Chapter 3
Methodology

3.1 Life cycle assessment

LCA is a tool for evaluating the environment impacts of a product or a system throughout its entire life span, usually from raw material extraction to final disposal. When comparing LCA GHG emission results of various energy chains, it is necessary to understand that the electricity generating options may not be true alternatives to each other. For instance, services provided by some energy technologies like irrigation and flood control, reliability of supply, and ancillary services such as voltage control, regulation, operating reserve, load-following and system black-start capability may not be easily provided by all technologies [1].

According to the ISO 14040 [2] and 14044[3] standards, a Life Cycle Assessment is carried out in four distinct phases as illustrated in the figure 3.1 shown to the right. The phases are often interdependent in that the results of one phase will inform how other phases are completed.

![Life cycle assessment framework](image)

Figure 3.1 Life cycle assessment framework
3.2 Goal and scope

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 [4]:

- The functional unit, which defines what precisely is being studied and quantifies the service delivered by the product system, providing a reference to which the inputs and outputs can be related. Further, the functional unit is an important basis that enables alternative goods, or services, to be compared and analyzed.
- 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.

3.3 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 techno-sphere).

The data must be related to the functional unit defined in the goal and scope definition. Data can be presented in tables and some interpretations can be made already at this stage. The results of the inventory is an LCI which provides information about all inputs and outputs in the form of elementary flow to and from the environment from all the unit processes involved in the study.

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% of the mass of a product, 99% of the energy used in its production and any environmentally sensitive flows, even if they fall within the 1% level of inputs.
3.4 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 with the total impacts in the region of interest, the U.S. 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 as a result of weighting.

3.5 Interpretation

Life Cycle Interpretation is a systematic technique to identify, quantify, check, and evaluate information from the results of the life cycle inventory and/or the life cycle impact assessment. 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.

A key purpose of performing life cycle interpretation is to determine the level of confidence in the final results and communicate them in a fair, complete, and accurate manner. Interpreting the results of an LCA is not as simple as "3 is better than 2, therefore Alternative A is the best choice"! Interpreting the results of an LCA starts with understanding the accuracy of the results, and ensuring they meet the goal of the study. This is accomplished by identifying the data elements that contribute significantly to each impact category, evaluating the sensitivity of these significant data elements, assessing the completeness and consistency of the study, and drawing conclusions and recommendations based on a clear understanding of how the LCA was conducted and the results were developed.

3.6 LCA uses

Based on a survey of LCA practitioners carried out in 2006 [5] LCA is mostly used to support business strategy (18%) and R&D (18%), as input to product or process design (15%), in education (13%) and for labeling or product declarations (11%). LCA will be continuously integrated into the built environment as tools such as the European ENSLIC Building project guidelines for buildings or developed and implemented, which provide practitioners guidance on methods to implement LCI data into the planning and design process [6].

Major corporations all over the world are either undertaking LCA in house or commissioning studies, while governments support the development of national databases to support LCA. Of particular note is the growing use of LCA for ISO Type
III labels called Environmental Product Declarations, defined as "quantified environmental data for a product with pre-set categories of parameters based on the ISO 14040 series of standards, but not excluding additional environmental information" [7]. These third-parties certified LCA-based labels provide an increasingly important basis for assessing the relative environmental merits of competing products. Third-party certification plays a major role in today's industry. Independent certification can show a company's dedication to safer and environmental friendlier products to customers and NGOs [8].

LCA also has major roles in environmental impact assessment, integrated waste management and pollution studies.

3.7 Type of LCA Methodology
LCA methods are generally distinguished between Process Chain Analysis (PCA) and input/output (I/O), although hybrid assessment tools (using elements of both) are also frequently used. PCA is a vertical bottom-up technique that considers emissions of particular industrial processes and operations and includes a limited order of supplying industries and their corresponding emissions, and is therefore an accurate but resource intensive technology [9]. PCA strongly relies on GHG content data being available for all relevant materials and processes [10], when in fact complete material inventories are not always available, and manufacturing data for complete systems difficult to estimate – in which case a hybrid approach could use PCA for material assessments and I/O to derive data for certain system operation and maintenance (O&M), manufacturing steps and other processes where complete information is not available [11].

I/O method is a statistical top-down approach, which divides an entire economy into distinct sectors. Based on economic inputs and outputs between the sectors, I/O generates the energy flows and the associated emissions [12]. For example, an established I/O database provides the estimates of the amount of energy required to manufacture classes of products and provides categories of services [39]. However, specific sectors do not exist in I/O table and must be modeled using PCA. LCA based solely on I/O analysis have reportedly produced results that are 30% higher in
The LCA can be applied to assess the impact of electricity generation on the environment and will allow producers to make better decisions pertaining to environmental protection [15]. All significant GHG emissions from electricity generation, related to the final product need to be accounted. For electricity this is usually expressed in grams of carbon dioxide equivalent per unit of bus bar electricity (i.e. gCO₂/kWh) [16].
3.8 Reference


[8] www.thegreenstandard.org


