Toolbox for Life Cycle Sustainability Assessment of Products

Valdivia, Sonia[1,]*; Ciroth, Andreas[2]; Sonnemann, Guido[1]; Ugaya, Cassia M. L. [3], Lu, Bin[4]; Alvarado, Carmen[5]

[1] United Nations Environment Programme, Division of Technology, Industry and Economics.

[2] GreenDeltaTC GmbH

[3] Technological Federal University of Parana

[4] University

[5] PRe Consultants

Abstract Life Cycle Assessments (LCA) are predominantly used to evaluate environmental impacts throughout the life cycle of a product or service. Sustainability, however, is a tripod based on environmental, economic, and social issues; which justifies the extension of the application of environmental LCAs by the missing key applications such as Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA). The techniques selected are ISO conform. The frameworks described for each of them present differences and commonalities that are discussed in this paper. Decision making processes are becoming more complex; answers to real problems need multi-criteria assessments. For instance, the assessment of socio-economic impacts of climate change cannot only rely on the application of an S-LCA or LCC. In order to move towards a life cycle sustainability assessment, there is a need to link existing tools. Aiming to contribute to better informed decisions on sustainability aspects of products, and following the advice of the International Life Cycle Board, UNEP and SETAC are developing a toolbox on Life Cycle Sustainability Assessment (LCSA). This proposal has the aim to show the outline of the toolbox under development: selected tools, their commonalities and differences, and a proposal of an integrated LCSA.

1 Life Cycle Sustainability Assessment

Life Cycle Sustainability Assessment (LCSA) is a technique to evaluate environmental, social, and economic impacts of a product over its entire life cycle. In the last decade, a number of sustainability assessment approaches, tools and discussion papers have been presented to Governments, academia, experts and agencies for development, addressing national (e.g. the Swiss contribution [1]), regional (e.g. Mattisse project funded by the EU [2]) or sectoral (e.g. proposal for the building sector [3] concerns. The World Bank, for instance, incorporates sustainability criteria in their assessments, however, no systematic quantitative tool is available yet, but a recommendation of principles to be used [4].

The development of all these approaches is a response to the need to evaluate sustainability; nevertheless, few of them are based on life cycle aiming to provide quantitative (and qualitative) results on sustainability aspects for informed decisions on products. Three examples, among others, are the following ones:

* the BASF ecoefficiency tool [5], which aims to integrate quantified social indicators into the BASF eco-efficiency analysis, originally addressing environmental concerns;

* the Product Sustainability Assessment tool (PROSA) [6], that gives particular attention to the analysis of social and economic aspects, and to the consideration of utility and consumer aspects;

* the Sustainability Assessment Model (SAM) [7], a tool for engaging people within organisations in sustainable development thinking and to evaluate the sustainability of projects.

Although the former examples given propose indicators and assessment methods, none of them are presented as a tool. Therefore, we propose a toolbox on Life Cycle Sustainability Assessment (LCSA) based on life cycle based techniques which are ISO 14040 conform (ISO, 2006a): environmental LCA (E-LCA), social LCA (S-LCA) and life cycle costing (LCC).

The toolbox has been discussed under the UNEP and SETAC Life Cycle Initiative aiming 'to interlink current LCA tools and provide a triple-bottom-line sustainable development toolbox' [8]. The aim of this LCSA toolbox is to contribute to better informed decisions on sustainability aspects of products, with impact categories and sub-categories for the three dimensions of sustainability; however without presenting impact assessment methods and interlinkages among the models, but providing recommendations on how to proceed with results obtained.

2 Overview of E-LCA, LCC and S-LCA

E-LCA aims to address the environmental dimension in a holistic manner by covering all relevant environmental impacts. Yet, in practice often a smaller subset of the possible and also of the relevant impacts identified by means of a hotspot assessment are taken into account; reasons are 1) to obtain a clearer picture that is easier to communicate, 2) some impacts are hard to grasp and operationalise, as noise, long term emissions, (still) land use, and therefore omitted for practicality reasons.

While LCC is a generic method used in industry since about 50 years; a specific approach has been developed to be used in the context of Life Cycle Assessment, called Environmental LCC [9 e 10]. Environmental LCC focuses on the economic dimension and only on microeconomic, real money flows; money flows can be positive (as revenues) or negative (as costs). LCC hotspot assessment can help assess where the cost or benefit are significant in the entire life cycle of products. Other types of economic impacts are not addressed, to avoid double counting and overlap.

