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An Overview of Life Cycle Assessments: Part One of Three

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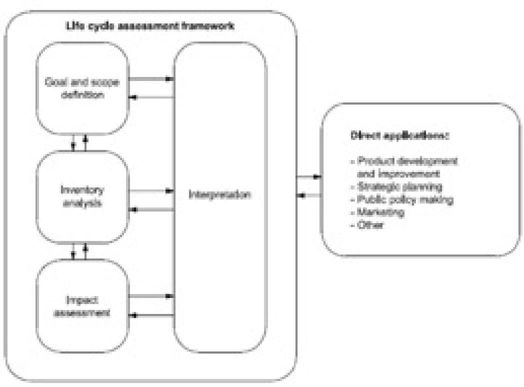


Stages of an LCA as per ISO 14044:2006. Click here to see larger version of the diagram.

Life cycle assessment (LCA) is an analytical method used to comprehensively quantify and interpret the energy and material flows to and from the environment over the entire life cycle of a product, process, or service. LCA is rapidly emerging as a key method, if not the key method, for evaluating the environmental effects of products, processes and even whole buildings. It is cited in numerous codes and standards, including the California Green Building Code, the ASHRAE 189.1 Standard, ICC 700, and the IGCC where it is included in the current draft as a project elective.

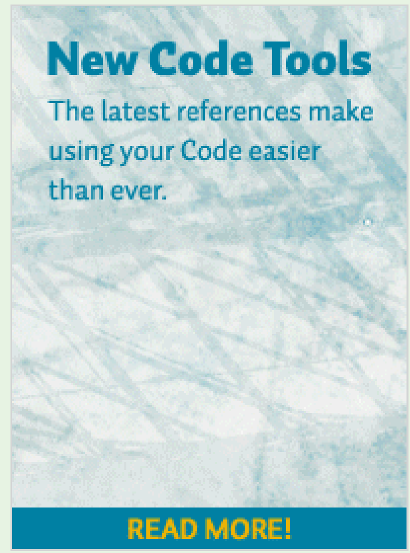
As defined in the ISO standards, LCA involves "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.[1] Other organizations use definitions that are essentially the same. Environmental flows include emissions to air, water, and land, as well as the consumption of energy and material resources. The flows are combined as explained below, to generate environmental impact measures.

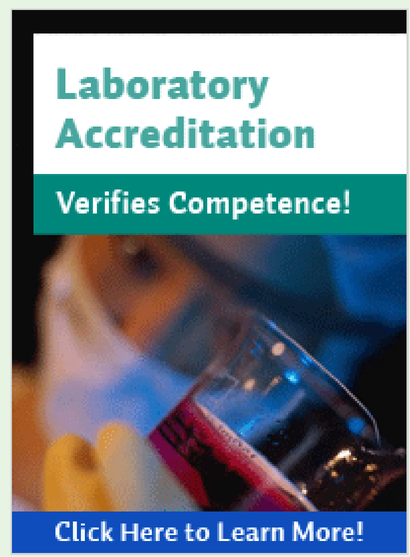
Two international standards, ISO 14040:2006 and ISO 14044:2006, describe an iterative four-stage or phased methodology framework for completing an LCA, as shown on the left side of the diagram above.

Goal and Scope Definition

An LCA starts with an explicit statement of the goal and scope of the study, which sets out the context of the study and explains how and to whom the results are to be communicated. This is a key step, and the ISO standards require that the goal and scope of an LCA be clearly defined and consistent with the intended application. The goal and scope document therefore includes technical details that guide subsequent work:

- the functional unit, which defines what precisely is being studied and quantifies the





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service delivered by the product system, providing a reference to which the inputs and outputs can be related;
- the system boundaries;
- any assumptions and limitations;
- the allocation methods used to partition the environmental load of a process when several products or functions share the same process; and
- the impact categories chosen.

Life Cycle Inventory

Life Cycle Inventory (LCI) analysis involves creating an inventory of flows from and to nature for a product system. Inventory flows include inputs of water, energy, and raw materials, and releases to air, land and water. To develop the inventory, a flow model of the technical system is constructed using data on inputs and outputs. The flow model is typically illustrated with a flow chart that includes the activities that are going to be assessed in the relevant supply chain and gives a clear picture of the technical system boundaries. The input and output data needed for the construction of the model are collected for all activities within the system boundary, including from the supply chain (referred to as inputs from the technosphere).

Inventory flows can number in the hundreds depending on the system boundary. For product LCAs at either the generic (i.e., representative industry averages) or brand-specific level, that data is typically collected through survey questionnaires. At an industry level, care has to be taken to ensure that questionnaires are completed by a representative sample of producers, leaning toward neither the best nor the worst, and fully representing any regional differences due to energy use, material sourcing or other factors. The questionnaires cover the full range of inputs and outputs, typically aiming to account for 99 percent of the mass of a product, 99 percent of the energy used in its production and any environmentally sensitive flows, even if they fall within the 1 percent level of inputs. Given this approach, there is no flow that is always relatively easy to collect compared to other flows from the perspective of those undertaking a study. However, industry people completing a questionnaire may have easier access to some types of data compared to others, depending on their situation.

