Appropriateness of Life Cycle Assessments for Product/Packaging Combinations

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Abstract
A life cycle assessment (LCA) is a tool for determining impacts on the environment. LCA’s cover the entire life cycle of an artefact, from raw materials to recycling or disposal. For assessments of packaging, the life cycles of both the packaging and the packaged content need to be taken into account, because these life cycles are strongly interrelated. A case study demonstrates these interrelations and their consequences. It also shows the ambiguity and non-decisiveness due to the subjectivity in the selection of data sources, impact assessment methods, system boundaries and software tools. To attain purposeful LCA’s, the assessments must adhere to the expertise related to product/packaging combinations. This publication addresses the data sources, impact assessment methods, system boundaries and tools involved in LCA’s for product/packaging combinations; it elaborates on how the outcomes of assessments vary with these aspects. The case study is used to illustrate the results.

Keywords
Life Cycle Assessment, Packaging Design, Product/Packaging Combinations

1 INTRODUCTION
In the business strategies of an increasing number of companies, the notion sustainability is considered to be of paramount importance. In many cases, this is infused by realistic concerns on the rationalisation of a company's products and activities; however, sometimes it scarcely surpasses a manifestation inspired by the marketing department. In the latter case, it is an ad-hoc reflection on the environmental concerns of consumers and (semi-)governmental organisations. If the attitude is well-intended and rational, companies will acknowledge the intrinsic value of earnestly incorporating sustainability in their development cycles. For fast moving consumer goods (FMCG), it is essential to address the development cycles of both the product and the packaging that makes the product a saleable entity. Moreover, it is an intermediary between products and consumers/users. From the perspective of sustainability, consumers and politics/politicians often point to packaging as a significant concern because of the perceived amount of waste. In contrast, however, packaging can also be deployed as a means to realise a more sustainable product. For example, without adequate packaging a product may depreciate or go to waste quickly during the distribution or use phase. Relatively small investments in packaging (material) or energy may prevent consequential losses of the contents being packaged. In other words, the visibility of the disposed packaging materials often conceals the losses due to discarded contents.

1.2 Sustainability & LCAs
It is well-nigh impossible to give an unequivocal definition of the notion sustainability; it therefore tends to become a term with a rather subjective denotation. As such, it is increasingly addressed embedded in development cycles, and –at the same time- it loses much of its expressiveness. This paradox stems from the fact that sustainability has been shaped into a multi-faceted and all-encompassing representative of ‘everything environmental’. As a direct consequence, different methods have been developed for determining the level of sustainability for developing more sustainable products or services. Examples are Walmart's scorecard, the ten golden Eco-design rules [2], the ecological footprint, life cycle costing, life cycle assessment, product material flow analysis, product energy analysis [3], Unit process life cycle inventory [4], etcetera.

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In this publication, life cycle assessment (LCA) is selected for the determination of the environmental impact of the (development) life cycles for product/packaging combinations. LCAs inherently allow for the most quantitative assessment (with adequate objectivity and transparency) of the wide variety of aspects that need to be addressed. It goes without saying that the credibility of the outcome depends on the sincerity that is exercised while employing LCA tools. The available variety of different impact assessments methods, tools, data sources and system boundaries can merely lead to meaningful results if the deployment is adequately underpinned. The publication focuses on the aspects that make an LCA relevant; a case study on the packaging of cheese illustrates the reasoning.

### 2 SYSTEM BOUNDARIES

For the life cycle assessment of product/packaging combinations, both cycles need to be addressed. When the package is filled with the product, the life cycles overlap (see figure 1). In the packaging life cycle, raw materials are extracted and processed into usable materials (for example granulate or cellulose), after which the packaging is produced. For products, these phases are roughly the same, although in many cases, the engendering of products requires more steps. After combining the product and the package, the resulting sales entity is transferred to the market. For FMCGs, the product reaches the consumers via retail channels. After use, i.e. when the content is finished, the package is disposed. Often, consumers throw away part of the product or content with the package. The package can be recycled, reused or incinerated or turned into landfill. In the case of reuse, recycling or incinerating, aspects (shape, material, energy) of the package can be applied in other life cycles. Obviously, the possibilities for FMCG's or disposed content to re-enter other life cycles are more complex.

When performing life cycle assessments and determining the impacts of different processes, it is essential to adequately determine which processes to take into account. For a quick screening, processes that (substantiated) are considered to have a relatively low environmental impact can be disregarded.

