LCM 2013

The 6th International Conference on Life Cycle Management in Gothenburg 2013

HOW CAN TEMPORAL CONSIDERATIONS OPEN NEW OPPORTUNITIES FOR LCA INDUSTRY APPLICATIONS?

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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.

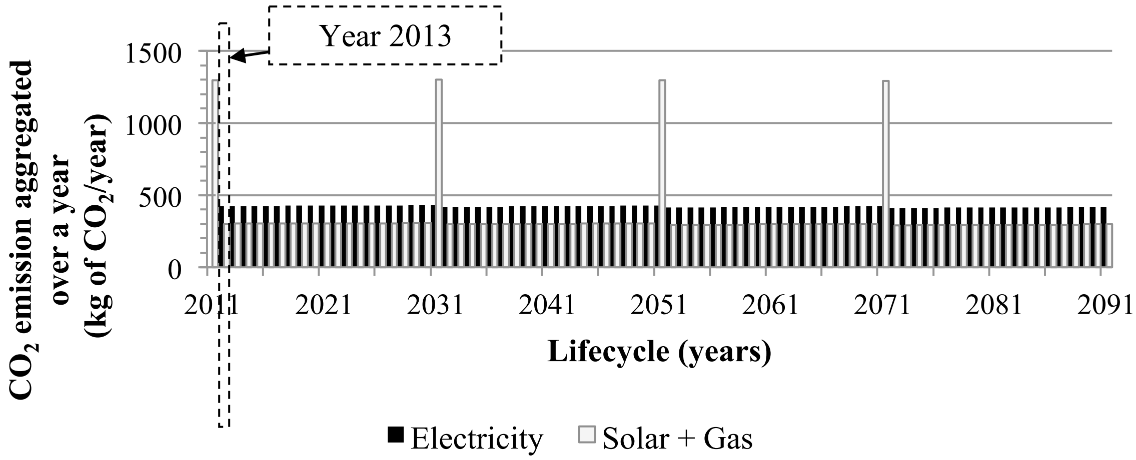

Figure 1: Annual temporal distribution of CO_2 emissions for the case study scenarios

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.

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