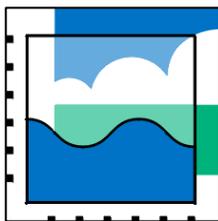


Life cycle assessment

An operational guide to the ISO standards



Final report, May 2001



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This document provides guidelines, operational models and data, and scientific background information on Life Cycle Assessment methodology. It has been subjected to internal and external peer review. Nevertheless, this does not guarantee that the contents are free of error.

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Note that parts of this document may require regular updating.

FOREWORD

In 1992 the Centre of Environmental Science - Leiden University (CML) collaborated with the Netherlands Organisation for Applied Scientific Research (TNO) and the Fuels and Raw Materials Bureau (Bureau B&G) to produce a Guide and Background document on the environmental Life Cycle Assessment methodology. Its full title was "Environmental Life Cycle Assessment of products. Guide and Backgrounds" by R. Heijungs, J.B. Guinée, G. Huppes, R.M. Lankreijer, H.A. Udo de Haes, A. Wegener Sleeswijk, A.M.M. Ansems, P.G. Eggels, R. van Duin and H.P. de Goede, 1992. Since then, there have been many methodological developments, which are indeed still taking place. To address these ongoing developments, the "LCA in environmental policy" project was initiated, resulting in the compilation of an entirely new Guide, which you have before you.

The "LCA in environmental policy" project was funded by the Dutch Ministry of Housing, Spatial Planning and Environment (VROM-DGM; co-ordinator ir. H.L.J.M. Wijnen), the Ministry of Economic Affairs (EZ), the Ministry of Agriculture, Nature Management and Fisheries (LNV) and the Ministry of Transport, Public Works and Water Management (V&W). The project was carried out between June 1997 and May 2001 by CML, with contributions by the Institute of Environmental Studies - Vrije Universiteit (IVM); the School of Systems Engineering, Policy Analysis and Management – Delft University of Technology (TUD/TB); Bureau B&G; the Interfaculty Department of Environmental Science, University of Amsterdam (UVA); IVAM-Environmental Research (IVAM-ER); TNO; and 2.-0 LCA consultants (Denmark).

To assess the wishes and requirements of potential users of LCA and allied tools for environmental policy in general and environment-related product policy in particular, a Pilot Paper was first prepared by IVM, the findings of which defined the basic parameters for further elaboration of the project. This Pilot Paper was published as an independent document by VROM-DGM. Next, TNO prepared a comprehensive inventory of the potential uses of LCA, as well as its limitations of scope, the requirements associated with specific applications and the potential overlap with other tools. In addition, possible extensions of the scope of LCA to include multi-functional systems (for example, cascade systems) were inventoried. The report of TNO is included as an appendix to this Guide.

For a number of LCA applications, TUD/TB and Bureau B&G have drawn up recommendations for embedding LCA in procedural guidelines. This is a topic that has not previously been addressed within LCA studies. This means it is innovative work that is still at an early stage of development. The efforts by TUD/TB and Bureau B&G have resulted in two reports, which have been incorporated in the main text of the present Guide.

Allocation is one of the most sensitive issues in LCA methodology. It is therefore especially important that coverage of this issue in the Guide and Background documents should enjoy the widest possible support. The topic of allocation was consequently addressed in particular detail in a desk study carried out by IVAM-ER in close collaboration with CML. The report on this desk study is included as an appendix to the present Guide. In addition, 2.-0 LCA consultants of Denmark have prepared a paper on this issue, which is likewise included in this Guide.

The treatment of the theme of toxicity in the 1992 Guide and Background document then was incomplete and unsatisfactory, lacking a fate analysis, for example. As part of a PhD project at the UVA, new toxicity factors for over 180 substances have been calculated, using the more recent USES 2.0 model as well as more sophisticated data. The results of this work have been integrated in the main text of the present document.

The new Guide consists of three parts. Part 1 - "LCA in perspective" - provides a general introduction to LCA and includes a discussion of the possibilities and limitations of LCA and the organisations involved in LCA.

