IMPLEMENTATION OF SUSTAINABLE PRODUCTION PRINCIPLES WITHIN SWEDISH MANUFACTURERS

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Abstract: Both, a common understanding on sustainable production principles and the identification of sustainable production practices within manufacturers constitute key starting points when the aim is to study how Swedish manufacturers are working towards sustainable production. Using an interview guide based on the sustainable production principles by the Lowell Center of Sustainable Production (LCSP), this paper provides an overview of how Swedish manufacturers comply with these set of principles.

Keywords: Sustainability principles, Swedish manufacturers, current practices.

1. INTRODUCTION

For the better part of the 20th century most manufacturers were focused exclusively on improving their operations to achieve more efficient results. Nowadays, the bar has been set higher and manufacturers are conscious about their operations' impacts on the triple bottom line or 3BL (people, planet and profit) as well as for accounting for the resource consumption and footprint generated by their manufacturing processes (Kleindorfer et al., 2005). High demands in terms of sustainability are assumed to be tackled not only by large organizations, but also by small and medium sized enterprises (SMEs). However, studies show that there is need for further studies related to sustainable practices in SMEs (e.g. Biondi and Iraldo, 2002; Vives, 2005; Lawrence et al., 2006).

According to the dictionary definition, the term "principles" alludes to fixed or predetermined policies, mode of action or conducts. Shrivastava and Berger (2010) defined principles as "sets of values, standards, guidelines or rules of behavior that describe the responsibilities or proper practices for organizations". For them, sustainability principles deal with "moving organizations toward sustainability by changing their vision/mission, their use of natural and human resources, their production and energy practices, and their products and waste management". This paper is interested in knowing how Swedish manufacturers are currently implementing sustainable production principles within their production processes. It is expected from the organizations to move closer to a sustainable production state, when these principles are implemented.

The paper used the sustainable production principles presented by the Lowell Center for Sustainable Production (LCSP) and referred in Veleva and Ellenbecker (2001). Considering the need of more studies on sustainability and SMEs, this paper involved both large organizations and SMEs within the sample. The Paper's final outcome is an overview of how Swedish manufacturers current production practices comply with the LCSP principles, which will also help manufacturers to picture examples of sustainable production practices, whilst allowing researchers to identify areas of potential research.

2. METHODOLOGY

Based on the nine sustainable production principles of LCSP, a structured interview guide was designed. This type of interview is very appropriate as it allows the comparison of results across respondents (Williamson, 2002). The study used a non-probabilistic sample of eleven manufacturing companies belonging to six different production sectors (plastics, metal mechanic/machining, foundry, engine manufacturers, furniture and hydraulic systems). Despeisse et al (2012) found that metal and automotive industries count with the higher number of published case studies about sustainable manufacturing practices. While casting, wood furniture and machining sectors are among those with less number of documented practices in literature. Agreeing with this Hassini et al (2012). found that automotive and electrical, electronic industries are among the sectors where the majority of reviewed literature on sustainable supply chain is focused. Considering this, our study did not include companies belonging to automotive and electronic sectors as a lot of research has been carried already. Instead, it elaborated on other sectors that have not get as strong attention in terms of sustainability studies as the former ones.

The sample technique was convenient as the purpose of this study was not of doing generalization of the results to the sectors involved in the study (Tanner, 2002), but to present an overview of implementation of LCSP principles in Swedish organizations. As this paper involved both large companies and SMEs, the selection of SMEs follows the respective definition of the European Commission (2003). Although the study tried to include one large company and one SME for each sector, due to time constraints we are still in the look for two more companies to complete the sample (for the furniture and hydraulic systems sectors). The criteria for selecting the companies were to be currently implementing what they considered sustainable production initiatives and to be located in Sweden. The respondents of the interview were Environmental/Quality managers or Managing Directors. The main data collection method was the structured interview, however data was also collected from the companies' website and during shop floor tours that some companies provided. Finally it is worth to mentioned that the size of the sample was not representative enough to make generalizations about punctual sector trends.