### 3 CALCULATION METHODS

Many methods for calculating the environmental impact of products/packaging result in a single indicator. An illustrative example is the carbon footprint, which aims at determining “the total set of greenhouse gas (GHG) emissions caused by an organization, event, product or person”. On the one hand, the calculation of the actual values is almost impossible, leading to the introduction of various kinds of estimators. On the other hand, calculating the carbon footprint does not always give realistic results for the environmental impact of the processes as it addresses only one relevant measure of environmental impact. This is exemplified by corn as a source for bio-plastic: it is preferable over oil-based packaging as carbon footprint is involved. At the same time, however, the soil that is needed for producing the bio-plastic packaging causes direct competition with food-production while threatening bio-diversity.

Consequently, there is an obvious need for assessment methods of environmental impact that do justice to all interrelated influences. However, there are different ways to establish sets of influences to take into account; each set consists of a number of so-called indicators.

Every process in a life cycle causes interventions, each contributing to one or more environmental effects. Every effect has a reference; for example, the reference for the greenhouse effect is often CO₂-e. The determination of the interventions that contribute to a specific environmental effect is called classification. Determining how much each of the classified substance contributes to a specific effect is called characterization. This value is different for each impact assessment method, effect, substance and class. Therefore, disentangling the steps in an impact assessment method is not straightforward [5]. Yet, there is even more to evaluating the results of an assessment method: normalisation offers the reference situation of the pressure on each environmental impact category. Normalisation allows for translation of abstract impact scores for every impact category into relative contributions of the product to a reference situation, all having the same unit. An example of a reference in the context of the Eco-Indicator ‘95 is ‘The yearly emissions of the average European’.

It is not pertinent to sum up the acquired values, because the importance of the different effects is not equal. To differentiate the effects, weighing factors have to be added. Determining weighing factors is a subjective process, which is a reason for ISO-standards to dissuade from using them. Weighing
factors, for example, address the issue whether the greenhouse effect is as important as the depletion of the ozone layer. After weighing, the outcomes can be aggregated and the environmental impact of different product or processes can be compared. When weighing factors are used, good documentation about establishing their values is important. Not all the impact assessment methods use the normalization phase and the weighing of the different effects. Employing such methods does not yield one overall environmental impact score, but a set of scores for the individual effects.

In LCAs, usually systems that are inherently and essentially different have to be compared. For this purpose, the notion functional unit is defined as a measure of the function of the studied system; it provides a reference to which all inputs and outputs can be related.

### 3.1 Types of impact methods

There are two types of impact assessment methods: problem oriented methods (mid-points) and damage oriented methods (end-points). The first classifies flows into environmental themes or effects like greenhouse effect, ozone depletion, acidification, etcetera. Examples of problem oriented methods are CML2000 and Eco-Indicator ’95. The damage oriented methods also starts with classifying the flows to different effects, but models each effect to human health, damage to ecosystems and depletion of resources. Examples of damage oriented methods are Eco-Indicator ’99 and ReCiPe.

For calculating the environmental impact for product/packaging combinations, ReCiPe is a useful method, as it has the most current and topical approach. Moreover, ReCiPe allows for a transparent and consistent way of translating the mid points into end points. The method is based on CML and Eco-Indicator ’99 and is developed by RIVM, CML, PRé Consultants, Radboud Universiteit Nijmegen and CE Delft [6]. The effects are developed conform the European environmental directives.

### 4 TOOLS

For methods that rely on merely one indicator, execution is straightforward and elementary. For example, determining carbon footprint can be done by hand by adding up the greenhouse gas emissions (in CO₂ equivalents) of the different processes. When multiple effects are taken into account, the required calculation is much more complex. A variety of commercial tools is available for calculating the impact on the environment, while referring to the different effects. In the context of this publication, a sub-set of the available tools is assessed: SimaPro and SimaBiz, PackageSmart, ECO-it, GaBi and its report function, Umberto, Instant LCA and PIQET. This set of tools is considered to be representative of the available spectrum; moreover, practical experience already established their applicability for the field of product/packaging combinations.

In this specific field of application, the following criteria for the tool are stated:

- It has to be possible to set up two life cycles. This means that the tool has to be suitable for packaging as well as for the product or content.
- It has to be possible to use the ReCiPe method, because this method is appropriate for determining the impact on the environment for a product as well as for a package.
- It has to be possible to use data from existing databases for doing quick life cycle assessments.
- It has to be possible to take all the processes of the life cycle into account. From extraction of raw materials, to use phase and finally the disposal phase.
- It must be possible to assess the reliability of the tool. This requires transparency of the structure (classification factors, normalization factors and weighing factors) behind the calculation (and changed).
- It has to be possible to compare the environmental impact of different product/packaging combinations.
- It has to be possible to add data for doing an intensive and detailed life cycle assessment.

### 5 DATA SOURCES

The choice of data sources to be used in life cycle assessments depends on the goals of that same assessment. When performing a quick screening to find the processes with the highest impact, secondary data from existing databases is sufficient. For such cases, different databases are available. The choice of database and the selection of information is for example dependent on the geographical location where a process occurs.

