# Chapter 6
# Introduction to LCA Methodology

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**Abstract** In order to offer the reader an overview of the LCA methodology in the preparation of the more detailed description of its different phases, a brief introduction is given to the methodological framework according to the ISO 14040 standard and the main elements of each of its phases. Emphasis is on the iterative nature of the LCA process with its many feedback loops between the different phases. It is explained how the integrated use of sensitivity analysis helps identify key assumptions and key data and thus ensure effectiveness by directing the focus of the LCA practitioner to those parts of the study where additional work contributes most to strengthen the results and conclusions of the study.

**Learning Objectives**
After studying this chapter, the reader should be able to

- Draw and explain the methodological framework for LCA.
- Present an overview of the phases of LCA, their purpose and main elements.
- Explain the iterative nature of LCA and its rationale in terms of helping the LCA practitioner focus on what matters most for the results and conclusions of the study.

## 6.1 Introduction

As described in Chap. 3, the need for agreement on common principles for how to perform an LCA was realised back in the 1980s. An international discussion of methodological issues took off around 1990 under the auspices of SETAC leading

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to publication of state-of-the-art reports and codes of conduct for different parts of the LCA methodology throughout the 1990s and feeding into the standardisation process that went on in parallel. Although many methodological aspects are still under discussion and development continues today, the fundamental structure has been stable since the appearance of the first ISO 14040 standard in 1997, and it is also applied in major LCA methodologies like the CML (Guinée 2002), EDIP97 (Wenzel et al. 1997), and by the ILCD guidelines from the EU Commission (EC-JRC 2010).

The methodology chapters in Part II of this book give a detailed presentation of the LCA methodology structured according to the ISO framework and referring to the recommendations and requirements given by the ILCD guidelines. References are not given consistently to these sources throughout the chapters but unless otherwise mentioned, they are the basis of the presented methodology.

The European ILCD guidelines for LCA (EC-JRC 2010) are strongly founded in the framework and methodological requirements of the ISO LCA standards (ISO 2006a, b) but they go further and offer methodological guidance at a much more detailed level than the standards do. They are the outcome of a comprehensive consultation process involving hearings of experts and stakeholders, and on this basis, we have chosen them as a useful reference for discussing LCA methodology and specifying methodological choices. In Chap. 37 the most important methodological actions and requirements of the ILCD guideline are presented in the form of a cookbook or checklist that you can refer to as a reference methodology to follow, or to deviate from at specific and transparently documented points of the methodology.

## 6.2 The Phases of LCA

We begin in this introductory chapter with a brief description of the main methodological phases and the way in which their results are assessed and refined in a focused iterative process. This will give you an overview of the methodology before you dig into the details and peculiarities of its different phases and elements, and it will introduce you to the iterative approach, which is fundamental for performing a successful LCA.

As illustrated in Fig. 6.1, the ISO standard distinguishes the methodological framework of LCA from its different applications, which are multiple such as product development, Ecolabelling, carbon footprint and other footprints (see Part III of the textbook for examples). Applications of LCA are treated in separate publications from the standard organisation. The LCA framework operates with four separate phases, Goal and scope definition, Inventory analysis, Impact assessment and Interpretation.

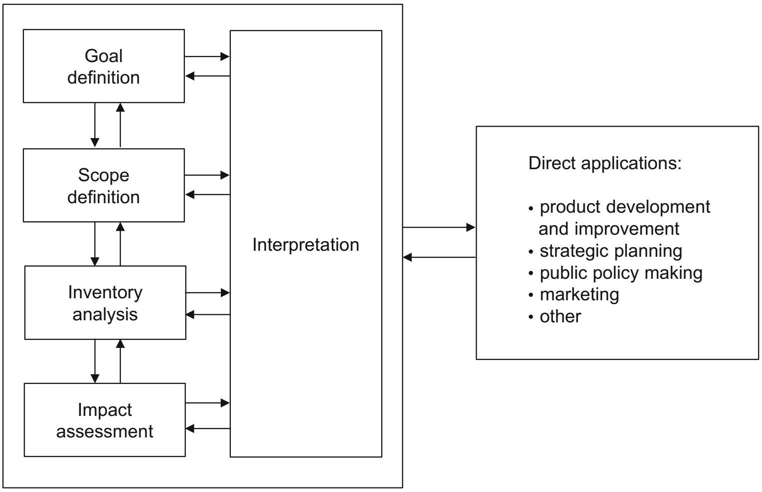


**Fig. 6.1** Framework of LCA modified from the ISO 14040 standard

### *6.2.1 Goal and Scope Definition*

An LCA starts with a well-considered and deliberate definition of the goal of the study (see Chap. 7). Why is this study performed? Which question(s) is it intended to answer and for whom is it performed? The goal definition sets the context of the LCA study and is the basis of the scope definition (see Chap. 8) where the assessment is framed and outlined in accordance with the goal definition, primarily in terms of