3. CONCEPTUAL FRAMEWORK

3.1. Sustainable production

The LCSP (1998) has defined sustainable production as "the creation of goods and services using processes and systems that are non-polluting; conserving of energy and natural resources; economically viable; safe and healthful for employees, communities and consumers; and socially and creatively rewarding for all working people". For Manzan and Miyake (2013) the scope considered by the LCSP in defining sustainable production is broader in comparison with other alternative approaches to instill environmental concerns (i.e. the adoption of end of-pipe technologies for pollution, cleaner production and green production or green manufacturing). This as it involves the production of goods, the impacts on the environment, working environment and social responsibility (triple bottom line). In contrast to the above mentioned models of production with environmental concerns, Manzan and Miyake (2013) mentioned that sustainable production is the only one that advocates for rewarding the workers creativity, having interaction with the community from an economic, social and cultural perspective; and holding cooperative relations with the supply chain.

3.2. Sustainability principles

After doing a brief literature review in Scopus using the keywords *Sustainable production principles*, it was found that one of the first attempts made to publish sustainable principles was made by Daly (1990). He determined the sustainability principles from a high and general perspective. Some of the principles proposed by him were: harvest rates should equal regeneration rates and waste emission rates should equal the natural assimilative capacities of the ecosystems; the sustainable use of non-renewables requires that the investment in the exploitation of these resources must be paired with a compensating investment in a renewable substitute; technologies that increase resource productivity must be prioritized over technologies focused on increasing resource throughput. Likewise, Gladwin *et al*., (1995) presented a set of eight operational principles and associated techniques of sustainable behavior. Veleva and Ellenbecker (2001) posed six main aspects to tackle when the aim is to have sustainable operations: Energy and material usage, natural environment, social justice and community development, economic performance, workers, and products. These aspects are shape based on the nine principles of sustainable production proposed by LCSP. For Al-Yousfi´s (2004) principles made emphasis in minimizing the use of nonrenewable resources; reducing/eliminating hazardous/toxic and harmful emissions/wastes; and achieving goals cost-effectively.

Tsoulfas and Pappis (2005) defined a set of principles for achieving eco-efficiency and building up environmentally friendly organizational systems. Sustainability principles for Lindsey (2010) were based in

three pillars: improved sustainability is achieved by reducing wastefulness; improved sustainability is achieved by improving quality; and sustainability is best achieved through the implementation of better systems. Likewise, Despeisse *et al*., (2012) based on former studies, restructured some principles as follows: use less material and energy; shift to biologically production models; move to solution-based business models; and reinvest in natural capital by replacing toxic and non-renewable materials.

Besides from these academic initiatives for defining principles, there have been governmental initiatives for the development of their own set of sustainable principles (e.g. The Government of Western Australia, 2004). In this regard, Shrivastava and Berger (2010) considered the main agreements on environment and development problems from 1968 to 2009 and created a list of principles representing "articulated desired changes" for governments, corporations, financial institutions, and individuals. And more recently, Ziout *et al*., (2013) highlighted these different levels of applicability but in regard to the implementation of sustainability indicators. This as indicators can measure sustainable development and sustainable production at a global, national, sector-wide, or company levels, or even at many levels, as the ones provided by Veleva and Ellenbecker (2001).
During our literature review we found that a large proportion of papers fall out of the scope of this study. One of the most common reasons for exclusion was not to deal with sustainability principles but instead they used the term *sustainability* to make reference to the capacity of performing or preserving in the long term a specific manufacturing practice. Some studies addressed sustainability from a public policy perspective, from an specific industry group, others showed governmental initiatives for developing sets of sustainable principles, and only a handful of papers considered sustainable principles from a production perspective (shop floor). From this small group of papers, only the principles by LCSP were dealing with the three elements of sustainability (environment, people and profit), while the rest of papers were centered exclusively on the environmental dimension of sustainability. Finally, as there is a need for inquiring about sustainable production principles from a triple bottom line perspective, the LCSP principles constituted the best guiding principles for this study.

2.3. Small and medium sized enterprises, SMEs
The European Commission (2003), characterizes SMEs based on the number of employees (<250) and turnover (≤ €50m) or balance sheet total (≤ €43m). Nonetheless, the former criteria is not the only differentiating characteristic of SMEs. Ghobadian and Gallear (1996) found a set of characteristics that distinguish SMEs from large organizations (e.g. Low degree of standardization and formalization, low degree of specialization, short decision making chain, very few interest groups, No specified training budget…). In the same way, Hudson and Smith (2007), stated that SMEs are flexible and dynamic organizations compared to larger organizations. As their organizational structure is flat with few management layers, SMEs can easily adapt to changing market needs and enjoy high possibilities for innovation. However, their flexible characteristics may be constrained by a lack of resources, both human and financial. Regarding management practices, SMEs have personalized management style, so that the firm's control relies usually in one single person, most of the times an owner-manager (Ghobadian and Gallear, 1996 and Hudson and Smith, 2007).