However, when doing a more intensive and detailed life cycle assessment, primary data is needed. After the quick screening, when zooming in on the processes with the highest environmental impact, more intensive life cycle assessment is appropriate to optimize (details of) those processes. The data that is required is specific for the product and company – by definition. Therefore, average values stemming from databases that describe e.g. the European context is insufficient. As a result, extensive data collection in the inventory stage is needed. This is both time and cost intensive, also because the validity of the collected data has to be assessed.
6 CASE STUDY (PART I) – LCA METHOD

The case study focuses on a packaging that contains 175 grams of sliced cheese. Both the package and content are produced in The Netherlands by FrieslandCampina, with Greece as the target market. The final product is transported to Italy by truck, shipped to Greece and transported by truck to the distribution centres. An estimated ten per cent of the cheese will be disposed by the consumer; Europeans tend to neglect the ‘best before’ date, so the cheese may become mouldy or dried and considered not fit to eat. The sketchy representation of the package is shown in figure 2.

6.1 Goal and scope definition

The goal of the life cycle assessment is to determine the processes that have the highest environmental impact. Consequently, this allows for identification of the processes that need to be changed to develop a more sustainable packaging for the cheese.

Another goal of the life cycle assessment is to understand the importance of taking the content into account when calculating the environmental impact for a package (see section 7).

6.2 System boundaries

It is common practice to indicate the (type of) processes that are considered to be out of scope for a LCA. For the cheese packaging, with the aim to quickly gain insight in the processes with the highest environmental impact, the disregarded impacts are:

- Life cycles of the equipment; one machine produces many products. The environmental impact of the life cycle of is divided over all the products that are produced by that machine. Therefore, machine life cycles are disregarded.
- Human energy inputs in processes; for a quick scan, it is unfeasible to determine the human energy in a life cycle.
- Transport of packaging between its production plant and the packaging line. Given the amount of packages to be transported by one truck, the environmental impact of one packaging is negligible.
- Transport between the cheese factory and the packaging line. This impact is negligible compared to the transport to Greece.
- Transport between the supermarket and the consumer in Greece is out of scope because this distance is small compared to the distance between The Netherlands and Greece. Moreover, as the consumer buys more than cheese, the impact of the consumer transport has to be divided over the different goods.

6.3 Functional unit

The functional unit for this analysis is determined as “fulfilling the packaging functions (to preserve and protect the product, distribute and inform the consumer) for 175 gram of sliced cheese”.

6.4 Inventory analysis

For the life cycle assessment of the cheese packaging, the Eco-Invent database is used, because this database contains data about the input and output substances for the extraction and processing of materials, production methods, types of transport, energy and disposal types. Moreover, it provides adequate documentation. Eco-Invent requires the specification of the amount and type of materials, production methods, energy, transport and disposal.

| Suitable for product and packaging: ability to set-up two life cycles |
| SimaPro/SimaBiz, GaBi/GaBi report, Umberto, InstantLCA(experts) |
| Determine the impact on the environment for a product as well as for a packaging: ability to use ReCiPe method |
| SimaPro/SimaBiz, GaBi/GaBi report, Umberto, Instant LCA |
| Enable quick life cycle assessment: ability to use data from the Eco-Invent database |
| SimaPro/SimaBiz, GaBi/GaBi report, ECO-it, PackageSmart, Umberto, Instant LCA, PIQET |
| Pay attention all processes of the life cycle, from extraction of raw materials, via use phase to disposal: ability to address entire life cycle |
| SimaPro/SimaBiz GaBi/GaBi report, Umberto, ECO-it, InstantLCA(experts) |
| Determine if the tool is reliable: ability to have insight in (and to change) the calculation methods (classification factors, normalization factors and weighing factors) |
| SimaPro, GaBi, Umberto, InstantLCA |
| Determine the relevance of the calculations: ability to compare the environmental impact of different product/packaging combinations |
| SimaPro/SimaBiz, GaBi/GaBi report, Umberto, Instant LCA(experts) |

Table 1 - Software tools for Life Cycle assessments and the criteria.
6.5 Evaluation

Most of the software tools in table 1 will – in one way or the other – be able to give results for the selected cheese packaging. However, the ease with which this is possible, and the underpinning and quality of the results varies considerably.

Tools that meet the most important criteria are SimaPro, GaBi, Umberto and Instant LCA (for experts). GaBi and SimaPro are very flexible tools; both allow to see the underlying structure behind and to change variables. The tools interact with the Eco-Invent database and it is possible to use the ReCiPe method. Also, they allow for the addition of data. This makes it possible to calculate the environmental impact of different products, even if the data is not available in the database.

