NEW DEVELOPMENTS IN THE METHODOLOGY FOR LCA

BY BO P. WEIDEMA, 2.-0 LCA CONSULTANTS, WWW.LCA-NET.COM

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Abstract

Many methodological choices in a life cycle assessment (LCA) depend on the goal of the study, i.e. its application area. A better definition of the application areas and especially a clear distinction between retrospective and prospective applications allows a more unambiguous description of the methodology to apply for different applications.

Keywords

Application areas / Prospective, comparative life cycle assessments / Product substitution / Functional unit / Choice of technologies / System expansion / Co-product allocation / Future forecasting / Site dependent impact assessment / Uncertainty

Introduction

In a paper presented to the RITE International Workshop on Total Ecobalance held in Tokyo on the 1st of February 1996 [1], I outlined several areas of methodological choices (definition of functional unit, choice of technologies, co-product allocation, future forecasts, and the impact assessment method), which all depend on the goal of the study, i.e. its application area.

I pointed out that there was, however, "no clear understanding of how the goal influences the methodological choices, i.e. what methodological adaptations are necessary in relation to a certain purpose," and that more research in this area was needed.

It is a pleasure for me to be able to present to you here, less than 3 years later, the first results of our research on this topic. These results show that it is indeed possible to reduce the ambiguity and uncertainty from these methodological choices through a more clear understanding of their relationships to the application areas.

Application areas

The methodological choices mentioned above are fundamentally determined by the products and interest groups affected and the temporal and spatial aspects of the studied systems. On this basis, six clearly defined application areas can be distinguished [2]. With respect to methodological choices, the most important distinction is that between the retrospective LCAs of the accountancy type (typically applied for hot-spot-identification and product declarations) and the prospective, comparative LCAs, which study possible future changes between alternative product systems (typically applied in product development and in public policy making) [3]. As the ultimate goal of most applications (even hot- spot-identification and product declarations) is to improve the studied systems, the relevance of retrospective LCAs may be questioned. In the following, I shall therefore focus mainly on methodology for prospective LCAs.

Product substitutions

In a prospective, comparative LCA, the object of study is the environmental impacts of a potential product substitution. Product substitutions may occur anywhere in the life cycle, from raw material substitutions, over substitutions in the production and use stages, to substitutions between alternative waste handling options. However, LCAs are typically limited to study the effects of substitutions at one specific stage in the life cycle, the range of possible substitutions at that stage being delimited by the functional unit (i.e. the functional unit typically does not specify what choices to make at other stages). The reason for this is that LCAs are typically aimed at situations where the influence of the decision-maker is limited to the specific substitution studied. However, if the decision-maker is able to affect substitutions at different stages in the life cycle, these substitutions may - both in principle and in practice - be specified in the functional unit, thus including in the study all possibilities simultaneously. This is most relevant

for long-term, strategic applications involving relatively well-defined products of enterprises with relatively large (expected) influence on the different actors in the life cycle.

The functional unit of a comparative study must always take into account the obligatory product properties ("must have" as opposed to the positioning properties "nice to have"), which are necessary for a user in that segment to accept the products as comparable and thus substitutable. To obtain a precise and indisputable definition, we have found it useful to analyse in detail the actual obligatory product properties required by the relevant geographical markets and market segments. In studies with a long time horizon (e.g. product development or strategic management), it may be reasonable to compare two products, for which substitution cannot be immediately realised, but where it is assumed that substitution will be realised under specific, future conditions of availability, price and product information. The shorter the time horizon of the study, the less relevant it is to include product alternatives, for which substitution is not likely to be realised under the present conditions.

Even when the decision-maker is not able to influence directly any substitutions elsewhere in the life cycle, the studied substitution at one stage in a life cycle may still lead indirectly to product substitutions in other life cycle stages. These substitutions are then not included in the functional unit, but the expected result of the substitutions (in terms of affected processes and their technologies) is simply included when modelling the product systems. To identify the affected processes, the following four types of information are required:

- The market segment affected, as determined by the obligatory product properties.
- The extent of the studied substitution, where:
    - small, short-term substitutions affect only capacity utilisation, but not capacity itself,
    - small, long-term substitutions affect also capital investment (installation of new machinery or phasing out of old machinery),
    - large substitutions affect also the determining parameters for the overall technology development, i.e. the constraints on the

possible technologies, the overall trends in the market volume, or the production costs of the involved technologies, so that the studied substitution in itself may lead to new technologies being brought into focus.

- Product availability, i.e. whether the market situation actually allows a choice between the products to be made (in this respect, markets may be differentiated geographically, be more or less regulated, more or less monopolised, and more or less transparent).
- The positioning properties of the products, as well as price and information, which influences the degree to which a potential product substitution will actually be realised.

We have formalised the last three of these points in a step-wise procedure, see [4].