One area where data access is likely to be difficult is from the technosphere. Those completing a questionnaire will be able to specify how much of a given input they use from supply chain sources, but they will not usually have access to data concerning inputs and outputs for those production processes. The entity undertaking the LCA must then turn to secondary sources if it does not already have that data from its own previous studies. National databases or data sets that come with LCA-practitioner tools, or that can be readily accessed, are the usual sources for that information. Care must then be taken to ensure that the secondary data source properly reflects regional or national conditions. Data from a European source, for example, may reflect quite different raw material sources, transportation modes and distances, energy forms used, and so on. Even within North America, or the United States for that matter, there can be significant regional differences and those should be properly reflected in the data.

Life Cycle Impact Assessment

Inventory analysis is followed by impact assessment. This phase of LCA is aimed at evaluating the significance of potential environmental impacts based on the LCI flow results. Classical Life Cycle Impact Assessment (LCIA) consists of the following mandatory elements:

- selection of impact categories, category indicators, and characterization models;
- the classification stage, where the inventory parameters are sorted and assigned to specific impact categories; and
- impact measurement, where the categorized LCI flows are characterized, using one of many possible LCIA methodologies, into common equivalence units that are then summed to provide an overall impact category total.

In many LCAs, characterization concludes the LCIA analysis; this is also the last compulsory stage according to ISO 14044:2006. However, in addition to the above mandatory LCIA steps, other optional LCIA elements – normalization, grouping, and weighting – may be conducted depending on the goal and scope of the LCA study. In normalization, the results of the impact categories from the study are usually compared

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with the total impacts in the region of interest, the United States, for example. Grouping consists of sorting and possibly ranking the impact categories. During weighting, the different environmental impacts are weighted relative to each other so that they can then be summed to get a single number for the total environmental impact. ISO 14044:2006 generally advises against weighting, stating that "weighting, shall not be used in LCA studies intended to be used in comparative assertions intended to be disclosed to the public." This advice is often ignored, resulting in comparisons that can reflect a high degree of subjectivity due to weighting.

Interpretation

The results from the inventory analysis and impact assessment are summarized during the interpretation phase. The outcome of the interpretation phase is a set of conclusions and recommendations for the study. According to ISO 14040:2006, the interpretation should include:

- identification of significant issues based on the results of the LCI and LCIA phases of an LCA;
- evaluation of the study considering completeness, sensitivity and consistency checks; and
- conclusions, limitations and recommendations.

The working procedure of LCA is iterative as illustrated by the back-and-forth arrows in Figure 1. The iteration means that information gathered in a later stage can highlight effects in a former stage that may require further analysis. When this occurs, the former stage and the following stages have to be reworked taking into account the new information. At the end, the results and conclusions of the LCA must be completely and accurately reported to the intended audience. The data, methods, assumptions, limitations, and results must be transparent and presented in sufficient detail to allow interested parties to comprehend the complexities and trade-offs inherent in the LCA. The report must also allow the results and interpretation to be used in a manner consistent with the goals of the study.

One continuing problem for LCA practitioners and entities promoting LCA is the limited understanding of the method by non-practitioners, and the corresponding problem of interpretation or, indeed, misinterpretation of results. Users of the results of studies are too frequently uninformed with regard to the appropriate and acceptable environmental impact measures, the sources of data, or even the relationship of data and tools to the ISO standards. For example, a typical user question is whether a specific tool complies with the ISO 14040 or 14044 standards, when in fact those standards don't directly address or set out specific requirements for tools. This lack of understanding can too readily undermine the value of LCA studies if those adversely affected present what are actually false arguments against the method, arguments frequently encapsulated in the phrase "LCA is not ready for prime time." For policy makers, the risk is that a lack of understanding will lead to dependence on questionable data or studies. Continuing education is therefore critical, as is the ability to readily consult with qualified practitioners.

Critical Review

If a study involves comparative assertions that will be disclosed to the public, the ISO standards require critical review, "…a process to verify whether an LCA has met the requirements for methodology, data, interpretation and reporting, and whether it is consistent with the principles."[2] At a minimum, an external independent expert is selected to act as chairperson of a review panel consisting of at least three members who have collective expertise in the technical subject at hand as well as in LCA.

Next in the Series

The next article in this three-part series will elaborate on the interpretation discussion above by focusing on common misconceptions, misunderstandings and outright mistakes, setting the stage for Part Three, which will deal with the potential future use of LCA in codes.

[1] *ISO 14040:2006. Environmental Management – Life Cycle Assessment – Principles*

and Framework. ISO 14044:2006. Environmental Management – Life Cycle Assessment – Requirements and guidelines.

[2]*ISO 14040:2006, section 7.1*

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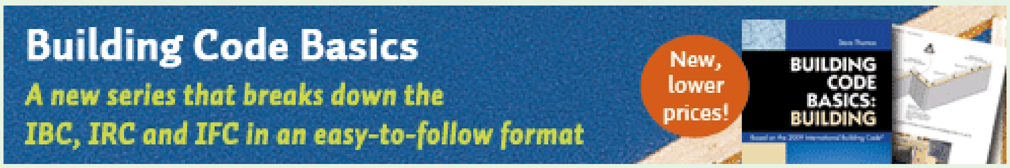
As always, your articles ideas and submissions are welcome. Send them to foliver@iccsafe.org along with a daytime phone number at which to contact you with questions.



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