

SPREAD IN LCA RESULTS FROM USING MULTIPLE DATA SETS AND MODELLING CHOICES: A CASE STUDY OF DISPOSABLE PS CUPS

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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 diverse 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 lead 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.

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