4. RESULTS

This chapter presents each of the nine LCSP principles together with the practices carried out by the companies which comply with these principles. The chapter ends up with a table summarizing the compliance of the principles within each of the companies in the sample.

Principle 1: *Products and packaging are designed to be safe and ecologically sound trough their life cycles; services are designed to be safe and ecologically sound.*
Regarding safe and environmentally sound products, in general, all the respondents linked having ecologically sound products with the recyclability of the materials used in their products and processes; as well as the safety of those materials used (according to REACH and ROHS regulation compliance). An example of this, is that the SME foundry associated this principle with producing wear and heat resistant products or long lasting products. For most of large companies the primarily aspect that their products need to comply is with regulations, which at the end is translated into safer products for users. Large companies mentioned to comply this principle by having a life cycle approach in their products. Reflection this, for the large metal mechanic company having a life cycle approach early in the design phase allows to have an operational phase with as lower environmental impacts, to use adequate materials and to produce highly fuel efficient products. SMEs in the metal mechanic and plastic sectors claimed that this principle is not applicable for them as the product design is not their responsibility but their customers.
Regarding safe and ecologically sound **packaging**, the majority of companies considering the environmental and quality aspects in the packaging decision. All respondents recycle or reuse the packaging of their incoming materials and final products (wooden pallets and cardboard are the most common materials used). SMEs

highlighted their role as followers of the demands imposed by customers (larger organizations), not only regarding the design of the products and materials, but also in packaging and delivery terms (frequency).

Principle 2: *Wastes and incompatible by products are continuously reduced, eliminated or recycled.*
In relation to waste reduction, most of companies mentioned the use of key performance indicators (KPIs) for quantifying their wastes, and stressed the importance of reducing the number of non-conforming products in order to reduce the waste. The majority of companies are aiming at reducing the amount of solid waste sent to landfills, having as most common practice recycling and reuse of waste (e.g. companies in the plastic and foundry sectors regrind and re-melt waste and nonconforming and used as raw material)
EPA's solid waste management hierarchy (EPA, 2007) states that the reduction of waste before recycling (source reduction) is preferred above recycling, energy recovery and disposal. Among the source reduction initiatives mentioned found, the large foundry optimizes the core's casting design resulting in the raw material reduction (sand used for cores). Similarly, the large plastic company aims to reduce the percentage of waste that goes for final treatment by modifying their operations (buying machines that use less oil emulsions). Other initiatives done by the companies such as material reuse and product redesign are classified under source reduction or waste prevention initiatives. Waste recycling initiatives is another way of complying with this principle (e.g. SME foundry recycles the sand waste from the casting cores within their own operations). Based on the EPA's waste management hierarchy, it can be said that the large foundry is more proactive in the waste management of its waste stream (sand waste) compared to its respective SME. This as the large foundry reduces the sand waste before recycling it and also recycles and reuses the remaining sand waste through collaborations with other companies reusing the waste sand as a raw material in the production of other products (e.g. concrete and asphalts).

Continuous reduction of waste is part of all companies objective. Waste is seen as burden with high economic impact "We do not want waste because it is not good for the environment and costly to get rid of". The most common waste is the solid waste of direct materials, however some few companies mentioned the waste of indirect materials. Companies highlighted the role of the environmental management standard ISO 14001 (e.g. For the metal mechanic and plastic SMEs having ISO 14001certification help them to continuously reduce waste, to set environmental goals, to keep track of safe materials, chemical and oils…).

Principle 3: *Energy and materials are conserved, and the forms of energy and materials are most appropriate for the desired ends.*
Regarding the **reduction of energy consumption,** all companies train their employees with the aim to increasing awareness on saving energy. Some common practices regarding this principle were: installation of LED lamps, motion sensor lamps, heat exchangers, mapping energy consumption for identification of energy savings, replacing ventilation systems, energy consumption systems that function only during working hours... Most of companies perform auditing activities on energy reduction aiming at identifying areas where idling losses are occurring. It was found that 6 out of 11companies (mostly large ones) installed heat exchangers. In relation to energy losses, both large metal mechanic and SME engine companies highlighted the importance of establishing energy targets for reducing energy/idling losses. According to the large foundry, appointing an energy manager represents a strong commitment towards the reduction of energy usage. All large organizations had energy manager positions apart from environmental one. In contrast, often SMEs had environmental and quality responsibilities shared within one single job denomination.

