livestock Science 128, 1–11.*

Fri Köpenskap, 2013. Winners at the retail gala 2012 http://www.fri-kopenskap.se/zino.aspx?articleID=40318 accessed: 2013-05-23.

ICA, 2013. Resurskocken – gör alla till vinnare. http://www.malmborgs.se/tuna/resurskocken/ accessed: 2013-05-23.

Swedish national food agency, 2011. *Guidelines for retail food inspection/Kontrollhandbok – butik,* Swedish national food agency, Uppsala.

MANAGEMENT OF SEAFOOD AND FISHERIES

Wednesday, Aug 28: 1:30 pm - 2:30 pm

Session chairs: Ian Vázquez-Rowe, CRP Henri Tudor, Luxembourg
Friederike Ziegler, The Swedish Institute for Food and Biotechnoly, Sweden

ANCHORS AWEIGH: THE APPLICATION OF CONSEQUENTIAL LCA PERSPECTIVE IN FISHING SYSTEMS

Ian Vázquez-Rowe, Enrico Benetto*
Public Research Centre Henri Tudor (CRPHT) / Resource Centre for Environmental Technologies (CRTE) - 6A, avenue des Hauts-Fourneaux, L-4362, Esch-sur-Alzette, Luxembourg (s).
Corresponding author: ian.vazquez@tudor.lu

Keywords: consequential LCA; fisheries; policy making; quota restrictions; stock abundance.

ABSTRACT

Attributional LCA, which monitors the static state of a specific production system, is increasingly used in fisheries to assess the environmental profile of fleets and seafood supply chains. This approach is not pertinent to assess the effects of (large scale) policies. In contrast, consequential LCA (C-LCA) has been successfully implemented in other sectors to assess the expected changes in environmental impact in a given production system and other (marginal) production systems that may be affected in response to changes in the main system. C-LCA commonly combines LCA with economic models to simulate the interactions occurring between the analyzed systems. However, the use of these models may not be the most appropriate approach to follow for fisheries. Hence, it seems feasible that C-LCA should be combined with stock prediction tools rather than with economic models, to determine how changes in stock sizes and quota restrictions may cause variations in the environmental impact of fishing fleets.

BACKGROUND

Consequential LCA (C-LCA) is usually based on combining LCA with economic modeling to simulate interactions occurring between the analyzed production system, and those that may be affected by its variations. For instance, economic equilibrium models, such as GTAP or partial equilibrium models are used to compute the economic consequences that may occur in the chosen life cycles. Once these are obtained, LCA is used to translate the consequences into environmental impacts. However, using economic tools as drivers of future environmental impact may be the most adequate approach for seafood production systems, since they are natural ecosystems where the main constraint is the availability of the natural resource, especially considering the current overexploitation of most fishing stocks. Therefore, the aim of the study is to provide a theoretical analysis on how to enhance the policy support utility of seafood LCA, by providing a specific framework to calculate the environmental consequences of changes in fishing quotas on an annual basis.

FRAMEWORK

The distortion of ecosystem dynamics in marine environments by anthropogenic activities can be mainly linked to the proliferation of fishing activities worldwide through the centuries. This phenomenon has gradually led to a situation, confirmed by recent FAO reports (FAO, 2012), in which an overwhelming majority of global fisheries are depleted, overexploited or fully exploited. A situation that not only hinders the natural capability of fish stocks to replenish, but also increases the social and economic risks of human communities reliant on this important source of income and nourishment. The need to develop adequate fishing management strategies to guarantee the sustainability of fishing stocks triggered a strong development of stock assessment techniques in an attempt to regulate fish catches through a wide range of actions. In the European Union (EU) these actions have been integrated for the last 40 years in a common strategy, named the Common Fisheries Policy (CFP). The CFP fixes a set of maximum harvest yield thresholds for those fishing species and fisheries where, based on stock assessments, the yields must be controlled to maintain the stock within sustainable practices or where sustainability has yet to be reached.

These thresholds, named total allowable catches (TACs), are a particular type of fishing quota restriction that use stock sustainability and the replenishment capability of the stocks as the main criteria to provide annual scientific predictions of individual fish species. While the annual change in TACs for an individual fishing species in a particular fishery in many cases is relatively limited, there have been cases in which the EU has enforced strong reductions in quota allowance from one year to the next (e.g. Atlantic mackerel in the Southern Stock in 2010) or has closed a fishery due to overfishing–e.g. anchovy in the Southern Stock in the period 2005-2009 (ICES, 2012). Moreover, decennial revisions of the CFP (currently in process in 2013) have delivered substantial changes in the management of fisheries. For instance, the current on-going proposal suggests a gradual ban on discarding, which may imply important changes in fishing practices, ecosystem dynamics in marine environments and in seafood supply chains.

The inclusion of fishery-specific impacts on marine resources in life cycle thinking is a long lasting controversy in the LCA community. In fact, no current assessment method in LCA considers any of the so called *fishery-specific impact categories* within their framework, despite the proliferation of these indicators in recent years (Emanuelsson, 2012; Langlois et al., 2012; Vázquez-Rowe et al., 2012). In this context, the debate between fishery-LCA practitioners has orbited around two main lines: those who defend higher comprehensiveness of LCA as applied to fisheries, in which new impact categories are developed to analyze the life cycle environmental impacts associated with human health (i.e. impacts on ecosystem services), natural resources (i.e. depletion of fish stocks) or ecosystem quality (i.e. biodiversity damage potential) as linked to activities developed in oceans (Langlois et al., 2012); and those who follow the Hospido and Tyedmers (2005) doctrine, seeing LCA as a complementary tool to evaluate environmental impacts beyond the already existing stock assessment methods, as well as other methods to evaluate fishery-specific biological concerns.

Nevertheless, this study does not provide a critical discussion on the advantages and limitations of applying one of the two perspectives, but rather delivers a top-bottom discussion on how these two approaches, when used appropriately, are equally valid to support an expected future development in fisheries-LCA in order to enhance its utility in fisheries management and policy making: the understanding of the environmental impacts linked to fishing systems as a consequence of changes in a particular production system.

METHOD

We propose a consequential method for LCA that considers a two-fold inclusion of stock assessment in life cycle thinking. This methodological improvement is based on a new framework where LCA no longer nourishes from stock assessment data in order to provide additional environmentally relevant information regarding seafood products, but becomes an integrated tool for assessing fisheries beyond the stock abundance of a specific species, creating a so called "two-way catch" perspective in which stock assessment (i.e. overfishing and biomass removal) is included in two different stages of the evaluation process.

On the one hand, scientific predictions on stock abundance, which currently are the scientific basis for the fixation of TACs, would be used in the goal and scope stage of LCA to determine the consequential modeling of the production system. More specifically, stock assessment advices annually delivered by the International Council for the Exploration of the Sea (ICES) would be used as the main source of data to understand the environmental consequences that arise from the loop between stock assessment itself and the final policy-making in the frame of the CFP (the latter eventually creating rebound effects on stock abundance and, therefore, on stock assessment results in the subsequent years). Consequently, it will be of key importance in fisheries C-LCA to monitor the reciprocal feedback between the stock assessment of the fishery, which conditions to a great extent the final TACs, and vice versa, since the final management decisions are going to determine to a great extent (in conjunction with several natural parameters and the extent of illegal fishing) the health of the fishery stocks and their capability to replenish through time. Thereafter, based on the identification of the main consequences (e.g. variable working load; seasonal closure of fisheries; deployment of vessels; reassignment of fishing areas, etc.) derived from the shock exerted to the system due to quota changes, the marginal suppliers for operational inputs would be identified (e.g. changes in energy demand, catch rates for the different species or selectivity in discards) for their inclusion in the consequential Life Cycle Inventory (C-LCI) and subsequent computation in the consequential Life Cycle Impact Assessment (C-LCIA).

On the other hand, as previously described, the inclusion of biotic resource depletion impact categories (or the combination of LCA with stock assessment methods) would be a central part of the methodological innovation in the impact assessment stage, widening the comprehensiveness of the impact categories covered in life cycle thinking. Hence, the proposed methodology would trigger an appealing insight to LCA, by not only providing a detailed analysis on how quotas will affect environmental impacts through consequential modeling, but also by expanding the comprehensiveness of environmental impacts monitored through LCA and potentially delivered for decision making and policy making.

DISCUSSION

C-LCA has shown to have important sources of uncertainty, linked not only to its methodological assumptions (e.g. difficulty to set boundaries; identification of marginal technologies, etc.), but also to the underlying uncertainties of reporting future outputs. Hence, studies usually tackle this limitation by providing a wide range of future scenarios, based on economic, environmental or policy making changes or predictions which are integrated into the expected variation which is the object of the C-LCA (Vázquez-Rowe et al., 2013). Therefore, the different shocks that should be simulated for the selected fisheries should be based on EU new fishing quota recommendations and other derived predictions, in order to understand how these recommendations may affect the environmental profile of fisheries.

Moreover, the predicted shocks that will ultimately determine the environmental consequences may imply important effects on the dietary patterns of European nations, since variations in seafood availability may change the way human populations obtain their protein supply. For instance, a final decision to reduce the TACs of a given species by 25% may entail a considerable shortage of this seafood product for the subsequent year. This issue would most possibly lead to marginal changes in the protein supply. While certain studies have monitored in the past how certain decisions may affect the environmental profile of a specific diet, the use of a consequential perspective in the post-landing stage of seafood supply chains may be calculated based on the predicted changes in seafood supply and on a consumer demand model focused on protein-based products. For instance, the use of basic economic models, such as AIDS (Almost Ideal Demand System) or other comparable models may be interesting perspectives if jointly used with C-LCA.

CONCLUSIONS

The proposed C-LCA method suggests a new framework where LCA no longer nourishes from stock assessment data to provide additional environmentally relevant information for seafood products, but becomes an integrated tool for assessing fisheries beyond the stock abundance of a specific species, creating a so called "two-way catch" perspective in which stock assessment is included in the impact assessment stage through impacts categories or combining LCA with stock assessment methods and the scientific predictions on stock abundance are used to estimate the environmental consequences of different quota restriction scenarios. Hence, it seems feasible that in the case of seafood extracted from natural ecosystems, C-LCA should be combined with stock prediction tools rather than with economic management tools to determine how changes in stock size may cause variations in the environmental impact of seafood.

REFERENCES

Emanuelsson A. (2012). Quantifying overfishing and ecosystem impacts related to seafood products. Life cycle assessment (LCA) and fisheries science to improve the sustainability of seafood. University of Gothemburg.

FAO. (2012). The state of the world fisheries and aquaculture. Food and Agriculture Organization, Rome.

Hospido A, Tyedmers P. (2005). Life cycle environmental impacts of Spanish tuna fisheries. *Fish Res 76, 174-86.*

ICES. (2012). ICES Advice 2012. International Council for the Exploration of the Sea.

Langlois J, Fréon P, Delegenes JP, et al. (2012). A new approach for fisheries impact assessment in LCA. 8th International Conference on LCA in the agri-food sector. St. Malo, October 2012.

Thrane M. (2006). LCA of Danish Fish Products. New methods and insights. *Int J Life Cycle Assess 11, 66- 74.*

Vázquez-Rowe I, Moreira MT, Feijoo G. (2012). Inclusion of discard assessment indicators in fisheries LCA studies. Expanding the use of fishery-specific impact categories. *Int J Life Cycle Assess 17, 535-49.*

Vázquez-Rowe I, Rege S, Marvuglia, et al. (2013). Application of three independent consequential LCA approaches to the agricultural sector in Luxembourg. *Int J Life Cycle Assess, accepted for publication.*

COLLECTIVE ACTION TO ADDRESS GHG EMISSIONS IN SEAFOOD – STANDARDS, TOOL AND MANUAL

Erik Skontorp Hognes, SINTEF Fisheries and aquaculture.*

** SINTEF Fisheries and aquaculture, PB 4762 Sluppen, 7465 TRONDHEIM.*

Tel.: +47 40 22 55 77, E-mail: erik.hognes@sintef.no

Keywords: Seafood, GHG assessment, standards, tool, manual

ABSTRACT

By providing means to make LCA based GHG assessments a more operative and applicable tool for the seafood industry the cooperation framework "Collective action to address GHG emissions in seafood" wish to help reduce the energy use and GHG emissions from food production. During the previous year two new standards for carbon footprint of seafood products have been developed to provide fair and transparent reporting on the carbon footprint of a seafood product. In addition a web based tool for carbon footprint of wild caught seafood products and a manual for GHG assessment of seafood products are under development.

INTRODUCTION

Seafood is a climate friendly food commodity compared to other meat sources such as poultry and red meat (Hognes, Ziegler, & Sund, 2011; Winther et al., 2009; Ziegler et al., 2012). Still the seafood industry wants to further reduce their energy use and climate impact (Ellingsen, 2004) and as a part of the focus on sustainable food production, and methods to report on the sustainability of food products, the seafood industry, retailers, consumers, governmental bodies, NGOs and researchers have asked for standards and tools for carbon foot printing of seafood products. A global cooperation named "Collective action to address GHG emissions in seafood"[1] has participated in the preparation of two standards for carbon foot printing of seafood products and is now developing a web based tool for carbon footprint of wild caught seafood products[2] and a manual for greenhouse gas assessment of seafood products.

Important aims of this work are to:

[1] More information on this project framework here: www.seafish.org/media/sustainability/greenhouse-gas-emissions-in-seafood

[2] The current version of the tool can be studied here: www.seafish.tictocdesign.com/co2emissions/tool

- Provide means and tools that can help to reduce climate impacts from food production by increasing the seafood decision maker's understanding of their climate impacts and their ability to use LCA as a tool in developing their products and business strategy.

- Make the use of carbon footprint (and LCA) more achievable: Standards and tools will make the required competence more available and with time expand and improve the availability of LCA data for the seafood industry.

- Secure fair and transparent carbon footprint documentation, that can be used in different forms of B2B and B2C communication, and that is accurate, repeatable and that can be audited.