S-LCA has the focus on social and socio-economic hotspots which are identified in consultation and validated by concerned stakeholders: consumers, local community, workers, value chain actors and the society. Stakeholder involvement is essential to develop S-LCA studies.

More specifically, the following topics need to be understood and aligned when combining E-LCA, S-LCA, and LCC (here and in the following always understood as Environmental LCC):

1) Goal and scope definition

    i) Functional unit: in all three approaches, the product utility should be considered, though in S-LCA a social utility (the utility to other stakeholders, beyond the consumer's) may be included;

    ii) Product system: regarding the modeling structure, while the E-LCA and LCC studies consider the unit processes along the life cycle, the S-LCA study adds the organizations that run the processes and the stakeholders;

    iii) cut-off rules could be different in each of the approaches: while in E-LCA, physical, economical or environmental relevance criteria might be used, in S-LCA, a socio-economical criteria is used (working-hours); in LCC, quite often different processes are relevant for the result, such as research and development processes; therefore, system boundaries need to be equivalent when combining the three approaches, but they will not necessarily be identical.

2) Inventory:

    i) in E-LCA and LCC, in praxis, only quantitative data is used. The situation is different in S-LCA, where more qualitative and semi-quantitative data is used;

    ii) in E-LCA, validation is performed using mass or energy balances, and by comparing emission factors. In S-LCA, mass and energy balances are not accessible usually; therefore, common model validation techniques, such as triangulation, need to be used.;

iii) In E-LCA, time is frequently not taken into account. S-LCA is at an early stage of implementation and applications are static without considering time effects. In LCC time is is often taken into account, and discounting is often applied as well.

3) Impact assessment:

i) in E-LCA positive impacts are not defined separately in the impact assessment method. Environmental benefits are understood as the negative value of a given impact. This is different in LCC and S-LCA, where positive impacts can occur (e.g. revenues in LCC and employment creation in S-LCA);

ii) In E-LCA all impacts are assumed to be linear.;

iii) Regionalization is an important issue in S-LCA and although also relevant for E-LCA, the first impact assessment methods did not include this.

iv) Characterization methods are available for some impact categories for E-LCA (although not to all of them as some impacts are hard to grasp and operationalise, as noise, long term emissions, (still) land use); in S-LCA, the first impact assessment methods are proposed [11]; in LCC, aggregated costs are already the evaluated impact, therefore an impact asssement methods as such is not necessary.

v) In E-LCA weighting of impact categories is an area of discussion. Impact categories can be grouped into 3 or four areas of protection (human health, Ecosystem quality, resources, etc). In many cases, a clear ranking of options can only be obtained if priorities among impact categories are defined.

4) Peer review is recommended for the three tools and is regular praxis for comparisons and public communication. In addition, in S-LCA, stakeholder consultation and involvement is needed before finalizing the critical review statements.

3 A way to implement an LCSA (UNEP, 2010b)

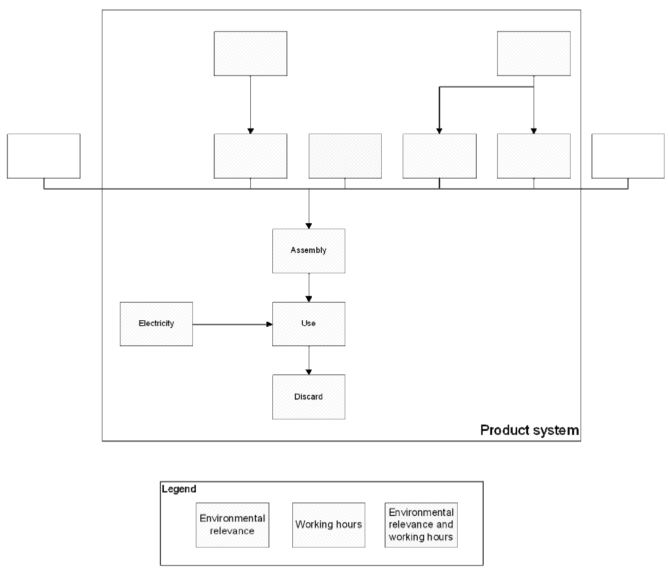
3.1 Goal and Scope Definition in LCSA

LCC, S-LCA and E-LCA pursue different overall aims. While the LCC has the aim to provide an indication on costs along the product chain, the E-LCA and S-LCA provide findings on environmental and social impacts, correspondingly.