On the **use energy from renewable sources**, companies are using district heating from waste incineration. However only 7 out of 11 companies said they were using electricity from renewable sources (e.g. wind energy, hydropower). Likewise, the large foundry changed their fossil fuel based heating centrals to bio oil based. In relation to **energy efficiency** the most common practices were having LED bulbs, implementing heat recovery, replacing machines old machines for more energy efficient ones. A couple of companies posed energy efficiency as a critical factor influencing the capital investment decisions.

Regarding **conservation and reduction of materials consumption**, the majority associate it as an R&D responsibility. Some related this principle with scrap minimization, optimization of material usage, and practices such as recycle and reuse. Only the large engine manufacturer connected this issue with both reduction of the material components in the product (direct material) and reduction of materials needed for running the production (indirect material). About the **use of fresh water**, most of the companies measure its consumption and have closed water loops (e.g. water close loops in paint shops). Collection and use of storm water for cooling processes, water recycled in close loops, closed loops systems for oil emulsions in machines are some initiatives for reducing the fresh water consumption.

Principle 4: *Chemical substances, physical agents, technologies, and work practices that represent hazard to human health or to the environment are continuously reduced or eliminated*.
All Companies track their used chemicals in products and processes conforming the European Union legislation REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) which requires declaring and finding alternative chemicals with lower impacts on human health and environment. Examples of this practices are the substitution of chromium 6 for chromium 3 and the substitution of the mineral oil as cutting fluids for vegetable oil based one (biodegradable cutting fluid) in machining processes.

Regarding **elimination of chemicals**, continuous initiatives of chemicals substitutions are being done by companies, which is coherent with the reduction of emissions that most of them aim for. This as if they stop using the substance, it will entail a reduction in emission of hazardous substances. Although chemical substitutions are mainly driven by regulations, most of large companies are the ones acting proactively in this regard, anticipating the future or potential legal restriction of substances in REACH (grey list) and working on finding substitutes for them. On substitution or elimination of chemicals, companies understand that the reduction or substitution is closely related with the reduction of emissions originated these chemical reactions.

As we know **hazardous emissions to air** are mostly produced by burning fossil fuels, from greenhouse gas (GHG) emissions from some chemicals used in industrial processes or from equipment leaks. It was seen that large companies have long experience from working on reducing volatile organic compounds (VOCs) and carbon dioxide ($CO_{2)}$. Only 5 out of 11companies (3 large and 2 SME) made reference to reducing VOCs. A common way for reducing VOCs emissions was the substitution of solvent-based paint for water-soluble paints in paint-shops. Regarding other hazardous emissions, foundries have cleaning systems for the harmful pollutants produced (e.g. sulphur oxides- SO_x, Nitrogen oxides- NO_x and heavy metal fumes). On lead emissions, the SME foundry mentioned to prevent the smelting of lead by buying raw material from certified suppliers, however filters in chimneys are corrective measures for it.

In relation to **emissions to water**, only 6 out of 11 companies (5 large and 1 SME) brought up hazardous emissions to water when asked about hazardous emissions to the environment. Most of SMEs understood that emissions to environment were only about air emissions, overlooking water emissions. Some practices on reduction of hazardous emissions to water are: filters in waste water streams for collecting heavy metals, closed processed waste water systems, prevention of oil leakages from equipment, biological based wastewater treatment for removing paint from close water systems in paint shops, workers awareness on leaks prevention…

Principle 5: *Workplaces are designed to minimize or eliminate physical, chemical, biological and ergonomic hazards.*
All companies keep statistics which allow them to assess the extent to which their employees are protected from work-related hazards/risks and to corroborate if the preventive actions against these hazards/risks are being effective. Safety inspection tours were also common in the companies to identify which situations or activities might be lead to exposure to risks or hazards. All companies received work environment inspections from the Work Environment Authority in Sweden, who verifies if they have a systematic management of its work environment. Many respondents stressed the importance of carrying out a workstation risk assessment in terms of the health and safety. An example of these practices for minimizing or eliminate hazards in work place was the installation of robots in the surface treatment process by the SME foundry.

On ergonomic risk, the metal mechanic SME_2 replaced manual welding for robotic welding motivated by safety and ergonomics issues. Regarding vibrations, both metal mechanic SMEs lowered the vibration level during the machining process by changing the shape of its raw material steel bars for certain products. On ergonomics, common practices were: reducing the heights of pallets for handling and storing material, installing mechanical lifting aid, employees rotation among different machines. Common practices are the continuous training of employees about hazardous risks as well as the importance of reporting accidents/incidents to supervisors.