- Defining the functional unit: a quantitative description of the function or service for which the assessment is performed, and the basis of determining the reference flow of product that scales the data collection in the next LCA phase, the inventory analysis.
- Scoping the product system, deciding which activities and processes belong to the life cycle of the product that is studied.
- Selecting the assessment parameters, i.e. the impacts that shall be assessed in the study.
- Selecting the geographical and temporal boundaries and settings of the study and the level of technology that is relevant for the processes in the product system.
- Deciding the relevant perspective to apply in the study: should it be a consequential study assessing the impacts that can be expected as a consequence of choosing one alternative over another, or should it be an attributional study assessing the impacts that are associated with the studied activity?
- Identifying the need to perform critical review, in particular if the study is a comparative assertion intended to be disclosed to the public.

The goal definition and the ensuing scope definition are very important to consider when the results of the study are interpreted since these definitions involve choices that determine the collection of data and the way in which the system is modelled and assessed. They therefore have a strong influence on the validity of the conclusions and recommendations that are based on the results of the LCA.

### 6.2.2 Inventory Analysis

Following the definition of goal and scope, the inventory analysis collects information about the physical flows in terms of input of resources, materials, semi-products and products and the output of emissions, waste and valuable products for the product system (see Chap. 9). The analysis studies all the processes that were identified as belonging to the product system, and the flows are scaled in accordance with the reference flow of product that is determined from the functional unit. Due to the comprehensiveness of most product systems, the inventory analysis often relies on generic data for many processes originating from databases with unit processes or cradle-to-gate data, presenting the in- and output flows for one unit process, e.g. for production of a material, generation of heat or electricity, transportation or waste management. Environmentally extended input–output analysis can be used to support and qualify the collection of inventory data as discussed in Chap. 14.

The outcome of the inventory analysis is the life cycle inventory, a list of quantified physical elementary flows for the product system that is associated with the provision of the service or function described by the functional unit.

### 6.2.3 Impact Assessment

Taking the life cycle inventory as a starting point, the impact assessment translates the physical flows and interventions of the product system into impacts on the environment using knowledge and models from environmental science (see Chap. 10). The impact assessment consists of five elements of which the first three are mandatory according to the ISO 14040 standard:

1. *Selection* of impact categories representative of the assessment parameters that were chosen as part of the scope definition. For each impact category, a representative indicator is chosen together with an environmental model that can be used to quantify the impact of elementary flows on the indicator.
2. *Classification* of elementary flows from the inventory by assigning them to impact categories according to their ability to contribute by impacting the chosen indicator.

3. *Characterisation* using environmental models for the impact category to quantify the ability of each of the assigned elementary flows to impact the indicator of the category. The resulting characterised impact scores are expressed in a common metric for the impact category. This allows aggregation of all contributions into one score, representing the total impact that the product system has for that category. The collection of aggregated indicator scores for the different impact categories (each expressed in its own metric) constitutes the characterised impact profile of the product system.
4. *Normalisation* is used to inform about the relative magnitude of each of the characterised scores for the different impact categories by expressing them relative to a common set of reference impacts—one reference impact per impact category. Often the background impact from society is used as a reference. The result of the normalisation is the normalised impact profile of the product system in which all category indicator scores are expressed in the same metric.
5. *Grouping or weighting* supports comparison across the impact categories by *grouping* and possibly ranking them according to their perceived severity, or by *weighting* them using weighting factors that for each impact category gives a quantitative expression of how severe it is relative to the other impact categories. Quantitative weighting allows aggregation of all the weighted impact scores into one overall environmental impact score for the product system, which may be useful when the results of the LCA are used in decision support together with other condensed information like the economic costs of the alternatives.

The main focus of this book is the traditional environmental LCA focusing on the environmental impacts of the product system, but for sustainability assessment, also social and economic impacts need to be considered. For these other dimensions of sustainability, a life cycle perspective is as relevant as it is for the environmental dimension and in a life cycle sustainability assessment (LCSA—See Chap. 5) they may be addressed through a social LCA (S-LCA) and a life cycle costing analysis (LCC). Both of these assessment techniques have their own distinct methodological foundation which shares the fundamental framework of environmental LCA but has many distinct elements in all phases of the methodology as introduced in Chaps. 15 (LCC) and 16 (S-LCA).

**Interpretation** The results of the study are interpreted in order to answer the question(s) posed as part of the goal definition (see Chap. 12). The interpretation considers both results of the inventory analysis and the impact assessment elements characterisation and, possibly, normalisation and weighting. The interpretation must be done with the goal and scope definition in mind and respect the restrictions that the scoping choices impose on a meaningful interpretation of the results, e.g. due to geographical, temporal or technological assumptions.