The GaBi report function and SimaBiz have the same functionalities. LCA experts can make the model in SimaPro or GaBi and create a report. Non-LCA experts can use these reports to change important/selected values and determine their influence. The interaction between the tool for LCA experts and the tool for non-experts may be very useful in industrial practice.

7 CASE STUDY (PART II) – LCA RESULT

The second part of the case study focuses on the relative impact of the packaging versus the impact of the content. In others words, the prevailing opinion in ‘the public debate’ that packaging has a major environmental impact is assessed. It goes without saying that if the impact of packaging can be reduced without increasing the impact of the product/packaging combination as a whole, there is no reason to refrain from doing that. However, at the same time, it is important to realise that impact of the packaging may be insignificant when compared to the impact of the content, or that a slight increase in the impact of the packaging can reduce the impact of the product/packaging combination as a whole (see also section 1).

Given the result of part I of the case study, SimaPro is used for calculating the environmental impact of the cheese package. This tool has enough flexibility to take into account the life cycle of both the package and the content. The use of the tool is deterministic, as it is possible to access the underlying structure of the calculation. Besides, it is possible to use data from the Eco-Invent database and to use the ReCiPe method. The weighing factors are set to one. This means that all effects on the environment are assumed to be equally important in this life cycle assessment.

Data for the cheese is obtained from the DK food database (www.lcafood.dk). As it focuses on food impacts, and does contain data on cheese, the data gives a good indication of the environmental impact of cheese compared to the environmental impact of the package. At least for the screening phase, this data is useful. If a more detailed overview of the environmental impact of the different processes in the life cycle of cheese is needed, primary data about the different processes needs to be collected, because data that is specific enough can not be found in existing databases. Figure 3 gives the outcome of the LCA analysis with SimaPro. Even if only supported with secondary data, it is directly clear that the impact of the content (the cheese) is four times higher than the impact of the package.

When looking at the cheese production process, extraction of the milk has the biggest environmental impact. In other words, the emission of methane by cows (a natural process) contributes most to the environmental impact when looking at the life cycle of the entire product-packaging system. Another process that significantly contributes to the environment is the transport of the cheese to Greece. Per sales entity, the weight of cheese is more than 3 times higher than the weight of the package. This means that, as transport is concerned, cheese contributes over three times more to environmental impact than the package.

![Figure 3 - Impact of the different processes in the life cycles of cheese and the package.](image)

Setting aside the influence of the content, the extraction and processing of PET for the tray and the extraction and processing of PP for the lid yields the highest impact on the environment. The environmental impact of the injection moulding process for the lid is 200% of the environmental impact of the thermoforming process for the tray. In the package, the lid has the highest environmental impact. Nevertheless, in the overall picture, this influence is hardly more than 4%; the consequences of cheese leftovers that are thrown away are nearly twice that value.
From this analysis, it can be concluded that there is a clear need to include sensitivity analyses in LCAs for product/packaging combinations. Such analyses are instrumental in answering the question which local optimisation does indeed contribute to global optimisation. This has direct consequences for the way in which environmental impact is dealt with in packaging development. Contrary to customs, LCAs can clearly not merely focus on the packaging; it is essential to address the entire chain, from both the packaging and the content perspective. Only then, straight and fair assessments of development decisions can be made.

8 CONCLUDING REMARKS

It is a complex challenge to making LCAs for product/packaging combinations that yield authentic, unequivocal and well-reasoned results in a structured and transparent manner. This is substantiated by the fact that the objectivity of the analysis is endangered by the accumulation of selections and assumptions as concerns e.g. system boundaries, calculation methods, tools and data sources. Moreover, the mutual dependencies that exist between the various aspects may dwindle the transparency and unambiguity of the analyses. Setting aside the quality of the calculations themselves, some stakeholders may benefit from including some subjectivity in the analyses, thus rendering the outcomes incommensurable.

Especially when integrating life cycles of products and packages in one LCA, there is a clear risk of inappropriate assumptions. Here, the suitability of available tools becomes a serious issue. However, the case study shows that, with careful reasoning, a practicable approach is possible. The case study also indicates that a separate treatise of the product and the package is futile, as it will lead to sub-optimisation at the very best. Consequently, there is a significant challenge to facilitate developers of FMCGs and the developers of the accompanying packages in such a way that they can reach better decisions in an integral manner. Therefore, future research will not only focus on better understanding and employing methods and tools for performing LCAs for product/packaging combinations. Research will additionally focus on facilitating product/packaging developers to more adequately integrate life cycles aspects in their work, thus yielding more adequate solutions for product/packaging combinations.

9 REFERENCES


10 BIOGRAPHY

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