Examples of emerging report methods that can include requests to report on the carbon footprint of food products are the "Sustainability consortium"[3] that currently includes retailer and industry members representing a revenue of 1.5 trillion USD. Another example is the ENVIFOOD protocol developed by the "The European Food Sustainable Consumption and Production Round Table"[4] . Both of these examples use LCA as a fundament for their reporting methods.

DESCRIPTION OF WORK

Two different standards for carbon footprint of seafood products are developed: one by Standards Norway (SN, 2013) and one by British Standard Institute (BSI, 2012), the latter is a set of supplementary requirements and guidance specific to seafood products to be used in conjunction with PAS 2050. Both these standards have the goal of providing background for a future seafood specification of the coming ISO 14067 standard for carbon footprint of products. An important part of the standards development was to communicate with stakeholders in the seafood industry and to map and understand their needs and requirements; the BSI development had an international scope for their stakeholder input. Members of the collective action framework participated in the committees for both standards.

The web tool for GHG assessment of wild caught seafood products is developed to facilitate the use and understanding of the standards, and to let the seafood industry and their stakeholders explore the climate aspects of seafood. The tool is a development of the current "seafood GHG profiling tool" by Seafish and Dalhousie University and covers fuel and electricity consumption in fishing, processing and transport, - from fishing to retailer gate. In addition to energy commodities inputs and outputs such as packaging materials, fishing gear and refrigerants emissions are also covered. It also provides an optional screening of the potential importance of capital investments in the fishing vessel.

---

[3] www.sustainabilityconsortium.org

[4] More about the ENVIFOOD protocol here: www.food-scp.eu

The GHG manual aims at making GHG assessment and LCA thinking more accessible and applicable for decision makers in the seafood industry. While standards provide clear rules for how a carbon footprint should be calculated, and tools can facilitate the calculations, neither of these is a good platform for thorough explanation and examples of how the practicalities of using GHG assessments within seafood production are solved. The main targeted audience will be the actor in the seafood industry that are well known with the seafood systems, but somewhat new to GHG assessments and LCA way of thinking, but wants to make these an operating part of their management system. As an example the manual will be of great value for seafood producers that wish to: 1) increase the quality of their environmental management system and reduce their energy use and GHG emissions and 2) prepare themselves for requests to report their carbon footprint to their clients, consumers, regulating bodies and NGOs. The manual will be produced as a compilation of contribution from seafood and LCA experts from all over the world and will be published as a web page.

RESULTS AND CONCLUSIONS

The British Standard is now published and the Norwegian Standard will be published during 2013. It is now interesting to study how the standards will be received by decision makers in the seafood value chain and others concerned. It is especially interesting to see how they will be used in B2B communication between retailers and seafood exporters/producers.
The tool and the manual will be finished by 2013. After that the challenge will be to make both of them a living and updated resource for seafood producers, retailer and consumers that wish to achieve a more sustainable, energy efficient and climate friendly food production.

AKNOWLEDGEMENT

SINTEF's participation in the collective action framework is financed by The Norwegian Seafood Research Fund (FHF). Among many partners in the collective action framework the activities described here are performed together with The Swedish institute for Food and Biotechnology (SIK), Seafish (UK) and Dalhousie University (Canada).

REFERENCES

BSI. (2012). Assessment of life cycle greenhouse gas emissions - Supplementary requirements for the application of PAS 2050:2011 to seafood and other aquatic food products. http://shop.bsigroup.com/en/Browse-By-Subject/Environmental-Management-and-Sustainability/PAS-2050/PAS-2050-2/.

Ellingsen, H., Pedersen, T. A. (2004). Designing for environmental efficiency in fishing vessels. *Journal of Marine Design and Operations. Proceedings of the Institute of Marine Engineering, Science and Technology, Part B6*.

Hognes, E. S., Ziegler, F., & Sund, V. (2011). Carbon footprint and area use of farmed Norwegian salmon www.sintef.no/Publikasjoner-SINTEF/Publikasjon/?pubid=SINTEF+A22673: SINTEF Fisheries and aquaculture.

SN. (2013). Carbon footprint for seafood - Product category rules (CFP-PCR): Standards Norway.

Winther, U., Ziegler, F., Skontorp Hognes, E., Emanuelsson, A., Sund, V., & Ellingsen, H. (2009). Project report: Carbon footprint and energy use of Norwegian seafood products www.sintef.no/Fiskeri-og-Havbruk-AS/Prosjekter/2011/Miljoregnskap-og-klimasporing-av-sjomat/. Trondheim, Norway: SINTEF Fisheries and aquaculture.

Ziegler, F., Winther, U., Hognes, E. S., Emanuelsson, A., Sund, V., & Ellingsen, H. (2012). The Carbon Footprint of Norwegian Seafood Products on the Global Seafood Market. *Journal of Industrial Ecology*, no-no. doi: 10.1111/j.1530-9290.2012.00485.x

LIFE CYCLE THINKING AS A TOOL TO INFORM FISHERIES MANAGEMENT

*Sara Hornborg**

The Swedish Institute for Food and Biotechnology (SIK), Sustainable Food Production and University of Gothenburg, Department of Biological and Environmental Sciences

SIK, Box 5401, SE-40229 Gothenburg Sara.Hornborg@sik.se

Keywords: seafood; LCA; fisheries management; fuel; by-catches

ABSTRACT

The fishing phase generally dominates the total environmental impact and resource use attributed to the seafood product. Great differences are however seen between similar products. These differences are the result of fisheries having different management in terms of e.g. gears and effort. The integrated perspective Life Cycle thinking brings could therefore prove to be important to inform fishing policy for an overall better resource use in seafood production. Based on examples of Swedish fisheries, resource management in fisheries supported by life cycle thinking is discussed. It is concluded that more integrated approaches is vital for the future development of the sector.

INTRODUCTION

In seafood production, the fishing phase generally dominates the total life cycle resource use and environmental impact attributed to the product (Ziegler, 2006). The differences between similar seafood products can be substantial, with e.g. gears, effort and quotas being important components explaining observed differences (Driscoll & Tyedmers, 2010). These measures are all taken by the authorities managing the fisheries, which unfortunately lack a system perspective. Therefore, actions taken have the potential to affect the resource use and environmental impacts in a broader perspective than is currently included in the decisional framework, such as increases in energy demand or seafloor area affected (Hornborg et al., 2012). This paper discusses where Swedish fisheries are now and future options of more integrated approaches to management.

MATERIALS AND METHODS

Results from prior studies of Swedish fisheries were combined and analyzed: species selective trawling for Norway lobster *Nephrops norvegicus* (Hornborg et al., 2012), discard assessments of Swedish demersal trawling by novel LCA methods (Hornborg et al. *in press*) and fuel efficiency in Swedish demersal trawling (Ziegler and Hornborg, *in review*). Data covered the year 2009.

Official landings from the Swedish Agency for Marine and Water Management (www.havochvatten.se) were also studied in terms of composition of threatened fish species (i.e. a status as Vulnerable (VU), Endangered (EN) or Critically Endangered (CR) according to the Swedish IUCN Red List; Gärdenfors et al., 2010).

RESULTS

Demersal trawling for crustaceans (northern prawn *Pandalus borealis* and Norway lobster) was in general more energy demanding per landing than mixed fish trawling in 2009, in particular when selective devices were used (figure 1). The selective fishery for *Nephrops* had the highest energy requirement per landing.

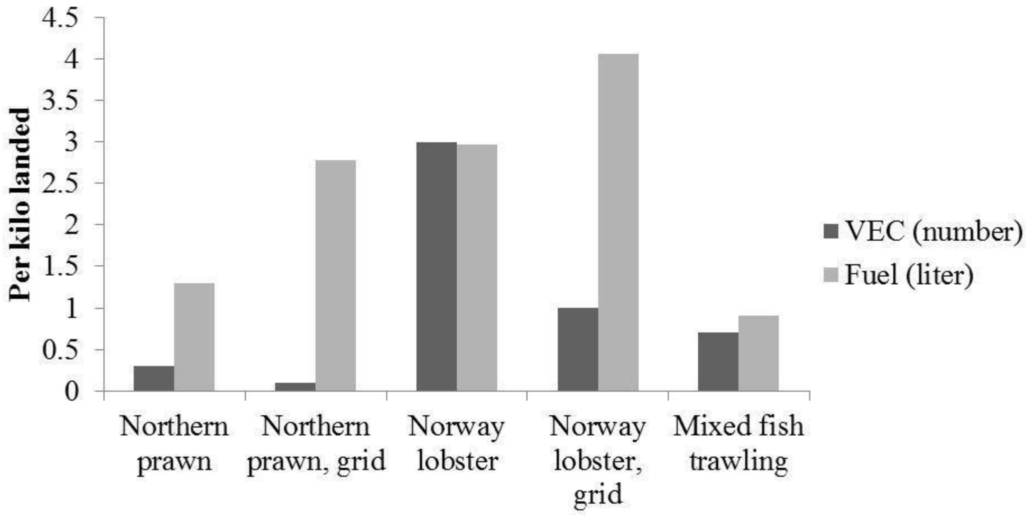


Figure 1. Discard of threatened fish species and fuel consumption per kilo landing in demersal fisheries on the west coast of Sweden in 2009 (fuel estimate for Norway lobster without grid is from 2007).

Five of the twenty most landed fish species in Swedish fisheries have a regional IUCN Red List status as threatened: Atlantic cod, haddock, whiting, pollack and ling (Table 1). Except for cod, which is targeted in the Baltic sea, these fish species are all caught in mixed fisheries. In terms of discard impact on threatened fish species (predominantly haddock, whiting and cod), demersal trawling for Norway lobster posed the greatest pressure; this was mitigated by using selective device (figure 1). In addition, selective trawling for *Nephrops* has been shown to affect a larger area of seafloor per kilo landing (Hornborg et al., 2012).

Table 1. Swedish landings of fish that are threatened according to the Swedish Red List.

Common name	Scientific name	Swedish Red List Category (2010)	Landings (tonnes)			
			2013	**2012**	**2011**	**2010**
Atlantic cod	*Gadus morhua*	EN	4596	14278	14436	13052
Haddock	*Melanogrammus aeglefinus*	EN	117	352	343	242
Whiting	*Merlangius merlangus*	VU	41	85	108	89
Pollack	*Pollachius pollachius*	CR	27	80	64	68
Ling	*Molva molva*	EN	12	37	36	39
Other with a regional threat category (CR, EN, VU)			3	261	375	458
Percentage of total landings			**5**	**9**	**8**	**6**

DISCUSSION AND CONCLUSIONS

Selective trawling protects threatened fish species but comes with trade-offs from a system perspective; the mixed demersal trawl fishery is more energy efficient per landing than selective demersal trawl fisheries. As fishing overcapacity has severely depleted many of the demersal fish species, mixed demersal trawling cannot be sustained at present. The managers of fisheries have been trying to reduce fishing mortality and implement rebuilding efforts of depleted fish species. However, fisheries for Norway lobster and northern prawn are too economically valuable to be restricted; selective demersal trawling for crustaceans is thus enabled despite high energy demand. This could however only be sustained in a short perspective. In the longer run, the prospects for energy intensive fishing methods are less certain. As there have been additional discussions on the risks with selective fisheries from an ecosystem point of view (Garcia et al. 2012), this could altogether indicate that it may be time to take a system perspective on the whole fishing sector. Given the present state, what is the overall optimum “fleet foraging strategy” in the defined area to ensure long-term sustainable seafood production from an overall resource management point of view?

One alternative way forward for is to enforce even stronger effort restrictions and only allow highly catch effective trawls that are obliged to land the whole catch. Fishing for *Nephrops* would then have to be based on creeling to a greater extent, which is more energy efficient and with less discard than demersal trawling (Ziegler and Valentinsson, 2008). Marine protein production from the area would then have to origin from other sources, such as mariculture of e.g. mussels. From adding a system perspective, and including product processing chain, increased utilization of otherwise discarded or wasted by-products would also generate more protein. Managing the area with a system perspective may prove to lower overall fuel demand, minimize seafloor interactions, increase utilization of available production and ease pressure on threatened fish species. Instead, the reform of the Common Fisheries Policy in the European Union during 2013 discusses details, such as if and how to implement a discard ban. As a result, increased use of selective demersal trawls in crustacean fisheries is seen. However, this picking bits and pieces out of the ecosystem in a highly energy demanding manner is the result of management lacking an integrated system perspective. Also, effective management has been shown to require increased transparency in order to not be influenced by harmful subsidies (Mora et al., 2009). Life cycle approaches could provide both an integrated and transparent decision support for the management of fisheries.

Data availability and available assessment methods have however been shown to be a major constraint for seafood LCAs. This also applies for managers of fisheries; there is a lack of data to determine biological reference points required for proper stock assessments of many of the fished stocks. Whiting, pollack and ling are all considered to be data deficient stocks. Still, these species are among the twenty most landed species by volume in Sweden. They have however been assessed by the Swedish Red List and are considered to be threatened (VU, EN, CR). This form of assessment has been shown to be fairly consistent with other metrics of vulnerability and has been proposed as a novel method in LCA (Hornborg et al., *in press*). Discard of threatened fish species varies between fishing practices, still discard estimates are only included in stock assessments of Atlantic cod, haddock and whiting; this is not the case for pollack nor ling. For an improved overall resource management, there is an emerging need to utilize other metrics and tools to evaluate current management regime. The added value of a life cycle approach, which utilizes a range of assessment methods, would be to create a framework that visualizes a broad range of aspects regarding the use and misuse of our common resources (both biotic and abiotic) on a product basis.