Part 2 consists of two parts, 2a ("Guide") and 2b ("Operational annex"). Part 2a provides an introduction to the procedural design of an LCA project, and guidelines on the best available practice for each of the steps involved in an LCA study, at two levels of LCA sophistication: simplified and detailed. The two levels of sophistication relate to different decision situations, linked to different methodological choices. On certain points of detail there may often be good reason for undertaking a more in-depth analysis than can be provided even by the 'standard' detailed LCA. This kind of in-depth analysis has not been specified here as a separate method; instead, we provide an indication of possible extensions that can improve the quality of detailed LCA in those respects where shortcomings are most obvious.

Part 2b provides the most up-to-date operational models and data associated with the best available practice for these two levels of sophistication, as a separate document. This has been done to facilitate updating of these operational elements, most of which are likely to change regularly. Part 2b thus operationalises the guidelines provided in Part 2a.

Part 3 provides the scientific background to the study, as well as a reasoned justification of all the choices made in designing a best available practice for each phase of an LCA.

Finally, we would like to thank all those active in the project resulting in this Guide, which involves, apart from the authors and editors, the steering committee, the think-tank, the supervisory committee and the international observers group. The number of people involved is so large, nearly a hundred, too many to mention individually. A list of all involved is presented in Annex A of Part 3. Two persons deserve special mention. At the top of the project pyramid, Henk Wijnen of VROM-DGM has taken care of co-ordination, budget extensions and the like. At CML, supportive work throughout the project has been carried out by Esther Philips.

Leiden, July 2001
Jeroen Guinée
Project Leader

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PART 1

LCA IN PERSPECTIVE

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1 Why a new Guide to LCA?

The first Dutch Guide to Life Cycle Assessment (LCA) was published in 1992. It was written by the Centre of Environmental Science - Leiden University (CML), the Netherlands Organisation for Applied Scientific Research (TNO) and the Fuels and Raw Materials Bureau (Bureau B&G), under the auspices of the National Reuse of Waste Research Programme (NOH). It is often referred to as "the NOH Guide", "the CML Guide", "the Dutch Guide", "Heijungs *et al.* (1992)", and so on. It has been used extensively and has stimulated discussions in scientific and societal fora. However, there are many reasons why an updated Guide is now needed.

In the past decade, there have been many advances in LCA methodology, especially through the scientific work of SETAC (the Society of Environmental Toxicology and Chemistry). In addition, there have been extensive developments in ISO standards relating to LCA. Thirdly, there is the increasing role of UNEP, stimulating the global use of LCA. And finally there is now a broad range of applications for LCA, giving many opportunities for clarification of the original text by means of up-to-date examples.

This new Guide has been commissioned by the Dutch Government, in particular by the Ministry of Housing, Spatial Planning and the Environment (VROM-DGM), the Ministry of Economic Affairs (EZ), the Ministry of Agriculture, Nature Management and Fisheries (LNV) and the Ministry of Transport, Public Works and Water Management (V&W).

The production process of the new Guide has been supported by a group of over a hundred people. They guided our strategy and read and commented on our proposals and texts. They included the Supervisory Committee, the Steering Committee, the project's Think Tank, the International Observers Group and numerous individuals. A full list of names is to be found in appendix A of Part 3.

The Document consists of three Parts:

- Part 1: LCA in perspective. An introduction to LCA, its purpose and background.
- Part 2: Guide. An overview of LCA in practice, consisting of two parts. Part 2a describes how to organise and set up a specific LCA project. Part 2b is an Operational Annex containing tables with data and other practical details.
- Part 3: Scientific Background. This part provides detailed materials and references in support of Parts 1 and 2.

The present Part 1 further clarifies the general purpose and perspective of LCA.

2. Main characteristics of LCA

This chapter explores what LCA is, and what role it can play in different types of decision situations. We also examine how LCA developments are embedded within an international framework of consensus building and standardising activities.

2.1 What is LCA?

In ISO 14040 (see below) LCA is defined as the "compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle". Thus, LCA is a tool for the analysis of the environmental burden of products at all stages in their life cycle – from the extraction of resources, through the production of materials,

product parts and the product itself, and the use of the product to the management after it is discarded, either by reuse, recycling or final disposal (in effect, therefore, 'from the cradle to the grave'). The total system of unit processes involved in the life cycle of a product is called the "product system".