The goal of the study is to evaluate the sustainability of two alternatives for heating water to take showers as a support for the product designer.

The functional unit chosen was heating 200 liters of water per day of 40^o C for a family with 4 people during 20 years in Brazil. Furthermore, the maintainance of products should be ease and for the low class (that is, the initial costs should not be higher than $ 20,00 and the usage costs, $ 20,00/month).

Due to the initial investments, only electric shower would be an option, nevertheless considering that each person takes a 5 min shower a day (10 hours / month) and the costs of electricity is of 0,50 $/ kWh, the maximum power of the product is 4000 W. So, the reference flow is a 4000 W showLet us consider that the electric shower life cycle. To assembly consider that the shower demands only 6 types of materials. As there are current LCA databases (although not reflecting Brazilian conditions), it was possible to use a cut-off considering an environmental relevance, which resulted in 2 materials. Nevertheless, while considering the working hours, 1 of these processes was not important, but another 2 processes should be considered. All the chosen materials were also important in costs terms. Following the same idea, two extraction processes were taking into account and the assembly, use and discard of the electric shower. Threfore, the product system of the study involves 10 unit processes, as shown below.



Furthermore, the organization in which the process runs should be identified for the S-LCA as some of the impacts subcategories are not related to the process, e.g., Public commitments to sustainability issues.

Box 1: Example of goal and scope definition

Furthermore, E-LCA is the basis of carbon footprint, EPD, reporting and is currently being used a lot as basis for communication and product improvement. Comparisons among products are also very common nowadays. When undertaking an integrated study, a common goal and scope has to be defined to the intended application and the audience to whom the results will be communicated. This includes information about whether the study intends to compare different products.

A common functional unit is defined and is the basis of all approaches developed in order to support decision making processes. Similar to an S-LCA [12], in LCSA an additional attribute of the functional unit related to the social utility or social performance of the products is needed.

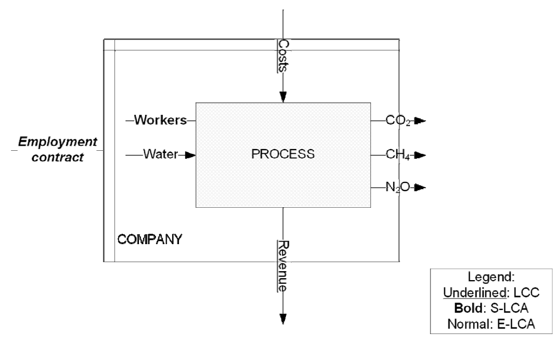
Apart from describing the functional unit, the scope should address the overall approach used to establish the system boundaries. The system boundary determines which unit processes are included in the LCA and must reflect the goal of the study. In an integrated application, we suggest to begin with an attributional modeling to limit the scope of the system. As for the cut-off, we suggest that one should consider all relevant cut-off rules, but if a unit process is included while considering any of the cut-off rule, it should be included in the product system. An example of a common functional unit and the product system are shown in Box 1.

3.2 Life Cycle Sustainability Inventory

As long as quantitative inventory indicators are available, results should be presented proportionally, i.e. per output produced. In case of qualitative inventory indicators a description of results obtained for each product is recommended. In Box 2 it is shown an example of the level in which data is collected.

Example of Life Cycle Sustainability Inventory

For each process, data needed for E-LCA, S-LCA and LCC is collected. In the figure below it is shown some of the data that should be collected for each unit process/company.



Box 2: Example of a LCS Inventory

4 Life Cycle Sustainability Impact Assessment

Considering the early stage of this LCSA framework, no proposals and recommendations are given on how to handle an integrated impact assessment. Nevertheless, we recommend to begin with steady-state rather than dynamic approaches. The time-horizon has different perspectives in E-LCA, LCC and S-LCA and it is proposed to present the results in light of different time horizons: short-term and mid-term time periods for LCC and S-LCA and mid-term to long-term ones for E-LCA.

5 LCSA Interpretation

The evaluation of results depends on the goal of the integrated study. It is often more easy to analyse results in two dimensions, i.e. to analyse whether there are trade offs between economic benefits and environmental or social burdens; then, the structure of the life cycle and the "spread" of impacts across the life cycle should be investigated, to understand which life cycle stages are critical; and these both approaches together should help to better understand if the product is socially and environmentally friendly, and viable from an economic perspective.