REFERENCES

Driscoll J & Tyedmers P. (2010). Fuel use and greenhouse gas emission implications of fisheries management: the case of the New England Atlantic herring fishery. *Marine Policy 34(3): 353-359*

Garcia SM, Kolding J, Rice J, Rochet M-J, Zhou S, Arimoto T, et al. (2012). Reconsidering the consequences of selective fisheries. *Science 335(6072):1045-7*

Gärdenfors U (ed.). (2010). Rödlistade Arter i Sverige 2010 – The 2010 Red List of Swedish Species. *ArtDatabanken, SLU, Uppsala. 590 pages. ISBN: 978-91-88506-35-1.*

Hornborg S, Nilsson P, Valentinsson D & Ziegler F. (2012). Integrated environmental assessment of fisheries management: Swedish *Nephrops* trawl fisheries evaluated using a life cycle approach. *Marine Policy 36(6):1193-201*

Hornborg S, Svensson M, Nilsson P & Ziegler F. (in press). By-catch impacts in fisheries: utilizing the IUCN Red List Categories for enhanced product level assessment in seafood LCAs.

Mora C, Myers RA, Coll M, Libralato S, Pitcher TJ, Sumaila RU, et al. (2009). Management effectiveness of the world's marine fisheries. *PLoS Biology 7(6)*

Ziegler F & Hornborg S. (in review). Stock size matters more than vessel size: The fuel efficiency of Swedish demersal trawl fisheries 2002-2010.

Ziegler F. (2006). Environmental Life Cycle Assessment of seafood products from capture fisheries. *PhD thesis, Göteborg University, Dept of Marine Ecology/SIK, The Swedish Institute for Food and Biotechnology. SIK report 754.*

Ziegler F & Valentinsson D. (2008). Environmental Life Cycle Assessment of Norway lobster (*Nephrops norvegicus*) caught along the Swedish west coast by creels and conventional trawls. LCA methodology with case study. *International Journal of Life Cycle Assessment 13(6):487-97*

VARIABILITY IN FUEL EFFICIENCY OF A NORTH EAST ATLANTIC DEMERSAL TRAWL FISHERY

E. Groen[2], F. Ziegler[1] E.A.M. Bokkers[2], K.M. Karlsen[3], L.Veldhuizen [2]I.J.M. de Boer[2], K. Donnelly[3], V. Sund[1]and C. Krewer[1].*
*[*1]SIK-The Swedish Institute for Food and Biotechnology, PO Box 5401, 40229 Göteborg, Sweden, fz@sik.se, [2]Wageningen University, the Netherlands, [3]Nofima, Norway.*

Keywords: LCA, fisheries, variability, fuel, cod

ABSTRACT

The purpose of the study was to better understand the variability in fuel efficiency of a Norwegian freeze trawler targeting cod, haddock, saithe and shrimps. Additional goals were to evaluate whether batch is actually a relevant resolution in LCAs and to increase the knowledge about the reasons behind variability. This was done by collecting daily data on fuel use and production for two years. Fishing trips targeting shrimps were shown to be significantly more fuel intensive than those targeting fish such as cod, haddock and saithe. Other actors explaining the difference between fishing trips were distance from port to fishing location, season, weather. Results can be used for internal improvement and as a basis for a simplified tool for environmental assessment.

INTRODUCTION

Life Cycle Assessment (LCA) has been identified as a useful, standardized approach to quantify environmental impacts in relation to a product from a supply chain perspective. A weakness is that LCAs are often resource intensive to undertake, which hampers operational day-to-day use and a drawback often pointed out by the industry is that results of different studies not fully comparable because of different goals and scopes. However, a finding common for many seafood LCAs is that on-board fuel use is often the single most important input in fisheries in current LCA calculations (Parker 2012, Vázquez-Rowe et al. 2012). Due to its large importance both from an environmental and economic point of view, and large variability both over time and between fisheries (Tyedmers 2001, Ramos et al, 2011, Vázquez-Rowe et al. 2012), depending on stock status, fishing gear and management regimes, it is important to understand more about the factors determining fuel efficiency to be able to increase it. While variability in fuel use between years has been shown to be extensive in the work cited, within-year variability has so far only been described by Almeida et al. (2013) and needs more attention. Decreasing the fuel use of the fishery is one of the most important steps in reducing the carbon footprint of the resulting seafood products.

In a Seventh Framework EU project called WhiteFish, the aim is to meet this challenge by developing a simplified tool assessing the broad sustainability of North East Atlantic cod and haddock fisheries based on the LCA methodology. In the first phase of this project, detailed fuel and production data was collected for the fisheries involved, which is presented in this paper. In the second phase, full LCAs will be carried out, forming the basis for a simplified tool, which will be developed in the third and final project phase. The project addresses several of the drawbacks of traditional LCA stated above by providing a simplified tool for operational internal use within companies, by presenting a product specific standard and by increasing the resolution from year to batch. In this paper, the purpose was to better understand the variability in fuel efficiency by using a part of the data collected in the WhiteFish project to gain insight into the variability in fuel use of a Norwegian freeze trawler targeting cod, haddock, saithe and shrimps over time. In addition, to evaluate whether batch is actually a relevant resolution in Life Cycle Assessment modelling and to increase the knowledge about the reasons behind variability.

METHODS

In this paper, a Norwegian demersal trawler doing primary processing on-board, i.e. heading, gutting and freezing of the fish is studied to better understand the variability in fuel efficiency. The trawler mainly operates in the Norwegian Sea and Barents Sea, but also makes a few fishing trips to the North Sea every year. It mainly targets Atlantic cod, haddock, saithe (hereafter called fish) and northern shrimps. The functional unit is defined as one kilo of edible seafood at the point of landing with a fishing trip of four to 14 days being the batch. Multifunctional processes in the fish production chain are: the fishing stage, resulting in several species landed simultaneously, and fish processing, resulting in several edible co-products (e.g. fillet and mince) and non-edible co-products such as heads and guts (and in later processing stages also skin and bones). We chose to distribute the environmental burdens of the fishery on the co-products based on mass. Heads and guts are currently discarded at sea. In this short paper, we assume that the non-edible parts of the landings are not used further, meaning that edible products carry the full burden. To translate fuel use from total landing to edible seafood we used official Norwegian fillet yield factors, in lack of specific and batch-based data on this matter. The data analyzed comprises two years of fishing (2011-2012) by the freeze trawler which makes around 20 fishing trips each year. Over 70 products are produced/landed every year, defined by the species, but also Marine Stewardship Council (MSC) or non-certified fish, several size categories per species as well as different product forms depending on the gutting method used. Fuel efficiency is measured as liters of diesel used per kilo of edible seafood landed and for comparison also in liters of diesel per kilo landed. We also studied an alternative indicator, perhaps more interesting from the fisherman’s point of view: Fuel efficiency per trip measured in liters of diesel used per economic landing value (kNOK).

Fuel use per landing was analysed for the effect of year (2011 vs. 2012) and type of catch (fish vs. shrimps) and potential interactions between the two using an analysis of variance. Fuel use per edible yield and fuel use per landing value were analysed for the effect of type of catch only for the year 2011 using a Mann-Whitney U test.

RESULTS

The variability between trips within a year was large (Fig. 1). Trips 5, 6 and 14 targeted shrimps and were more fuel intensive than the other ones. The translation from total landing to edible yield did not change the ranking between trips, but reinforced the difference between trips targeting shrimps and fish, as the main fish species had a similar yield, while the yield of shrimps was lower.

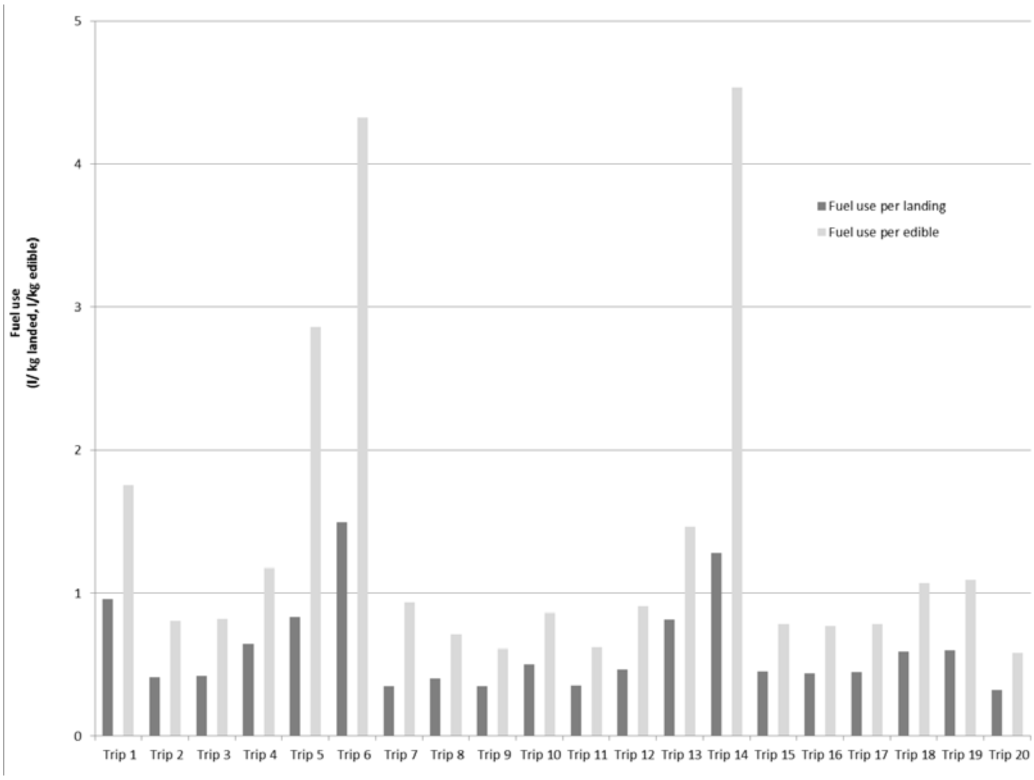


Figure 1. Fuel use in 2011 measured in liters of diesel per landing and per edible yield at landing.

The same trips stand out as most fuel intensive per landing value, which is due to prices per kilo being surprisingly similar between the main species landed. Trips 1 and 13, targeting fish had a lower value of the landings. The target species in these trips was saithe, which is a lower value species than cod and haddock and the prices achieved were lower.

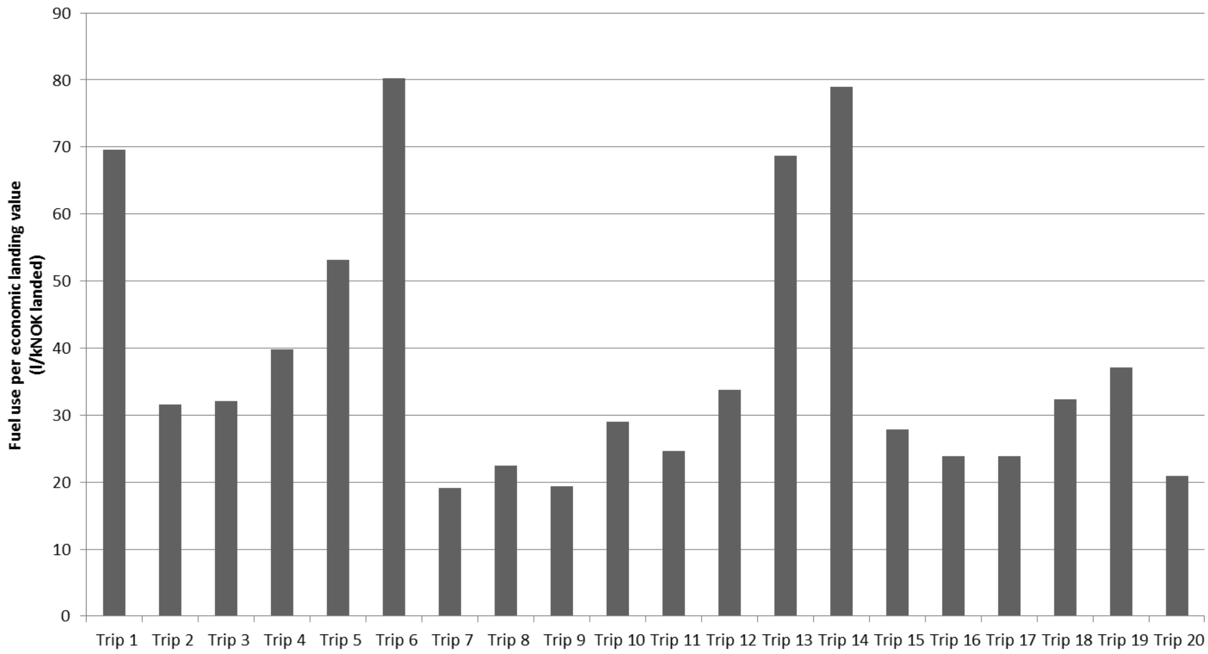


Figure 2. Fuel use in 2011 measured in liters of diesel per economic value landed

The statistical analysis showed that the fuel use per landing was higher for trips targeting shrimps than for trips targeting shrimps (P<0.001). The interaction effect (P<0.05) between catch type and year showed year had a different effect on the trips targeting shrimps than on the trips targeting fish. Trips targeting shrimps had a higher fuel use per edible yield and fuel use per landing value than the trips targeting fish (both P<0.01).

DISCUSSION

The level of resolution of the data in this study gives new possibilities to look into details compared to previous studies. While variability over several years has been described recently in seafood LCA literature (Ramos et al. 2011, Vázquez-Rowe et al. 2012), considering variability within a year in the fuel efficiency of fisheries is a novelty in seafood LCAs and has so far only been described by Almeida et al. (2013).

For some of the most fuel intensive fishing trips (In 2011: trips 5, 6 and 14 and in 2012: trips 4, 5, 12, 14 and 17) a common explanation was the target species being northern shrimps. Shrimp trawling is known to be more fuel intensive than fish trawling (Thrane 2004, 2006; Tyedmers 2001). Trawling for crustaceans has considerably lower Landings Per Unit of Effort (LPUE) values than fish trawling especially when using species-selective grids (Hornborg et al. 2012), as in this fishery. The LPUE seems to be the most important factor explaining the higher fuel intensity.