Method for handling co-products

If a co-product does not appear in similar quantity in all studied systems of a prospective, comparative study, it is necessary to expand the studied systems, so that they all yield comparable product outputs. The processes to include when making such system expansions must be those processes actually affected by an increase or decrease in output of the by-product from the studied systems. Thus, to identify those processes one may apply the above-mentioned procedure for identifying the processes and technologies actually affected by a product substitution [4]. When applying this formal procedure we have found that system expansion is always possible, i.e. that it is always possible to identify those processes, which will be affected by a shift between the studied systems. Obviously, the identification can be made with more or less precision, but we have found that even an uncertain identification of the affected processes yield more useful results than an arbitrary allocation according to e.g. economic relationships between the co-products.

It should be noted that for LCAs of the retrospective type, where no system expansion is possible and a full (100%) allocation of the environmental inputs and outputs is required, co-product allocation by economic relationships is the only possibility.

From the observation that system expansion is always possible for prospective studies, and never for retrospective (leaving only the option of economic allocation for such studies), we obtain a much simpler description of the procedure for co-product handling than the description in ISO 14041, although leading to the same result as when following the ISO procedure.

The use of future forecast

For prospective studies, the data to be applied should reflect the relevant time horizon. For the short and medium term (1-5 years) forecasts for single processes (e.g. primary steel manufacture) may be based on simple extrapolation of trends and historical data [5]. For long term (5-25 years) forecasts, and forecasts for processes and systems, which are less specific (e.g. the general disposal system of society) and of larger importance for the LCA result, it becomes increasingly relevant to use modelling methods, such as trend impact analysis, which adjusts the extrapolations with the expected impact of mechanisms analogous to those determining past events [6]. For generic studies, aimed at influencing many stakeholders (e.g. ecolabelling), it may be relevant to use participatory methods incorporating the insight and opinions of experts and stakeholders. Scenario methods, incorporating several parallel forecasts, are most relevant for system forecasts used in long-term, strategic studies for both societal decisions and product development. The product development process may also benefit from the systematic creativity in exploratory methods, which combine analytic techniques dividing a broad topic or development into increasingly smaller subtopics or consequences, and imaginative techniques aimed at filling all gaps in the analytical structure. For long-term, strategic applications, involving relatively well-defined products of enterprises where the decision maker is expected to have a large degree of control over the future, it may be relevant to apply normative forecasting, which investigates how we want the future to be and how to obtain this goal [7].

The model for impact assessment

The absence of spatial and temporal information in the data from typical life cycle inventories put constraints on the possibilities of subsequent impact assessment to predict actual impacts.

As I already mentioned in my earlier presentation referred to above [1], our method and software for LCA includes the possibility for adding "site factors" with which one may characterise the local conditions under which the emissions occur and the sensitivity of the actual recipients of the emission.

Until recently, this possibility was not systematically applied, since the actual site factors to use had not been developed. We have been working intensively on this subject, and have now demonstrated that it is indeed possible to develop such general site factors for different emission types. As a result of this, we now also know more about how large the variation is for some values used in impact assessment and thus how large the additional uncertainty is, when the location is unknown [8].

The use of site factors is most relevant in enterprise specific studies, historical studies and studies with a short to medium time horizon where the geographical location is typically better specified, than in long-term, strategic and generic studies where the actual locations of the product systems are not yet determined. However, even when the precise geographical location is unspecified, some general site aspects of a process can be known (such as the typical stack height or location of a process: indoors/outdoors, marine/landbased, mobile/stationary), allowing a more precise impact assessment [9].

Conclusion

To summarise, specific relationships between application area and methodology has been demonstrated on the following areas:

- the influence of the decision maker determines the amount of simultaneously studied substitutions defined by the functional unit, and the time horizon determines the scope of product alternatives to include in the study,
- the distinction between retrospective and prospective applications determine whether the processes to include are those which have (retrospectively) contributed to an existing product or those affected by a (prospective) product substitution, and whether to handle co-products by (retrospective) economic allocation or (prospective) system expansion,

- the distinction between small/large and short-term/long-term changes determine the technologies to consider and whether to consider capital goods, maintenance etc.,
- the time horizon and complexity of the studied system determines whether forecasts should be made by extrapolation, modelling or scenario methods; the amount of stakeholders affected determine whether participatory methods are relevant, and for specific applications in product development, exploratory and normative forecasting may be relevant.

The methodological improvements described above all work towards reducing the uncertainty of LCA results. However, it must be acknowledged that applications aimed at predicting future consequences of a choice will always have an inherent uncertainty simply because their area of study is an uncertain future. This uncertainty cannot be removed, but it may become more acceptable if generally agreed standard scenarios are developed and applied.

We are presently investigating the relative importance of the uncertainties related to the above mentioned methodological improvements, with the aim of giving advice on how best to reduce the uncertainties in a given application.

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