Principle 6: *Management is committed to an open, participatory process of continuous evaluation and improvement, focused on the long-term economic performance of the firm*.
All companies count with a strategic plan describing how the company intends to grow. Those plans are generally constituted by goals that are broken all the way down to the department/business function/section level. They all stated that continuous monitoring of these goals and actions plans is very important for their consecution. Exemplifying this, the large engine manufacturer mentioned “In the plant we have daily follow up, we have the cost versus the target. On a weekly basis I get the report, on the monthly basis, we get the consolidated report".

Likewise, the large foundry mentioned to have high expectations in terms of economic goals, acknowledging the importance of investments prioritization to obtain the best payback considering the environment, safety, and quality aspects when it comes to take investments decisions. All respondents made emphasis on continuously sharing of information with operators and employees at all levels of the company concerning the company's strategic plan, goals, targets and performance from previous months. However, none of the respondents brought up issues such as reduction of compliance costs related to environment, health, safety (EHS) within this principle.

Principle 7: *Work is organized to conserve and enhance the efficiency and creativity of the employees*
Regarding the **efficiency of employees,** the large engine manufacturer and the SME_2 metal mechanic respondents have linked employee efficiency with standardization. This might be as standardization formalizes processes and creates accountability. The rest of respondents focused their answers of this principle on employee creativity. Many companies encourage, quantify and set goals for the number of suggestions for improvements or creative initiatives given by employees. Collection methods for employee's ideas vary from installing a suggestion box, to bringing up the new ideas during morning meetings, quality & environment meetings or improvement meetings. Companies expressed to be very aware of the value of operator's knowledge and experience when it comes to suggestion for improvement. In relation to rewards for creativity, they vary from monetary incentives to the best idea of the month, publicizing their successes in the whole company, to including their names on the company´s hall of fame. Team work is perceived by many companies as a way of using people skills and to promote creativity. Team work is commonly used among companies for solving problems.

Principle 8: The security and the wellbeing of all employees is a priority, as it is the continuous development of their talents and capacities.
On **employee security**, companies have their own health and safety management system (which includes activities for assessing risks, and monitoring them). All respondents stressed the importance of preventive actions for controlling, mitigating or eliminating risks. Exemplifying this, the plastic SME mentioned has as decision priorities safety in first followed by quality and financial aspects. In relation to the **continuous development of talents and capacities,** all respondents highlighted the importance of training plans. Large organizations offer carrier development programs, they have their own career site, and strongly promote the rotation of employees between different areas. Likewise, SMEs promote job rotation by counting with multifunctional workers. Regarding **education and training**, all companies think that education plans should aim to further develop employees skills at work. Companies associate the word *training* with high competent workers, high quality products, competitiveness and "getting better" as a company. Another key point on employee development is the employees performance evaluation or performance appraisal. All companies carry out annual individual performance evaluations where aspects such as job satisfaction, educational needs and additional competencies are discussed. For many respondents the quality standard ISO 9001 serves as a tool for working systematically training and competence. ISO 9001 and its management review meetings support this principle as the meeting agenda tackles aspects such as safety, work environment, training planning, environmental issues among others.

Principle 9: *The communities around workplaces are respected and enhanced economically, socially, culturally and physically; equity and fairness are promoted.*
The most common ways in which both large companies and SMEs enhanced the communities was by providing job opportunities for the locals and by having collaborations with educational institutions. All respondents are involved in collaborations with local high schools and/or universities. The companies in the sample are interested and willing to participate in research projects with the academy, as well as, to involve students by offering them summer jobs and thesis work possibilities at their site. Most of the companies also invite students from local high schools to factory tours, so students get to know the production processes and maybe become employees in the future. On communication with the local community, periodical meetings are hold together with the municipality authorities (Kommun) where modifications in their plants, significant changes in production process and its potential environmental impacts are tackled. Large companies take this a step further as they spend and participate in volunteering work with locals and having a stronger local presence in different associations by sponsoring for example local sport teams.