It was harder to identify common characteristics of the fuel efficient trips, but due to the differences found between trips targeting fish and shrimps, using the annual average fuel use of the vessel (as is typically done in current seafood LCAs) would have over-estimated the fuel use of fish and underestimated that of shrimps in this case. Other potential factors explaining the fuel use, in addition of LPUE, are steaming time or distance from port to fishing location, weather, availability of quotas as well as strategic decisions taken by the skipper in each fishing trip. This vessel seems to fish most efficiently when targeting cod and haddock on the banks of the Norwegian, Greenland and Barents Seas. The fuel efficiency independently of how measured, ranks the trips in the same way, indicating that fuel efficiency in this fishery reflects both environmental and economic sustainability.

CONCLUSIONS

We showed substantial variability in environmental performance between fishing trips, mainly because of different LPUE when targeting different species and therefore this level of resolution (batch) is highly relevant to identify improvement options. In the fishery studied, the fuel efficiency depends mainly on the catch rate and it seems to be an indicator of both environmental and economic performance in this fishery.

REFERENCES

Almeida, C., Vaz, S., Cabral, H., Ziegler, F. 2013. Environmental assessment of sardine (*Sardina pilchardus*) purse seine fishery in Portugal with LCA methodology including biological impact categories. Manuscript submitted to I J LCA

Parker, R. (2012). Review of life cycle assessment research on products derived from fisheries and aquaculture: A report for Seafish as part of the collective action to address greenhouse gas emissions in seafood.

Ramos, S., I. Vázquez-Rowe, I. Artetxe, M.T. Moreira, G. Feijoo, and J. Zufía. 2011. Environmental assessment of the Atlantic mackerel (Scomber scombrus) season in the Basque Country. Increasing the timeline delimitation in fishery LCA studies. *International Journal of Life Cycle Assessment* 16:599-610.

Thrane M. Energy consumption in the Danish fishery. Identification of key factors. Journal of Industrial Ecology 2004: 223-239.

Thrane M. LCA of Danish fish products. New methods and insights. International Journal of Life Cycle Assessment 2006; 11(1):66-74.

Tyedmers P. Energy consumed by North Atlantic fisheries. In Fisheries impacts on North Atlantic ecosystems: Catch, effort and national/regional data sets. Fisheries Centre Research Reports 2001 ; 9(3):12-34.

Vázquez-Rowe, I., Hospido, A., Moreira, Ma.T., Feijoo, G. (2012). Best practices in life cycle assessment implementation in fisheries. Improving and broadening environmental assessment for seafood production systems. *Trends in Food Science and Technology, 28, 2, 116-131.*

SUSTAINABLE PRODUCTION 2

Wednesday, Aug 28: 1:30 pm - 2:30 pm

Session chairs: Björn Johansson, Chalmers University of Technology, Sweden
Per Hanarp, Volvo Group, Sweden

GREEN KPI'S AS DRIVERS FOR ENVIRONMENTAL IMPROVEMENTS ON SHOP FLOOR LEVEL – A CASE STUDY AT ABB

Linnea Petersson[1,], Lennart Swanström[1], Monica Bellgran[2]*

ABB AB, Corporate Research, SE-721 78 Västerås, SWEDEN,

Div of Product Realisation, Mälardalen University, SE-631 05 Eskilstuna, SWEDEN

** linnea.petersson@se.abb.com*

Keywords: Key performance indicators; Environmental KPI's, Green performance map; Environmental improvement work.

ABSTRACT

This paper is based on a case study, where local key performance indicators (KPI's) were developed for two production cells at one of ABB's Business Units. The two studied cells represented two important ABB Group environmental targets, since one cell was more energy intensive, while the other generated more unwanted process waste. The study indicated that employees at production cell level became more motivated in performing environmental improvement work after being engaged in developing local KPI's that suited their specific production situation. Using environmental KPI's designed to fit each production cell could also be used as driver for more focused environmental improvements by supporting the local operational management in prioritizing environmental improvement projects.

INTRODUCTION

Environmental management in manufacturing companies has undergone a strong development; from pollution control and emission prevention, to becoming more clearly linked to the company's business strategy due to stakeholders' tougher requirements on environmental performance. Consequently, an increasing number of companies are realizing that resource and energy efficiency and pro-active environnmental management can give a competetive advantage rather than merely being a question of fulfulling environmental laws and regulations.

Central key performance indicators (KPI's) are being used on corporate level as a tool to drive, control and monitor environmental improvements for the entire company. However, it can be questioned if this approach is the most efficient way in achieving resource and energy efficient manufacturing sites. We believe that all employees at production shop floor level needs to be engaged in the continuous environmental improvement process and that local KPI's tailored for each specific cell could be a tool in achieving this. The local KPI's need to be aligned with the Group KPI's and implemented in the local environmental management system. Development of local KPI's demands operational tools and processes to map the environmental aspects and improvement potentials of each step in production. One such green mapping tool is environmental value stream mapping developed by the US-Environmental Protection Agency (EPA, 2007).

This case study that was carried out at one of ABB's Business Units together with Mälardalens University, who provided knowledge regarding application of environmental improvement tools, like Green Performance Map (GPM) (Romvall *et al*. 2011; Bellgran *et al.* 2012) and Green Lean (Kurdve *et al.* 2011). The GPM tool was used in this study and it facilitated the identification and prioritization of environmental aspects in the two studied production cells. The aim of the study was to investigate how to facilitate environmental improvement work at the two production cells, increase the level of engagement of the shop floor workers, and to see if/how the use of KPI's could be utilized in the process. The conclusion of the study was that an understanding of the specific environmental issues within each production cell could be enhanced and that the Green Performance Map (GPM) proved to be a valuable tool in the process.

METHODOLOGY

This paper is based on a case study including literature review on environmental KPI's, interviews, observations and a workshop on GPM. The main areas covered in this study were how to increase the engagement of shop floor workers with regards to sustainability and responsibility for environmental performance on site.

Local KPI's

- Mapping of ABB's environmental targets and KPI's on multiple levels (global, country and local business unit).
- Mapping of resources used at the two studied cells, like energy, scrap rate, value added and non-value added materials.
- Development of measurable environmental indicators for each of the two studied cells.

Green Performance Mapping

- Workshop on Green Performance Mapping using one of the investigated cells.

RESULTS

The use of the GPM tool proved to be a good starting point for assessing the environmental issues in each cell. The use of the GPM tool was preceded by a training session where the structured method was presented. The exercise was carried out in a group consisting of shop floor workers, process engineers, production manager and environmental specialists. The tool helped the group to analyze the cell in a new structured way. Figure 1 shows the final results, where the most negative non-value added environmental aspects were marked with red. The discussion held during the process was of high value for the Business Unit. It indicated creativity with regards to problem solving, identification of new critical issues and a will to change and improve. ABB Sweden has a process for organizational developments that involves all staff, where the use of the GPM tool easily could be introduced for manufacturing sites.

The results from the GPM process proved to be valuable when planning future environmental improvement projects. The tool made it easy to identify non-value added materials. Based on the outcome of the GPM for each cell together with observations and interviews local KPI's could be developed, as illustrated in Table 1. The new KPI's triggered discussions with suppliers, process engineers and real estate. For example, cell 1 used a high level of value-added material, which unfortunately due to the high margin of material delivered in the packaging resulted in a large amount of unnecessary waste. Together with the supplier this could be reduced. It was decided to use two KPI's for cell 2 in order to address both oil spills and energy used.

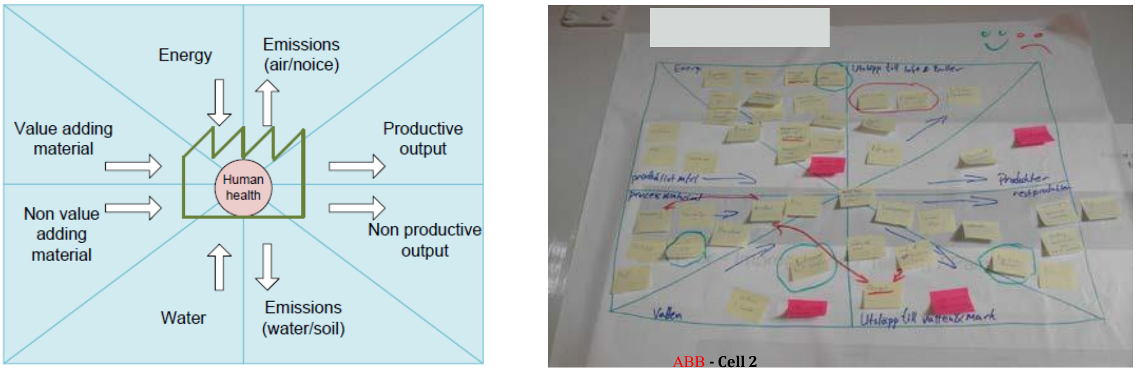


Figure 1. Left: The GPM model (Romvall et al. 2011), Right: The GPM model applied at Cell 2 at ABB.

Table 1. Environmental Key Performance Indicators developed for the two studied cells.

Cell 1	Cell 2
Waste [kg] / Produced unit - Metallic waste - Polymeric waste - Scraped units	Oil used [L] / Produced unit Electricity [Wh] / Produced unit

On one hand, it is important that the local ABB Business Units are addressing sustainability issues that are considered important on corporate level by the ABB Group. On the other hand, the opposite is also crucial i.e. developing and utilizing unique local KPI's to drive improvements should be positively recognized on corporate level. It is hence important that the developed local KPI's have a clear purpose and are in line with the global environmental targets. The ABB's environmental targets for 2012 were based on improved resource efficiency, with the main focus on energy use.

The present study also identified other factors that could be implemented in order to increase the overall engagement in environmental questions, such as:

1) To address environmental issues during the Gemba daily meetings
2) To delegate the responsibility of the environmental performance to the production line manager, i.e. to place responsibility on operations level rather than support level (environmental experts or similar)
3) To define environmental targets in the personal development plan of all employees.

DISCUSSION

Development and utilization of local KPI's – A concrete way to increase environmental engagement

Two different strategies could be used in order to increase the focus on environmental sustainability within an organization; either Top-down or Bottom-up. The decision to create a more environmental friendly product portfolio is an example of a Top-down strategy, while creating local KPI's together with shop floor workers is an example of a Bottom-up strategy. Bottom-up strategies are often more successful with regards to creating engagement among a larger number of employees, while Top-down strategies are more successful in altering the environmental profile of a company. Combining the both strategies is consequently the preferred approach of a multinational manufacturing group with the ambition of taking the lead within the environmental area.

The process used in developing the local KPI's was highly valuable for the environmental performance of the production line. The workers grew with the responsibility of setting the indicators that would measure their own performance. The study furthermore concluded that the GPM helped the workers to visualize their production cell in a way that supported the identification of environmental aspects and helped prioritizing among them, and eventually the planning and execution of relevant actions to reduce the environmental impact of the cell.

CONCLUSIONS

The main conclusions from this paper are summarized below:

- The process of developing local KPI's for the production cells lead to an energy boost for environmental improvement work at the Business Unit.
- The process of developing local KPI's could easily be included in the current structure ABB Sweden has for local organizational improvements.
- Green Performance Map was an appreciated tool, which was able to clearly visualize the input and output of the investigated production cell. It was also able to distinguish between value added and none value added resources.

ACKNOWLEDGE MENTS

The authors would like to thank Martin Kurdve for leading the workshop on Green Performance Map and Green Lean at ABB.

REFERENCES

U.S. Environmental Protection Agency (EPA). 2007. Lean & Environment Toolkit, www.epa.gov/lean

Bellgran, M., Höckerdal, K, Kurdve, M., Wiktorsson, M. 2012. Green Performance Map, Handbok, Mälardalen University, Eskilstuna.

Kurdve, M., Hanarp, P., Chen, X., Qiu, X, Zhang, Y., Stahre, J., and Laring, J. 2011. Use of environmental value stream mapping and environmental loss analysis in lean manufacturing work at Volvo. Swedish Production Symposium, SPS11

Romvall, K., Kurdve, M., Bellgran, M., and Wictorsson, J. 2011. Green performance Map – An Industrial Tool for Enhancing Environmental Imporvements within a Production System. 3rd CIRP Conference on Industrial Product Service Systems, Braunschweig, Germany

MAKING VIABLE THE RECYCLING OF CARBON FIBER/THERMOSET MATRIX COMPOSITES.FIRST ELEMENTS OF STUDY

*M. Prinçaud *[1], S. Pompidou[2], H. Andriankaja[2], G. Sonnemann[1], N. Perry[3]*

[1] *Univ. Bordeaux, ISM, UMR 5255* [2] *Univ. Bordeaux, I2M, UMR 5295*
[3] *Arts et Metiers ParisTech, I2M, UMR 5295*

** Univ. Bordeaux, ISM, UMR 5255, F-33400 Talence, France*
m.princaud@ism.u-bordeaux1.fr

Keywords: C/epoxy composite, LCA, aqueous solvolysis, recycled carbon fiber

ABSTRACT

Originally developed for high-tech applications, carbon/epoxy composites have been increasingly used in leisure and sports industries, for several years. Nevertheless, the carbon reinforcement is an expensive constituent, and it has been recently shown that it is also the most environmentally impacting in a composite part manufacturing. In this way, recycling these materials (even restricted to the reinforcement recovery) could lead to reduce economic and environmental inadequacies, while satisfying legislative requirements for their end-of-life.

This article is the basis for a life cycle analysis that assesses benefits and environmental challenges of this recycling loop. The recovery of the carbon reinforcement (based on the solvolysis of the matrix by water under supercritical conditions) offers an average gain of 70% for all eco-indicators.

INTRODUCTION

Carbon fiber/thermoset matrix composites were originally developed for high-tech applications in aeronautic and aerospace fields. However for several years, these materials have been increasingly used in automotive and leisure and sports industries. In these sectors, one may seek aesthetic criterions or a simple feeling of high technology, more than high technical properties. Thus, constituents' characteristics, and specifically reinforcement's (*e.g.* Young's modulus, tensile strength, etc.), are considered as a secondary matter and may be oversized regarding the function of the product. This is particularly true for non-structural decorative parts (*e.g.* with a carbon look finish), for which the reinforcement is the most expensive constituent, and where glass fibers, very much cheaper, cannot be used.