6 Critical Review

The integrated approach proposed is conform to ISO 14040/44. According to ISO, a critical review (CR) is mandatory for LCAs intended for comparative assertions where results are aimed to be made available to the public. If such studies claim to be performed according to ISO 14040/44, a CR shall therefore not to be considered as voluntary.

7 Next steps

The authors have identified the following gaps that need more development for advancing the implementation of LCSA tools:

The set up of integrated databases including the development of guidance documents on data management and uncertainties for integrated assessments; broader availability of data and software to help implementing the three approaches in a linked and consistent way.

More fluent integration of all three dimensions in one integrated assessment and better understanding of linkages of their impacts and potential escalation effects; hence, more convergence of separate “schools” of people applying social, cost, environmental assessment.

More applications of integrated tools meaning E-LCA, LCC and S-LCA and learning experiences in order to reduce “trade-off errors” in sustainability decision support (e.g. not supporting a product chain that is environmentally positive and socially questionable, or vice versa; not claiming that a product is more sustainable because uses less resources, or have direct less carbon emissions, without assessing other aspects needed in a sustainability assessment).

More guidance and examples of review processes considering the importance of having strong involvement of concerned parties, especially when doing an S-LCA.

8 Final Remarks

It is proposed to start looking at the whole picture instead of focusing on individual elements. The framework for LCSA is a toolbox with high potential to be used by decision makers in Governments, agencies for international cooperation, business and consumers’ associations. Still more research and applications are needed, but its application is already feasible and encouraged to speed the learning curve of the society.

9 Acknowledgement

Acknowledgements to the International Life cycle Board and Partners of the UNEP/SETAC Life Cycle Initiative for providing the financial resources needed for this partnership.

10 References

[1] SFOSD ARE (Swiss Federal Office for Spatial Development ARE) (2004). Gregor Ochsenbein, ARE: Daniel Wachter, Sustainability assessment – Conceptual framework and basic Methodology (at http://www.are.admin.ch/themen/nachhaltig/00270/03005/index.html?lang=en)

[2] ROTMANS J, HAXELTINE A, JÄGER J, JORDAN A, MINNESMA M, OLSSON L, WEAVER P (2008). Matise: Methods and Tools fo r Integrated Sustainability Assessment (ISA) in the Building Sector (at http://www.matisse-project.net/projectcomm/fileadmin/skripts/matisse_finale.pdf)

[3] EL-HARAM M, WALTON J, HORNER M, HARDCASTLE C, PRICE A, BEBBINGTON J, THOMSON C, ATKIN-WRIGHT T (2007). Development of an Integrated Sustainability Assessment Toolkit for the Building Sector, published in the proceedings of the SUE-MoT Conference on International Conference on Whole Life Urban Sustainability and its Assessment, http://download.sue-mot.org/Conference-2007/Papers/El-Haram.pdf

[4] WORLD BANK (2010) Available at: www.worldbank.org.

[5] BASF (2010) The Socio-Eco-Efficiency Analysis SEEBALANCE®, BASF

[6] ÖKO-INSTITUT (1997). PROSA – Product chains analysis (at http://www.prosa.org/)

[7] CAVANAGH J, FRAME B, LENNOX J (2006). The Sustainability Assessment Model (SAM): Measuring Sustainable Development Performance, Australian Journal of Environmental Management, Volume 13, pages 142-145.

[8] VALDIVIA, S.; CIROTH, Andreas; SONNEMANN, Guido; UGAYA, Cassia M. L., Lu, Bin; Alvarado, Carmen (2010) The UNEP/SETAC Life Cycle Sustainability Assessment Toolbox. Ecobalance.

[9] HUNKELER D, KLÖPFFER W, SWARR Th, PEESONEN H, CIROTH A, BRENT A, PAGAN B (2011). Environmental Life-Cycle Costing: A SETAC Code of Practice, SETAC publication.

[10] HUNKELER, D, REBITZER, G, LICHTENVORT, K (eds.): Environmental Life Cycle Costing. Lead authors: CIROTH, A; HUNKELER, D; HUPPES, G; LICHTENVORT, K; REBITZER, G; RÜDENAUER, I; STEEN, B; Taylor & Francis 2008.

[11] CIROTH, A., FRANZE, J. (2011): LCA of an Ecolabeled Notebook - Consideration of Social and Environmental Impacts Along the Entire Life Cycle, ISBN 978-1-4466-0087-0, Berlin.

[12] UNEP (2009) Guidelines for Social Life Cycle Assessment of Products. Available at http://lcinitiative.unep.fr.