Sensitivity analysis and uncertainty analysis are applied as part of the interpretation to guide the development of conclusions from the results, to appraise the robustness of the conclusions, and to identify the focus points for further work in order to further strengthen the conslusions.

## 6.3 The Iterative Nature of LCA

In Fig. 6.1 a number of arrows indicate that rather than a linearly proceeding process, LCA involves many feedback loops between the different phases of the LCA. Insights from the impact assessment are used in refining the inventory analysis and insights from both of these phases may feed back to the scope definition, e.g. in the setting of the boundaries of the product system, what to include and what to exclude. Sensitivity and uncertainty analysis are thus not just performed in the interpretation at the end but throughout the study as part of both inventory analysis and impact assessment in order to identify the key figures or key assumptions of the study and the data that are associated with the largest uncertainties (see Chap. 11). Each phase of the methodology provides feedback to the previous phases of the study and helps target the next iteration of the LCA. The best precision is obtained with minimum work effort if the focus is on improving the key figures wherever possible and needed, and on reducing the largest uncertainties.

In practice, the first iteration will often be a screening that covers the full life cycle, but in terms of inventory data largely is based on easily accessible data from available databases. Following the impact assessment, the parts of the product system that contribute most strongly to the total results can be identified, and the chosen boundaries of the product system can be tested. As a consequence, the scoping may have to be refined. The impact assessment results also allow identifying those inventory data or assumptions made in the inventory analysis that have the largest influence on the overall results or for which the uncertainties are so large that they potentially could be key figures. These data should be the target of the next iteration, where effort should be focused on testing and refining these assumptions or data and get more representative or recent data. Based on the revised inventory a new impact assessment is performed, and the sensitivity analysis is performed once more to see which are now the key figures and key assumptions. Large uncertainties may also accompany the factors applied in the characterisation of some of the inventory flows in the impact assessment, and if the sensitivity analysis indicates that such uncertainties may have a decisive influence on the results, these factors will also be the target of a consecutive iteration. Figure 6.2 illustrates the iterative approach to performing an LCA.

As illustrated by the narrowing spiral in Fig. 6.2, the uncertainty of the LCA results is reduced through the repeated iterations, and these are carried on until the remaining uncertainty of the results is sufficiently small to meet the goal of the study. If the goal is to identify which among several alternatives has the lowest environmental impacts, the number of needed iterations may be low if the alternatives show large differences in their impacts, while a higher number of iterations will be needed if the alternatives are more similar. An LCA performed to support an environmental product declaration with a general requirement to the uncertainty of the impact scores can require a high number of iterations before all impact scores are determined within the stipulated level of uncertainty.

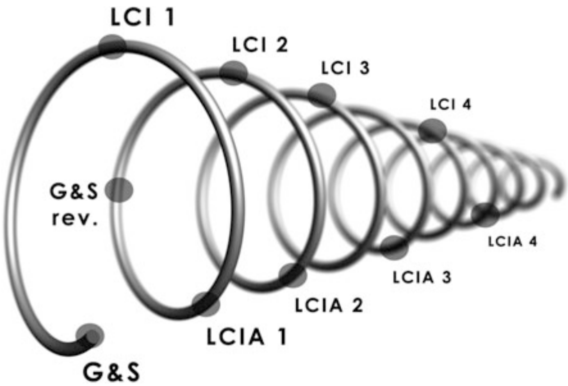


**Fig. 6.2** Using sensitivity analysis and uncertainty analysis as integrated tools, the phases of the LCA methodology are repeated with focus on improving and strengthening the identified key figures and assumptions in consecutive iterations until the strength of the conclusions meets the requirements posed by the goal and scope definition

With this overview of the LCA framework, its interconnected phases and how iteration is used to ensure effectiveness when performing an LCA, you are now prepared for diving into the intricate details of the many elements of the LCA methodology. Enjoy!

## References

This chapter is to a large extent based on the ILCD handbook and the ISO standards 14040 and 14044. Due to the scope of this chapter, some details have been omitted, and some procedures have been rephrased to make the text more relevant to students. For more details, the reader may refer to these texts:

EC-JRC (2010) European Commission—Joint Research Centre—Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook—General guide for Life Cycle Assessment—Detailed guidance. First edition March 2010. EUR 24708 EN. Luxembourg. Publications Office of the European Union.

ISO: Environmental management—life cycle assessment—principles and framework (ISO 14040). ISO, The International Organization for Standardization, Geneva (2006a)

ISO: Environmental management—life cycle assessment—requirements and guidelines (ISO 14044). ISO, The International Organization for Standardization, Geneva (2006b)

## Additional References Quoted in the Text

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## Author Biography

**Michael Z. Hauschild** Involved in development of LCIA methodology since the early 1990s. Has led several SETAC and UNEP/SETAC working groups and participated in the development of the ISO standards and the ILCD methodological guidelines. Main LCA interests are chemical impacts, spatial differentiation and science-based boundaries in LCIA.