As a consequence for these scopes, alternative solutions to technical and economic inadequacies have to be found, but kept in line with the environmental impact of the product. Indeed, it has been shown that the carbon reinforcement is environmentally the most impacting constituent in a carbon/epoxy composite's elaboration process (Duflou, De Moor, Verpoest, & Dewulf, 2009) (cf. analysis Figure 1). First, recycling end-of-life composites (even restricted to the reinforcement recovery) could lead to reduce some anthropogenic impacts, by decreasing the use of first-generation raw materials (mainly petroleum) for their production. Besides, it would help design engineers to balance energy efficiency and cost, by opening new opportunities for developing second-generation composites, firstly dedicated to the manufacture of medium or low loaded parts. Lastly, recycled carbon fabric could widen the range of reinforcements on the marketplace, between first-generation carbon and glass fibers.

All this has to be led in line with European directives that already force industries to improve their products' recyclability (*e.g.* in automotive industry (European Parliament & Council of the European Union, 2000, p. 53)). However, making viable this new recycling sector requires overcoming users' reluctances by ensuring the second-generation semi-product's validity from economic and environmental aspects. Therefore, we carried out a life cycle assessment (LCA), in which the resource efficiency and potential environmental challenges of the carbon/epoxy composites' recycling process are analyzed.

MATERIALS AND METHODS

Every stage of the life cycle of the composite part has to be modeled in the LCA, from its manufacture to its end-of-life treatment, following the usual steps defined by the ISO 14040 standards (ISO, 2006).

Materials, goal and scope

As previously mentioned, we focus on carbon/epoxy composites. The deposit of materials to be recycled consists possibly in end-of-life aeronautic parts, but most likely to date, in composite offcuts. The composite part chosen for the LCA is assumed to be processed in Europe, with a Japanese carbon reinforcement. Its mass is supposed to be 1 kg. Thus, we aim at studying the interest of recycling such materials, that is to say more generally, the viability of the recycling process.

Life cycle inventory

The following analysis is based on Duflou *et al.*'s data (Duflou *et al.*, 2009), who assessed the manufacturing of composite semi-structural panels in automotive industry. All these data have been recalculated relative to the mass of the chosen product (*i.e.* 1 kg).

In our case study, the use phase is not taken into account. Indeed, to the best of our knowledge, the only input data that can be taken into account concern transport operations. Like so, as rather classically, the present simulation led to show that this factor did not contribute much to the overall impacts (less than 5%).

Regarding the product's end-of-life, two scenarios have been modeled:
- the first one consists in burying the composite part, that is what is currently done;
- the second one consists in the recovery of the carbon reinforcement. The recycling process we focus on has been developed at laboratory scale (ICMCB, Bordeaux). It consists in
  (i) an aqueous solvolysis of the matrix by water under supercritical conditions (temperature around 400°C and pressure about 250 bar);
  (ii) and a hydrothermal oxidation of the effluent to clear matrix components from water, at the end of the solvolysis process.

This technology is the only one that allows the fiber to be recovered. Therefore, it is a real (but partial) recycling, and not a simple material valorization (Morin, Loppinet-Serani, Cansell, & Aymonier, 2012). Lastly, the devices use energy, water and oxygen, and only emit water and carbon dioxide.

Lastly, O. Mantaux and A. Gillet from the MPI Department of the Mechanics Institute of Bordeaux, have developed a prototype for packaging these second-generation fibers in an attractive form for users (*i.e.* designers). Data matching the remanufacturing stage have not been taken into account yet in this very first LCA. However, this energy input is assumed to be very weak, compared to those involved in the first-generation reinforcement process. As a consequence, the life cycle only loops after the manufacturing of the first-generation carbon reinforcement, with no specific additional remanufacturing.

Method

The LCA is led with the SimaPro software and the ReCiPe Midpoint (H) method (Goedkoop *et al.*, 2012). As previously mentioned, in the recycling stage, the skipped material is the reinforcement. In other words, the production of a new raw material with non-renewable resources (*i.e.* first-generation carbon reinforcement), is avoided.

RESULTS AND DISCUSSION

Environmental validation

The LCA of a 1 kg composite part that takes into account the recycling of the reinforcement, clearly shows the interest of this end-of-life option. Actually, it almost offsets the whole environmental impacts of the composite manufacturing (cf. Figure 2). For example, emission of greenhouse gases may be divided by 10, compared to the landfill option, despite electricity consumption in the recycling process. The environmental gain is on average about 70%, according to the ReCiPe Midpoint (H) method.

Economic validation

In 2010, a market study led by Alcimed has shown that there will always be relevant uses for

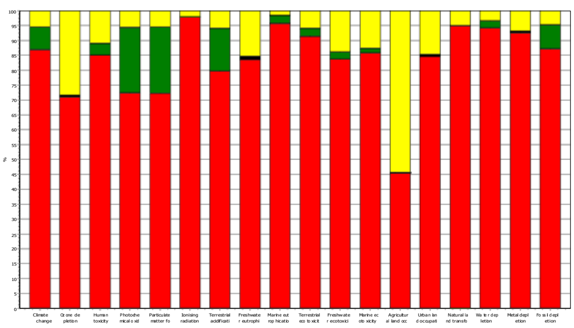


Figure 1. Environmental impacts due to the carbon reinforcement (*red*), the epoxy matrix (*green*) and the injection molding process (*yellow*), while processing a 1 kg carbon/epoxy composite part. The analysis is based on Duflou *et al.* (2009) data.

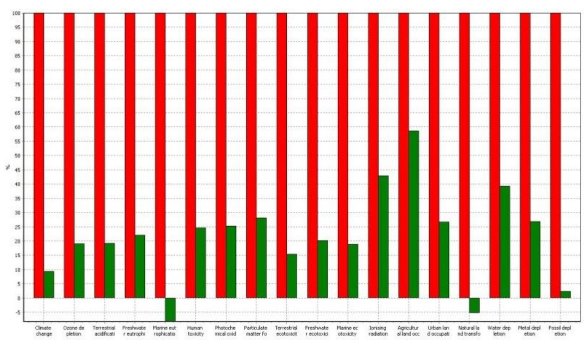


Figure 2. Life-cycle impact assessment of the landfill of a 1 kg carbon/epoxy composite part (*red*), compared with the reinforcement's recycling (*green*). The analysis is based on the ReCiPe Midpoint (H) method.

recycled reinforcements or for semi-products based on second-generation fiber, whatever their mechanical characteristics are, and as long as the price remains reasonable (Alcimed, 2010). The integration of recycled carbon fiber is only interesting if the mechanical performances/price ratio is higher than glass fiber's. Therefore, in light of excellent second-generation reinforcement's mechanical properties (Mantaux, Aymonier, & Antal, 2009), this ratio should be much higher than for new carbon fibers. Thus, the viability of the recycling will be provided if the second-generation semi-products price does not exceed 70-80% of the new ones.

CONCLUSIONS

In the present context, the use of carbon/epoxy composite is ever increasing. Now, it is well known that those composites can be recycled (Morin *et al.*, 2012), keeping good mechanical properties (Mantaux *et al.*, 2009). Taking right now into account that they will be soon subjected to regulation, it is essential to show that the composite recycling network will be viable, both economically and environmentally.

The recovery of the carbon reinforcement (which is the most environmentally impacting constituent in the composite manufacturing) by an aqueous solvolysis of the composite's matrix, leads to an average gain of about 70% for all eco-indicators compared to the landfill end-of-life option.

Lastly, the remanufacturing process developed by the Mechanics Institute of Bordeaux allows obtaining a semi-product easily usable. Consequently, from an economic point of view, the mechanical performances/price ratio of the second-generation carbon fiber should be higher than the virgin carbon fiber's, or the glass reinforcement's one.

ACKNOWLEDGEMENTS

The authors would like to express their thanks to the stakeholders of the RECCO Project.

REFERENCES

Alcimed. (2010). Evaluation du gisement de fibres de carbone à recycler et de leur valorisation pour le consortium RECCO.

Duflou, J. R., De Moor, J., Verpoest, I., & Dewulf, W. (2009). Environmental impact analysis of composite use in car manufacturing. CIRP Annals - Manufacturing Technology, 58(1), 9–12. doi:10.1016/j.cirp.2009.03.077

European Parliament, & Council of the European Union. Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles - Commission Statements (2000)

Goedkoop, M., Heijungs, R., Huijbregts, M., De Schryver, A., Struijs, J., & van Zelm, R. (2012, July). ReCiPe 2008. A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. First edition (revised). Report I: Characterisation

ISO. (2006). ISO 14040:2006 Environmental management. Life cycle assessment. Principles and framework (Afnor., p. 28).

Mantaux, O., Aymonier, C., & Antal, M. (2009). Recycling of Carbon Fibre Reinforced Composite Materials with Supercritical Water Dissolution. Presented at the JNC 16, Toulouse (France).

Morin, C., Loppinet-Serani, A., Cansell, F., & Aymonier, C. (2012). Near- and supercritical solvolysis of carbon fibre reinforced polymers (CFRPs) for recycling carbon fibers as a valuable resource: State of the art. Special Edition on the Occasion of Gerd Brunner's 70th Birthday, 66(0), 232–240. doi:10.1016/j.supflu.2012.02.001

WASTE PREVENTION IN THE PHOTOVOLTAIC SECTOR BY INDUSTRIAL SYMBIOSIS

Scherhaufer, S., Beigl, P., Obersteiner G.: *University of Natural Resources and Life Sciences Vienna, Institute of Waste Management, Muthgasse 107, A-1190 Wien; gudrun.obersteiner@boku.ac.at*

Keywords: LCA; Photovoltaic; Waste Prevention; Industrial symbiosis

ABSTRACT

The FP7-project ZeroWIN wants to find innovative approaches and effective strategies for the prevention of waste in industrial networks based on industrial symbiosis. The paper presents the results for a photovoltaic case study and describes the implemented measures as well as their environmental impacts. Measures related to industrial symbiosis cover e.g. the use of second hand or off-spec PV modules or the replacement of the steel structure by wooden components which also could be by-products from other industries. Beside other measures the focus was laid on the design for easier dismantling and therefore replacement of components which fail in the total life time of a PV system.

INTRODUCTION

One well-known and promising possibility to reduce environmental effects within industry is industrial symbiosis. Different approaches are more or less applied and especially the sharing of services or utility like the usage of the waste steam from a waste incinerator in neighboring plants where the heat is used as an input. Within the framework of the EU-FP7 program, the project ‘ZeroWIN’ wants to concentrate on the usage of by-products. New and innovative approaches and strategies for the prevention of waste in industries based on industrial symbiosis have been examined and developed.

Network activities between traditionally separated sectors shall be established to enable an exchange of by-products and materials in such way, that they are not disposed as waste, but continued to be used as quality assured material in other industrial branches. Case studies concerning construction, electronic devices and photovoltaic systems play an important role within the project, as the feasibility and sustainable performance can be proved or improved, respectively.

Within this paper the results for a photovoltaic case study will be presented. Study objects was an off-grid photovoltaic system

The photovoltaic sector shows an important development during the last years not least because of his growing very fast growing. The world-wide photovoltaic market doubled in 2010. This is due to a major increase in Europe with a total of over 29 GW cumulative installed capacity in 2010. It is leading with 70% of the total world-wide capacity (Jäger-Waldau et al., 2011).

Compared to other renewable energy technologies photovoltaic plants show though environmental burdens in the production phase. Pehnt (2006) compared PV with electricity systems of wind, hydropower, geothermal and bioenergy in an LCA. The results of the LCA showed that the cumulative energy demand (CED) and the global warming potential (GWP) revealed the most burdens in the photovoltaic system. It is mainly due to the very energy intensive process of the PV panel manufacturing as mentioned in various publications (Alsema and Wild-Scholten, 2004) and (Raugei et al., 2007). The metals which are used in the Balance of the System (BOS) are also influencing the LCA significantly. Jungbluth et al. (2008) showed for the BOS a share of 30 to 50% of the burdens depending on the environmental indicator.

Improvement options proposed in the literature therefore also focus mainly on design recommendations in the production technology of PV panels (c.f. Alsema and Wild-Scholten, 2004, Raugei and Frankl, 2009). Also for the BOS proposals for optimization can be found.

The goal of the study was to show improvement potentials of a pilot scenarios compared to the baseline through waste prevention strategies. Therefore the focus the study was not technical improvement but to find out possibilities for e.g. design improvements or optimization of the installation and decommissioning phase options. How the life time can be increased and which other options for material reduction or reuse strategies for a better environmental performance exist, were focuses of this study.

In literature the use of secondary materials is mentioned by Alsema and Wild-Scholten (2004). In the EOL phase the reuse of silicium or the reuse of aluminium from the BOS (Sander et al., 2007) were found. In the use phase life prolongations through increased life time of moudles and inverters was furthermore mentioned (Alsema and Wild-Scholten, 2004).

Additionally an outstanding invention to increase the improvement potential was the development of a power conditioning equipment with special conditions. The development of this prototype was carried out within the ZeroWIN project. The pilot scenarios have been implemented in practice in Barcelona (Spain) in the year 2013 within the same project.

MATERIALS AND METHOD

The environmental assessment was carried out in three steps. Firstly a so called baseline assessment was elaborated to analyse the hotspots of a PV system. Along with the identification of hotspots waste prevention strategies were developed in a consortium to improve the environmental performance. In a second step the improvement strategies were assessed to show the effects in fictial pilot scenarios (mid-term assessment). Finally pilot scenarios were set up and the implemented strategies were analysed in a final assessment. The steps were accompanied with unpublished reports (available only for the project's consortium) and several discussions in partner meetings.

For the assessment LCA methodology was used based on ISO 14040 (International Standard Organisation (ISO), 2006) and 14044 ((ISO), 2006). It is based on a consequential approach on a fictional baseline. The baseline is based on standard technology without improvements on waste prevention strategies which were developed in the course of the project ZeroWIN. The modelling was carried out with GaBi 5 (AG, 2012). In addition to databases of GaBi 5, databases from Ecoinvent (Frischknecht and Jungbluth, 2007) were consulted.