Table 1. translates the detailed findings of practices implemented by the companies into the status of compliance or not compliance of the LSCP principles. Some of principles entail underlying sustainability issues (i.e. Principle 3 is subdivided in reduction of energy consumption, use of energy from renewable sources, reduction in the use of materials…). These individual issues, as well as, the compliance of the whole principle is represented by tick or check marks in the table. Likewise, the not compliance to some of the underlying

sustainability aspects is also represented by the absence of check mark. It is worth to mention that the table does not include the level of implementation of the principles which may vary among the different companies.

Table 1. Companies compliance with the LCSP principles.

Principles	Sectors												
	Foundry		Plastics		Engine manufacture		Metal mechanic			Furniture		Hydraulic systems	
	Large	SME	Large	SME	Large	SME	Large	SME1	SME2	Large	SME	Large	SME
Principle 1													
Disassembled, reused or recycled products	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
Recyclable or biodegradale packaging	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
Principle 2													
Reduction, recycle or elimination of of waste	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
Principle 3													
Reduction of energy consumption	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
Use energy from renewable sources	✓	x	✓	x	x	✓	✓	✓	x	-	✓	✓	-
Reduction in the use of materials	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
Reduction of fresh water consumption	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	N.A	✓	-
Principle 4													
Reduction of emissions to air and GHG emissions	✓	✓	✓	x	✓	✓	✓	✓	x	-	x	✓	-
Reduction of emissions to water	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
Principle 5													
Workplaces are designed to minimize physical hazards	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
Workplaces are designed to minimize chemical hazards	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
Workplaces are designed to minimize biological hazards	✓	N.A	N.A	N.A	N.A	N.A	N.A	N.A	N.A	-	N.A	N.A	-
Workplaces are designed to minimize ergonomic hazards	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
Principle 6													
Management focused in the long term economic performance of the firm	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
Principle 7													
Work is organized to enhance efficiency of employees	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
Work is organized to enhance creativity of employees	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
Principle 8													
Security and well-being of all employees is a priority	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
Continuous development of employees talents is a priorit	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-
Principle 9													
Communities near workplaces are respected and enhance	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	-

N.A: Not applicable

5. DISCUSSION AND CONCLUSION

Among the study sample it was clear that companies are currently developing more initiatives aimed at complying with principles #2 (waste management) and #3 (energy management). This might be due to the cost reduction benefit implicit in waste elimination and energy savings. Waste is seen by the companies as burden with high economic impact. However, in terms of energy it was seen that sourcing of energy from renewable resources was not fully pursued by all the respondents, which could be explain by the additional cost that clean energy may represent for the companies. Regarding waste management, it was found that the majority of companies (both large and SMEs) are aiming at reducing the amount of solid waste sent to landfills, having as most common practice the recycling and reuse of waste. Here, the aspect that makes the difference between proactive and reactive companies in terms of waste management is the reduction of waste generated before recycling or reusing. Concerning to the industrial sectors, the foundry sector, metal mechanic/machining and engine manufacturer sector might be more prone to undertake proactive sustainable initiatives than its peers. This, as they are suppliers within the automotive and transport industries which have is known for having high impacts on the natural and human environment along all stages of the product's life cycle (Koplin et al., 2007).

It was found that quality and environmental management systems (ISO 9001 and ISO 14001) constitute important enablers for companies in their way to comply some sustainable production principles. This is very valuable specially for SMEs. However, obtaining accreditation is costly and time consuming which represents a challenge for SMEs considering their lack of resources. Nevertheless, in such a case SMEs decide to undertake this road, their job will not stop when a certificate is obtained, but it will be instead a continuous work for staying environmentally responsible and sustainable. Another facilitator for complying the principles is the Swedish regulation, which acts as a strong driver and enabler for implementing sustainable production. The former as companies stated that by complying with regulations (in energy and materials used, waste

management, emissions, chemicals used, health and safety and workers) actions are translated into sustainable products and processes for the consumer.

There are differences regarding the degree of implementation of principles between SME and large companies. It was seen that SMEs barely complied with principles, while Large companies not only complied but went a step ahead, being more proactive on the implementation of sustainability principles. This may be explained due to SMEs limited budget, or lack of resources both human and financial. However, this aspect could be lessen to a certain degree when SMEs belong to sustainable supply chains. With regard to limitations of our study, the job position of the respondents might have influenced the answers for those questions about social and economic sustainability. This as the respondents (mainly environmental managers) expressed that those topics were not their main area of expertise. Finally, it is worth to mention that the first principle does not fit the scope of our paper as it alludes to design and packaging. This as, our paper intended to study how sustainable production principles are implemented within the production processes which sets the boundaries on the production function (excluding design and logistics).

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