The environmental assessment is based on the CML 2001 methodology (Guinée et al., 2002) which operates with midpoint indicators. Environmental categories were chosen within a workpackage in the project according to the feasibility and the relevance in the involved sectors. The following categories were determined:

- Acidification Potential (AP) [kg SO_2-Equiv.]
- Global Warming Potential (GWP 100 years) [kg CO_2-Equiv.]
- Human Toxicity Potential (HTP) [kg DCB-Equiv.]
- Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Equiv.]
- Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv.]

The functional unit has been defined as the service of generating 53,130 kWh of an average PV plant with an installation of 2.76 kWp in a life time of 20 years in a fictional European location. The study covers a whole PV system from production, design, installation and decommissioning of the PV plant and its maintenance.

RESULTS AND DISCUSSION

Figure 1 shows as result for the Baseline Assessment the distribution of environmental indicators through components and life cycle stages of a grid-connected PV system. Benefits occur in the decommissioning phase as recycling is accounted in this life cycle stage. Recycling of certain materials like copper from cables or steel from the steel structure demand benefits to the environment. The operation of the PV module, meaning the production of energy in the system, is not considered as a benefit as the use phase is out of the system boundaries. The total energy output is considered in the functional unit of one kWh.

It can be noticed that, as already shown in literature, throughout all environmental categories the production process of PV modules has the most contributions, followed by the steel structure and the installation of the PV system where further materials are used.

Based on the outcome of the baseline assessment and the possible options for real implementation measures for the optimization of the PV system were defined. Nine measures were implemented in the final pilot PV system. They included an increase of the performance ratio as well as the life time and the change of batteries. The use of off-spec modules, reused structure, reused cabinet for battery system and cabling where measures following as far as possible the idea of industrial symbiosis and industrial networks. Also a smart grid battery system is introduced.

Figure 2 shows the relative results of selected environmental category. The benefits, meaning the decreased emissions from the baseline, are shown for each improvement measure.

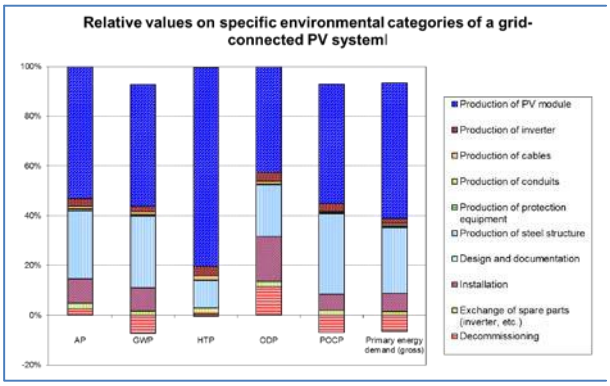


Figure 1. Relative values on selected environmental categories (Baseline)

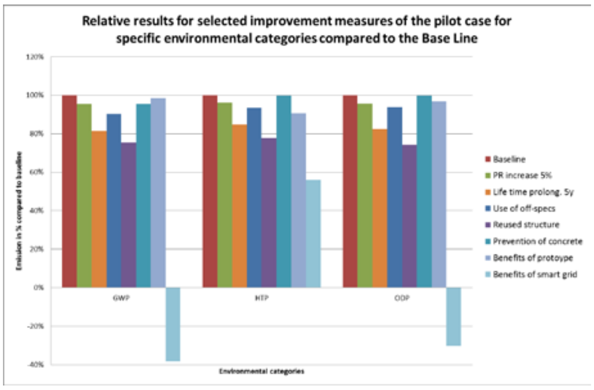


Figure 2. Relative results for improvement measures compared to baseline)

The Reuse of the structure turned out to have a large impact compared to the baseline system (Reduction potential of 24.6%). In the final pilot PV system the complete array structure for supporting the PV modules is reused from construction and demolition sector. Other measures like the life time prolongation and the use of off-specs also turned out to have a relevant reduction potential (18.5 and 9.7 %). The overall result for the reduction potential compared to the baseline under consideration of all implemented measures (except the benefits of saved energy in the smart grid) is about 36 % for the GWP. If the benefits of the smart grid system are considered, the total environmental performance switched to benefits to the environment.

CONCLUSIONS

The paper shows the environmental effects of tested measures concerning an off-grid photovoltaic system. In general it turned out that if a maximum of measures is implemented within the ZeroWIN project set targets for a decrease of 30% greenhouse gas emissions as well as a total of 70% of overall re-use and recycling of waste can be achieved.

REFERENCES

ALSEMA, E. A. & WILD-SCHOLTEN, M. D. 2004. Environmental life cycle assessment of advanced silicon solar cell technologies. 19th European Photovoltaic Solar Energy Conference, 7-11 June 2004. Paris

FRISCHKNECHT, R; JUNGBLUTH, N. (2007): Ecoinvent reports, Ecoinvent Centre, Swiss Centre for Life Cycle Inventories, Data v2.0 (2007)

JUNGBLUTH, N., TUCHSCHMID, M. & WILD-SCHOLTEN, M. D. 2008. Life Cycle Assessment of Photovoltaics: Update of ecoinvent data v2.0.

JÄGER-WALDAU, A., SZABÓ, M., SCARLAT, N. & MONFORTI-FERRARIO, F. 2011. Renewable electricity in Europe. Renewable and Sustainable Energy Reviews, 15, 3703-3716

PEHNT, M. 2006. Dynamic life cycle assessment (LCA) of renewable energy technologies. Renewable Energy, 31, 55-71

RAUGEI, M., BARGIGLI, S. & ULGIATI, S. 2007. Life cycle assessment and energy pay-back time of advanced photovoltaic modules: CdTe and CIS compared to poly-Si. Energy, 32, 1310-1318.

RAUGEI, M. & FRANKL, P. 2009. Life cycle impacts and costs of photovoltaic systems: Current state of the art and future outlooks. Energy, 34, 392-399

WROUGHT-TO-WROUGHT STRATEGIES: ECONOMIC AND ECOLOGICAL ASPECTS REGARDING ALUMINIUM RECYCLING

J. Hammervold, J. Pettersen, MiSA AS Norway*

**Innherredsvegen 7, 7014 Trondheim, Norway, email: johanne@misa.no*

Keywords: aluminium; recycling; refining; LCA; LCC.

ABSTRACT

This paper presents a life-cycle management tool comprising costs and environmental impacts for each life cycle phase of a vehicle control arm. A flexible model is developed for the EOL phase describing refining technologies to link any given aluminium scrap fraction of a certain chemical composition with desired wrought alloy purity. This provides a novel link between typical EOL aspects regarding treatment and recyclability, and the material science relevant for product design and production.

INTRODUCTION

High-end products made from wrought aluminium are currently produced from primary aluminium, to meet the high purity requirements. Possibilities of using 75 % recycled aluminium in a vehicle component are investigated within the SuPLight (SuPLight 2013) project, which is financed through the European Commission's 7th framework programme.

This paper describes a tool developed to assess the lifecycle environmental performance and the lifecycle costs of a control arm in a vehicle with a lifetime of 200 000 km, including a detailed model for the aluminium scrap treatment processing routes. Within the SuPLight project, 7 generic test components with variable alloy and trace element concentration levels have been tested in regard to formability, mechanical properties and corrosion resistance. These generic test components are the basis for the scrap treatment process route scenarios.

The aluminium market is undergoing a rapid change, and a novel dynamic material flow model for the global vehicle system was developed by Modaresi and Müller (2012). The study predicts an aluminium scrap surplus already in 2018 and reaches a level of 14 million metric tons in 2050. These dynamics will be used as a basis for future predictions of the aluminium market concerning prices and technology penetration. Modaresi and Müller recommend various policy options that can hinder or delay scrap surplus. Two of these are especially relevant for this study; technologies for sorting and refining. Sorting technologies must separate the scrap into castings, wrought aluminium, and different alloy families. Such technologies has been developed (e.g. lacer-induced breakdown spectroscopy and colour identification in conjunction with etching), but are currently not economically viable. Refining technologies for separating alloying elements and impurities (e.g. chlorination, fluxing and electrolysis) are currently very costly and have significant environmental drawbacks.

METHOD

The tool is developed through modeling within SimaPro (PRé Consultants 2012), applying the LCI database ecoinvent v2.2 (Ecoinvent Centre 2010) for the background data. The impact assessment method ILCD (European Commission 2012) combined with cumulative energy demand is used.

The functional unit of the case study presented here is *One vehicle control used in vehicle with a lifetime of 200 000 km*. The recycle content (cut-off) approach is applied, which means that the sorting, remelting and refining of the aluminium scrap is considered as production of raw material as input to the ingot production. In the following this is referred to *Production of recycled aluminium*. The detailed modeling of the production of recycled aluminium links the chemical composition requirements for the product, and hence allows for environmental and economic consequences of both changes in the purity requirements and future policies and market mechanisms.

THE LIFECYCLE TOOL

An overview of the tool, including the detailed model of EOL is shown in Figure 1.

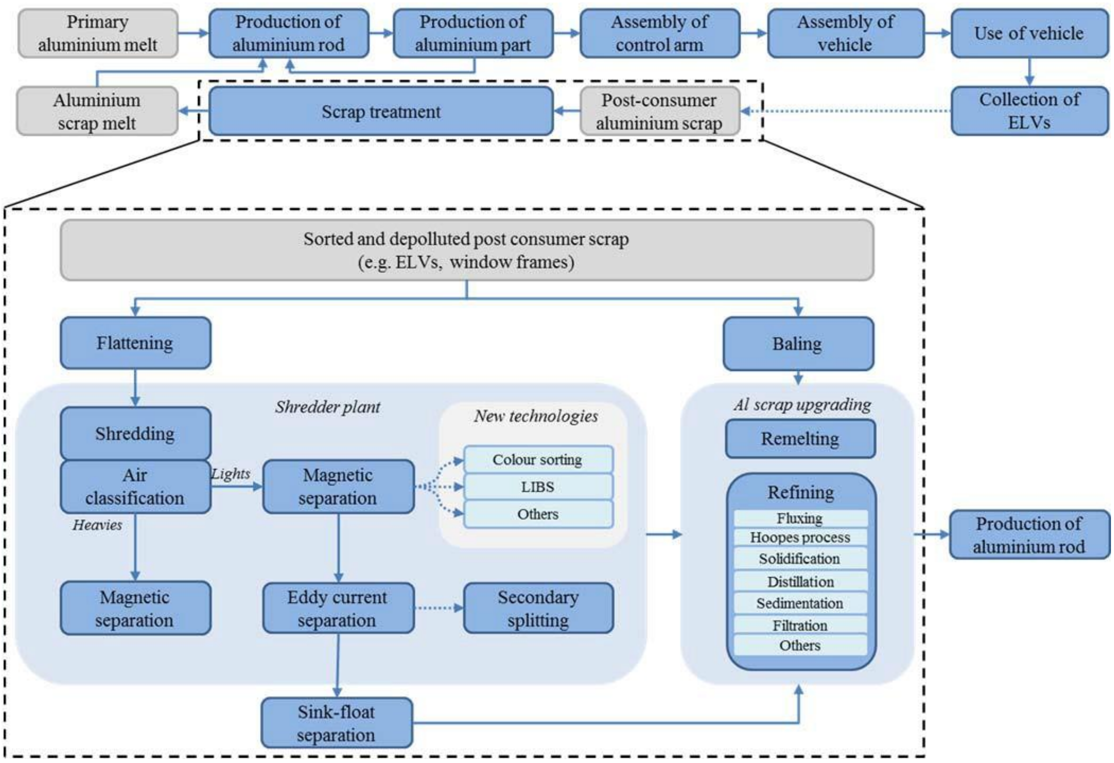


Figure 1: Overview picture of the LCA tool

Lifecycle costs are included in the LCA tool, divided into material costs, production costs and user costs. Material costs include the materials used in the production technology processes from scrap treatment to vehicle assembly. Production costs comprise operation of production facilities and equipment, and labor. User costs include operation and service of the vehicle.

The tool will be applied to compare scenarios with certain variables; chemical composition, scrap treatment technologies, scrap share in production of the component, production process routes and weight of the component. This allows for optimization of the lifecycle environmental impacts and costs, given a set of constraining conditions for the variables. The model will also be flexible regarding future forecasts of price variations for primary aluminium and aluminium scrap fractions undergoing various EOL treatment technologies. A scenario of an equivalent control arm produced from steel is also included as reference.

The purpose of the detailed EOL model is to investigate to what degree material quality, i.e. aluminum purity requirements affect the lifecycle environmental and economic performance of the vehicle control arm. The model is developed based on a vehicle control arm as a case, but can easily be adjusted to fit for other aluminium parts in any other means of transport.

PRIMARY RESULTS

Results for global warming from the current preliminary lifecycle tool, shows that a control arm produced from primary aluminium (base scenario) gives 12 % less lifecycle CO_2 emissions than a control arm produced from primary steel. For the base scenario 26 % of the emissions are related to production and 74 % to use. For steel, the respective shares are 7 % and 93 %, due to a less emission-intensive production and higher fuel consumption in the use phase. This is because a similar component made from steel will be heavier. These results are shown in Figure 2, including results for more categories.

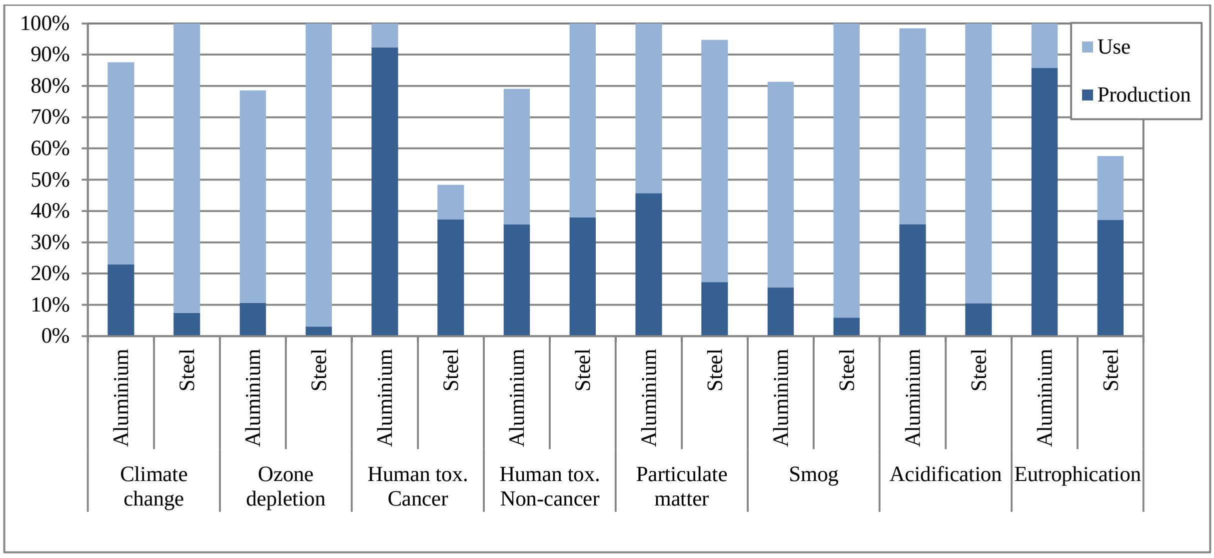


Figure 2: Relative results for aluminium and steel control arm

Three scenarios for the aluminium control arm are compared to the base scenario. The results are given in Figure 3. A share of 25 % and 75 % aluminium scrap gives reductions of 3 % and 9 % respectively in the CO_2 emissions compared to the base scenario. A combination of 75 % recycled aluminium and 1 % increased weight of the control arm gives 36 % higher emissions of CO_2 than the case is for the control arm produced from 100 % primary aluminium.

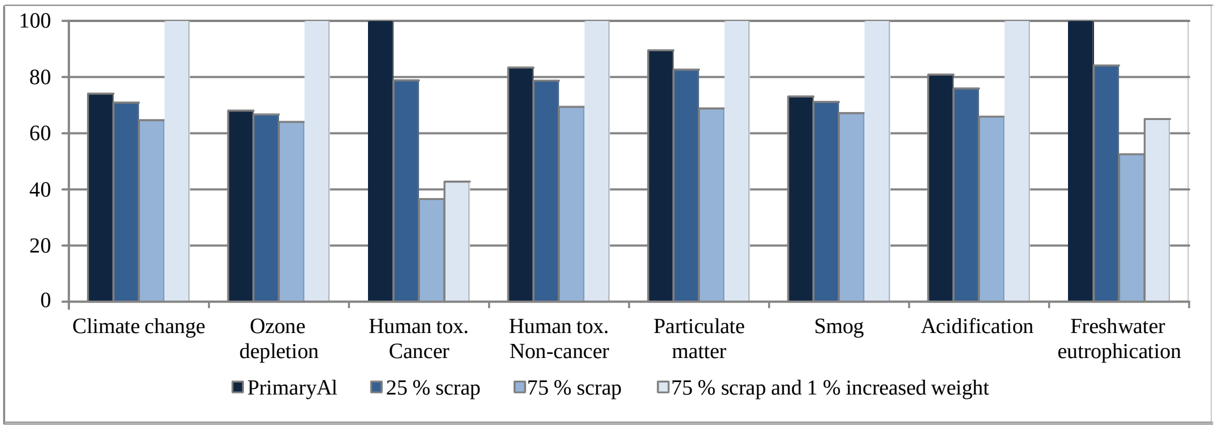


Figure 3: Relative results for various scrap share and weight for aluminium control arm

CONCLUSIONS AND FURTHER WORK

The preliminary results strongly indicate that the environmental impacts occurring in the use phase outweighs savings related to increased use of scrap in the production. The exceptions are in the impact categories human toxicity (cancer effects) and eutrophication.

Further development of the tool encompasses inclusion of more detailed data, testing and quality checking. The tool shall also be improved by including parameterisation of costs, related to primary aluminium and scrap treatment processes in particular. The lifecycle tool will further be integrated as a plugin to the simulation-based optimisation tool developed within the SuPLight project, including plugins dealing with *Tolerance analysis*, *Metallurgy*, *Mechanical* (including *Material simulation*), *Business models*, *Reverse logistics*, *Eco-design* and *Socio-ethical LCA.*

ACKNOWLEDGEMENTS

The authors would like to acknowledge the European Commission for their financial support through the SuPLight project (grant agreement n° 263302). We also wish to express our gratitude and appreciation to all the project partners for their contribution during the development of various ideas and concepts presented in this paper.

REFERENCES

Ecoinvent Centre (2010). Ecoinvent data v2.2, Swiss Centre for Life Cycle Inventories.

European Commission (2012), Joint Research Centre, Institute for Environment and Sustainability. Characterisation factors of the ILCD Recommended Life Cycle Impact Assessment methods. *Database and Supporting Information. First edition. February 2012. EUR 25167.* Luxembourg. Publications Office of the European Union; 2012

Gaustad, G., E. Olivetti, et al. (2012). "Improving aluminum recycling: A survey of sorting and impurity removal technologies." *Resources, Conservation and Recycling 58(0): 79-87.*

Modaresi, R. and D. B. Müller (2012). "The Role of Automobiles for the Future of Aluminum Recycling." *Environmental Science & Technology 46(16): 8587-8594.*

PRé Consultants (2012). SimaPro 7.3.3. Amersfoort, The Netherlands, PRé Consultants.

SuPLight, Deliverable D2.3: Silicon content limitation level on formability and product performance in cast and formed AlMgSi. SuPLight, EU FP7 Project, Nº263302 (2013).

FOOD WASTE IN A VALUE CHAIN PERSPECTIVE 2

Wednesday, Aug 28: 1:30 pm - 2:30 pm

Session chairs: Ole Jørgen Hanssen, Ostfold Research, Norway
Clementine O'Connor, BIO Intelligence Service, France

FOOD LOSSES IN THE LIFE CYCLE OF LASAGNE BOLOGNESE: READY-TO-SERVE VS. HOME-MADE

*Karin Flury[1] *, Niels Jungbluth[1], Graham Houlder[2]*

[1]ESU-services Ltd., Zurich; [2]EAFA – European Aluminium Foil Association e.V., Düsseldorf.

**Margrit Rainer-Str. 11c, CH-8050 Zurich, flury@esu-services.ch*

Keywords: food waste; LCA; Lasagne Bolognese; ready-made; home-made

ABSTRACT

A considerable amount of food waste is caused in households due to bad storage, poor planning and consumer's preference for fresh food. Food waste due to bad handling in industrial processes on the other hand is minimal. This leads to the question whether overall food losses of a ready-made meal are lower than for a meal freshly prepared at home. This question was investigated in an LCA study comparing ready-made and home-made lasagne Bolognese. The aim of the study was to examine what possible differences in the food losses imply for the environmental impacts of equivalent lasagnes. The data needed were derived from literature, own measurements and supplemented by data from the food industry. Contrary to the expectations, the amount of total food waste was estimated to be about the same for both products. The losses occurring in the production chain of the ready-made lasagne are driven by losses in the food industry and returned products reaching the expiry at the point of sale. In case of the home-made lasagne, the major losses are caused at the household. The environmental impacts of the two types of lasagne are comparable. In both cases, the major contribution to the impacts derives from the food ingredients.

INTRODUCTION

Ready-made meals are sold and consumed in most European markets. Consumers tend to buy them primarily for their convenience and with little thought as to how their environmental performance compares to home preparation using fresh ingredients. Differing factors could be the handling of food wastes at different stages in the life cycle or different energy consumption rates due to the preparation at scale and the efficient preservation of ready-meals under chilled conditions. To examine possible differences and the consequences for the environmental performance, an LCA case study has been conducted (Flury et al. 2013). The study investigates and compares the environmental impacts of the preparation of a ready-made lasagne Bolognese and a home-made lasagne Bolognese over the full life-cycle. The food losses and the energy consumption for the processing and preparation are examined in more detail.

METHODS

As a basis for the lasagne recipe, the composition of Trattoria Lasagne al Forno by a major UK retailer was used. The composition is assumed to be the same for both lasagnes in order to avoid any bias introduced by differences in the recipes. Investigated are a chilled ready-made and a freshly prepared home-made lasagne Bolognese. This study considers the cultivation, preparation, storage and distribution of the ingredients and the respective preparation of the lasagnes. It represents an average European production and supply chain. The home-made lasagne is prepared from ingredients bought in a supermarket. They are from conventional, seasonal production. The ready-made lasagne is packed in an aluminum tray. The functional unit is defined as **"the preparation of two portions (800 g) of lasagne Bolognese ready to consume in a household"**. The weight of all inventories refers to the weight before the heating in the oven. As both alternatives have the same portion size, left-overs on the plate are not considered.

The supply chains of both types of lasagne are modeled based on a previous study of Büsser & Jungbluth (2009). It is supplemented with industry data, information on food wastes (Gustavsson et al. 2011, Kranert et al. 2012, Lorrayne 2008) and own measurements. Background data are based on ecoinvent v2.2 (ecoinvent Centre 2010), updates thereof (LC-inventories 2013) and the ESU database for food production and consumption (Jungbluth et al. 2013). SimaPro 7.3.3 is used to calculate the life cycle inventory analysis, impact assessment, to run a Monte-Carlo simulation and to document the data (PRé Consultants 2012).

In the full study, the results are analysed for a representative range of impact categories. Presented in this short article is the Global Warming Potential (GWP) according to Solomon et al. (2007).

RESULTS

The overall mass of food losses in the ready-made production chain (24 %) is comparable to the ones in the supply chain of the home-made lasagne (26 %). The stages where the main food losses occur varies however (Figure 1). While the highest losses in the supply chain of the ready-made lasagne occur during the preparation in the food industry, most ingredients for the home-made lasagne are wasted at the household. In the food industry, food losses occur when the manufacturing is shifted to another type of product and the facilities need to be emptied and cleaned. Losses at the point of sale are a bit higher for the ready-made lasagne than for the ingredients of the home-made lasagne as it is always a whole lasagne that is disposed of in case of damage or expiry and not only single ingredients. In the absence of any studies proving otherwise, the central storage between agricultural stage and food industry or retail, respectively, is assumed to be the same for both chains, resulting in similar food losses. In general, food losses vary considerably for different types of ingredients.

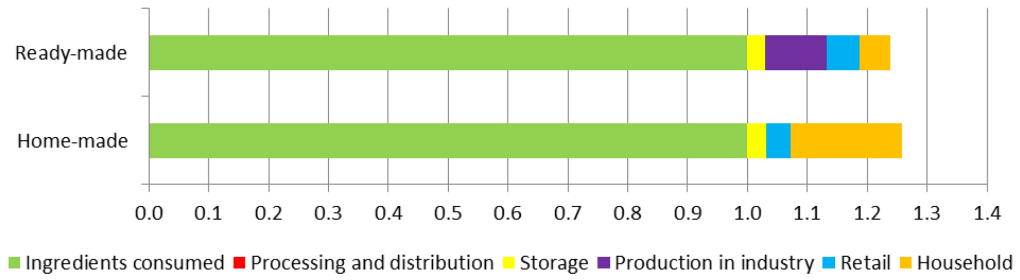


Figure 1. Comparison of cumulated relative food wastes in the different stages of the supply chains of ready-made and home-made lasagne Bolognese. The value 1 on the x-axis refers amount of ingredients in the lasagne provided at household.

The slightly higher food losses in the chain of the home-made lasagne consequently result in a higher contribution of the ingredients to the overall GWP of the lasagne (Figure 2). The packaging of the ingredients on the other hand causes less GHG emissions than the packaging of the ready-made lasagne. Only some ingredients for the home-made lasagne need to be cooled in contrast to the whole ready-made lasagne. The contribution of the distribution and selling stage is therefore lower. The industrial lasagne production and the heating of the ready-made lasagne at the household are reported separately while the preparation of the home-made lasagne includes the cooking of the sauces as well as the baking of the lasagne. The overall impacts of the production and preparation of the ready-made lasagne are slightly higher due to its considerably longer baking time. The overall greenhouse gas emissions of the ready-made lasagne and the home-made lasagne per kilogram of lasagne provided at household are comparable. They amount to 7.5 and 7.2 kg CO_2-eq, respectively.

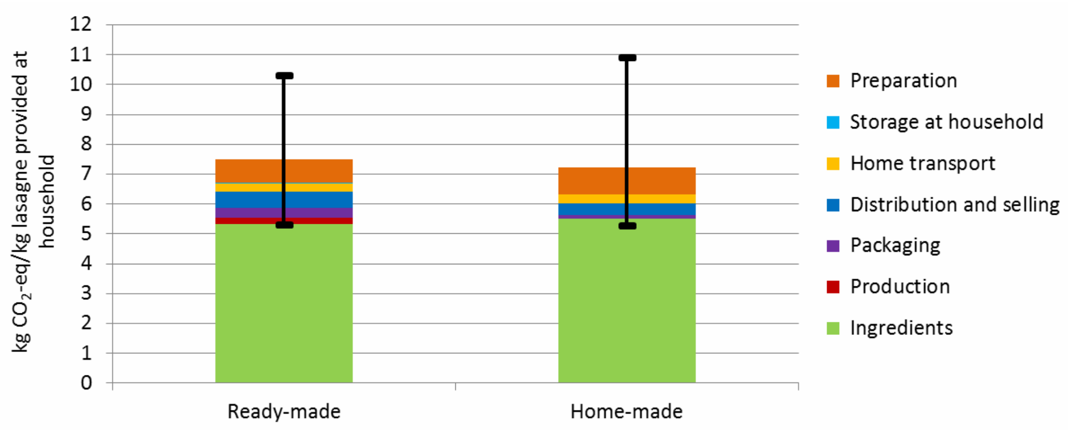


Figure 2. Comparison of the Global Warming Potential (GWP) of the ready-made and the home-made lasagne Bolognese, including the 95% confidence interval. The contribution of the different life-cycle stages is distinguished.

DISCUSSION

The easy preparation of the ready-made lasagne presumably reduces the food losses due to burning or bad seasoning. However, a considerable portion of the food losses at the household level are caused due to bad storage, bad planning and due to preferences. It cannot be assumed that ready-made lasagnes are exempt from this.

It has to be considered that so far neither much nor detailed data is available on food losses in different stages of the food supply chain. Thus, some assumption had to be taken and the resulting uncertainties mean that no clear ranking of one option over the other is possible.

CONCLUSIONS

In terms of the environmental performance, there is no significant difference between the ready-made lasagne and the home-made lasagne, despite the additional packaging and reheating of the ready-made lasagne. The food losses as well as the impacts on climate change are in the same range. Both, the food industry and the households could reduce their food losses by an increase in efficiency and better planning. A special focus on an improved management of food with a limited shelf-life could further reduce losses in the retail stage. More robust and detailed data is needed in order to better understand the food waste in the different stages. Independent of the lasagne type, a lower content of meat as well as an efficient cold chain could decrease the environmental impact considerably.

REFERENCES

Büsser S., Jungbluth N. (2009). LCA of Ready-to-Serve Bolognese Lasagne Packed in Aluminium Containers. ESU-services Ltd. commissioned by European Aluminium Foil Association e.V. (EAFA), Düsseldorf. Uster, CH.

ecoinvent Centre. (2010). ecoinvent data v2.2, ecoinvent reports No. 1-25. Swiss Centre for Life Cycle Inventories. Dübendorf, CH.

Flury K., Büsser S., Jungbluth N. (2013). Ready-to-serve vs. home-made lasagne: An LCA with a focus on food waste in different production chains. ESU-services Ltd. commissioned by European Aluminium Foil Association e.V. (EAFA). Düsseldorf. Zürich, CH.

Gustavsson J., Cederberg C., Sonesson U., van Otterdijk R., Meybeck A. (2011). Global food losses and food waste: Extent, causes and prevention. Swedish Institute for Food and Biotechnology (SIK) commissioned by Food and Agriculture Organization Of The United Nations. Gothenburg, SE.

Jungbluth N., Flury K., Doublet G., Leuenberger M., Steiner R., Büsser S., Stucki M., Schori S., Itten R. (2013). Life cycle inventory database on demand: EcoSpold LCI database of ESU-services. ESU-services Ltd. www.esu-services.ch/data/data-on-demand/.

Kranert M., Hafner G., Barabosz J., Scheider F., Lebersorger S., Scherhaufer S., Schuller H., Leverenz D. (2012). Emittlung der weggeworfenen Lebensmittelmengen und Vorschläge zur Verminderung der Wegwerfrate bei Lebensmitteln in Deutschland. Universität für Bodenkultur Wien, Institut für Abfallwirtschaft. Wien, AT.

LC inventories. (2013). Corrections, updates and extensions of ecoinvent data v2.2. ESU-services Ltd. www.lc-inventories.ch

Lorrayne V. (2008). The food we waste. ISBN:1-84405-383-0. Waste and Resource Action Programme (WRAP), Oxon, www.wrap.org.uk.

PRé Consultants. (2012). SimaPro 7.3.3. Amersfoort, NL.

Solomon S., Solomon S., Qin D., Manning M., Alley R. B., Berntsen T., Bindoff N. L., Chen Z., Chidthaisong A., Gregory J. M., Hegerl G. C., Heimann M., Hewitson B., Hoskins B. J., Joos F., Jouzel J., Kattsov V., Lohmann U., Matsuno T., Molina M., Nicholls N., Overpeck J., Raga G., Ramaswamy V., Ren J., Rusticucci M., Somerville R., Stocker T. F., Whetton P., Wood R. A. and Wratt D. (2007). Technical Summary. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, United Kingdom and New York, USA.

FOOD WASTE VOLUME AND COMPOSITION IN HELSINKI REGION HOUSEHOLDS

K. Silvennoinen O. Korhonen**

**Latokartanonkaari 9, 00790 Helsinki, Finland, kirsi.silvennoinen@mtt.fi*

** Latokartanonkaari 9, 00790 Helsinki, Finland, otso.korhonen@mtt.fi*

Keywords: food waste; households; type of housing; packages; Finland

ABSTRACT

The focus of this research is to produce detailed information on amounts and types of avoidable food waste in households using sampling analysis in landfill. We sorted and weighed food by its type e.g. vegetables, bread, fruits, potatoes, meat etc. Also we sorted food being in unopen packages, opened packages and without packages. Amounts of food waste varied by type of the housing. When extrapolated amounts for one year, largest food waste amounts was resulted houses with only one or 2-9 apartments (25-30 kg/pp), and the least houses with more than 20 apartments (15 kg/pp). The monetary value of food waste was also examined.

INTRODUCTION

The focus of this research is to produce detailed information on amounts and types of avoidable food waste in households using sampling analysis in landfill. We defined the avoidable food waste as all food or food material that could have been eaten if handled or stored differently. Helsinki metropolitan area waste management process two kind of containers that include food waste: mixed waste and bio waste. Here we studied only food waste from mixed waste and amounts of food waste from bio waste we got from study that have been made earlier 2010. Bringing together these two studies we will have the total amount of avoidable food waste amounts and types in Helsinki metropolitan area and possibility to find methods to prevention.

MATERIALS AND METHODS

We worked for one week period (10.9.-14.9.2012) in Ammässuo landfill in Espoo area. The study was divided for two different parts: one sorted all waste from loads of mixed waste collection vehicles and the other continued to investigate all the waste originally being food or food raw material. The methods of sorting was manual with sieves. The samples were from 13 different areas covering Helsinki metropolitan area and all different types of housing were studied separately (number of apartments in the house: 1, 2-9, 10-20 and more than 20 apartments). The sample covered 15106 inhabitants and 7177 households. We investigated all particles sizes including the small ones like fine material (>10 mm). For analysis we got all data from mass of the loads and number of inhabitants and households. Number of samples were 34 and one sample size was 100 kg of mixed waste from the one load. The total volume of waste from loads was 51735 kg in households and volume of all samples 3400 kg.

We sorted and weighed food by its type e.g. vegetables, bread, fruits, potatoes, meat etc. Also we sorted food being in unopened packages, opened packages and without packages. The economic examination was done based on price data from Statistics Finland (OFS 2013). Used prices for different products were from September 2011.

RESULTS

Amounts of avoidable food waste varied by type of the housing 15-22 kg/pp/year. When extrapolated amounts for one year, largest amount was produced from houses with one apartment (detached house), row and low-rise houses with 2-9 apartments and 10-20 apartments, and the least with apartment houses with more than 20 apartment. When accounting also for avoidable food waste from bio waste containers (HSY 2011), the total amount of avoidable food waste was 22-27 kg/pp/year.

Other studies in Finland has resulted also significant differences in waste volumes between housing types: row houses and detached houses produced more mixed waste and bio waste than apartment buildings per capita (HSY 2011, HSY 2013). The row and detached houses produce more bio waste from garden but also more food waste (HSY 2011).

Avoidable food waste consists of different types of food. These food types groups were cheese and other milk products, bread, meat and fish and eggs, pasta and rice, apples, fruits and berries, potatoes, vegetables and other products. The main group to avoidable food waste was bread, vegetables and group other products (Figure 1). The group other products consist of other cereal products than bread, readymade and pickup food, gravies and spices, desserts, pastry, candy, snacks and drinks. The groups that generated the least food waste were pasta and rice, and fruit and berries. Meat, fish and egg group had relatively high percentage 14% of all avoidable food waste.

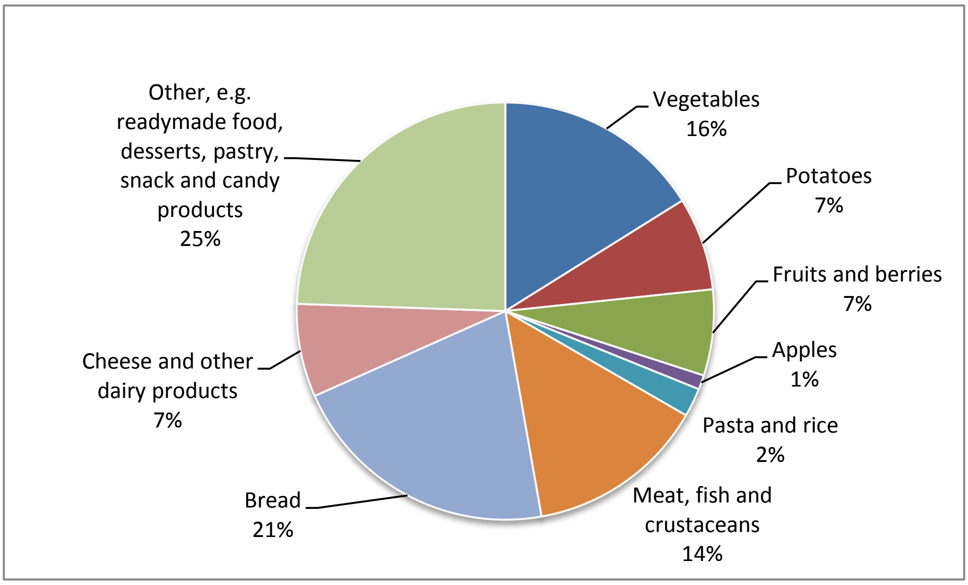


Figure 1. Contribution of avoidable food waste

We examined avoidable food waste by if item having a package. The food item could have been loose (without any package), unopened package or open package. The loose food waste was the largest proportion of these three accounting half of the total food waste. Second largest was food waste from opened packages and food waste from unopened packages was the smallest contributor. In the unopened packages category the amount of waste was nearly double compared between detached house and the over 20 apartment houses, also the amount of loose waste was over double between the two. The opened packages did not differ that much between any of the housing sizes but the over 20 apartments it was a little bit lower than the other.

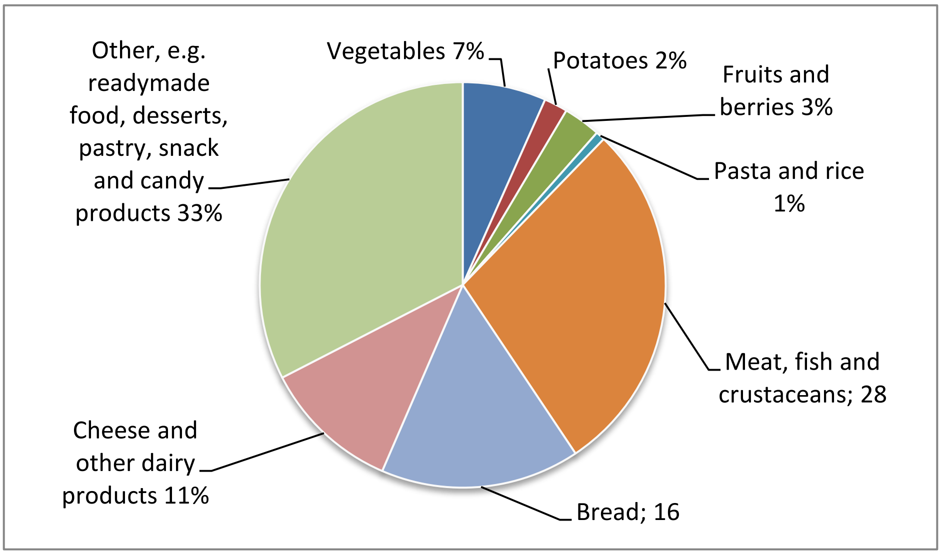


Figure 2. Contribution of monetary value food waste

When looking at the value of food waste the group others still remain the largest but meat, fish and crustacean grows to cover almost a third of the total value of the waste compared to the 14% when only looking at the volume (Figure 2). The impact of cheese and other dairy products increases from 7 to 11 %. For vegetables, potatoes and fruits and berries their effect decrease quite drastically from covering a third of the volume to being only 12% of the total value of the food waste.

The value of the avoidable food waste was about 125 € per citizen in a year, and one kilogram of waste cost about 5,6 €.

CONCLUSIONS

The study resulted that approximately 24 millions of kilograms of food is wasted in Helsinki metropolitan area every year by households, average 23 kilograms per citizen.

The most wasted food groups were group other (including e.g. ready made food, pastry, snack and candy), bread, vegetables and meat products. The group other have large economical value having products like snack and other very processed food, also meat products value high comparing vegetables, potatoes or fruits.

Comparing our results to other studies amounts of food waste seems to rather low, and some of the international studies (Gustavsson 2011) have shown rather large food waste volumes. Anyway this study and the earlier diary study (Silvennoinen et al 2012) showed similar volumes of avoidable food waste amounts in Finnish households.

REFERENCES

Gustavsson, J., Cederberg, C., Sonesson, U., Otterdijk, R. and Meybeck, A. (2011). Global Food Losses and Food Waste. FAO Rome, Italy. 2011

HSY Helsinki Region Environmental Services Authority 2011. Pääkaupunkiseudun biojätteen koostumus (Properties of Biowaste in Helsinki Metropolitan Area). HSY Publications 6/2011.

HSY Helsinki Region Environmental Services Authority 2013. Pääkaupunkiseudun kotitalouksien sekajätteen määrä ja laatu vuonna 2012 (Quality and quantity of household mixed solid waste in the Helsinki metropolitan area 2012). HSY Publications 2/2013.

Official Statistics of Finland (OSF): Consumer price index [e-publication]. ISSN=1799-0254. Helsinki: Statistics Finland [referred: 24.5.2013]. Access method: http://www.stat.fi/til/khi/tau_en.html.

Silvennoinen, K., Koivupuro, H., Katajajuuri, J-M., Jalkanen, L., Reinikainen, A. 2012. Ruokahävikki suomalaisessa ruokaketjussa (Food waste volume and composition in Finnish food chain). MTT Raportti 41.