The environmental burden covers all types of impacts upon the environment, including extraction of different types of resources, emission of hazardous substances and different types of land use. The term 'product' is taken in its broadest sense – including physical goods as well as services; it includes goods and services at both operational and strategic levels. It is important to note that in comparative LCA studies, it is not the products themselves that form the basis for the comparison, but the function provided by these products.

LCA is, as far as possible, quantitative in character; where this is not possible, qualitative aspects can – and should – be taken into account, so that as complete a picture as possible is given of the environmental impacts involved.

Most important, a cradle-to-grave analysis involves a 'holistic' approach, bringing the environmental impacts into one consistent framework, wherever and whenever these impacts have occurred, or will occur. One fundamental reason for choosing such an approach is related to the fact that the final consumption of products happens to be the driving force of the economy. Therefore, this final consumption offers core opportunities for indirect environmental management along the whole chain or network of unit processes related to a product.

Another fundamental reason is that a cradle-to-grave approach avoids 'problem shifting'. It is important in eco-design not to solve one environmental problem merely by shifting it to another stage in the product's life cycle. For instance, making a car out of aluminium instead of steel means that its gasoline consumption is reduced, but the production of aluminium requires more energy than that of steel. Only when all these facts are taken into account can it be judged whether a car made of aluminium is truly more environmentally friendly than one made of steel.

The main applications of LCA are in:

- analysing the origins of problems related to a particular product;
- comparing improvement variants of a given product;
- designing new products;
- choosing between a number of comparable products.

Similar applications can be distinguished at a strategic level, dealing with government policies and business strategies. The way an LCA project is implemented depends on the intended use of the LCA results.

2.2 Role of LCA in relation to products

LCA can play a useful role in public and private environmental management in relation to products. This may involve both an environmental comparison between existing products and the development of new products, which also includes comparisons with prototypes. In this section, we discuss different technical types of applications; in section 2.6, we will briefly discuss procedural situations, which can be distinguished for different technical types of applications.

For instance, a major application involves 'green' procurement – that is, a 'green' purchasing policy, which can be implemented by both authorities and companies. However, the ranking

of resources, materials or products for purchasing reasons need not necessarily be done on a quantitative basis, using LCA. Thus, tropical hardwood with a label from the Forest Stewardship Council (FSC) can, without LCA, be compared with hardwood without such a label (as long as all other aspects remain the same), using a simpler and more focused style of analysis based on just one qualitative criterion. However, if different types of processed wood are to be compared for other reasons besides avoiding the use of tropical hardwood, LCA may well make an essential contribution.

Another application concerns eco-labeling (i.e. assigning a 'green label' to environmentally-friendly product alternatives), enabling consumers to make comparisons between products. Eco-labeling programmes like the EU's are increasingly based on LCA. Up to now, some of these programmes have not lived up to their expectations. Positive examples in this area are the Blue Angel eco-labeling programme in Germany and the Green Swan eco-label in Scandinavia.

A further application in relation to products is the design of more environmentally friendly products, otherwise known as eco-design. This is an activity of increasing importance, which imposes specific requirements on the available life cycle information: it must be very simple to use. It is generally an activity in which the results of LCA are used within the company, rather than in the market place.

2.3 Role of LCA in wider applications

Apart from direct product applications, it is also possible to use LCA in a wider sense. Rather than dealing with well-defined physical goods or simple services, LCA is applied here to complex business strategies or government policies relating to consumption and lifestyle choices in various sectors of society. As in the situations described above, it is the function provided which is the core object of the LCA project, but now this function is more complex, more encompassing, and related to strategic decisions.

Examples of the wider applications of LCA include:

- The choice of one-way packaging by an industry. The EU's Packaging Directive allows this, on condition that it can be proved that this creates less of an environmental burden than the use of reusable packaging materials.
- Comparison between different types of waste management by a municipality, or the development of a waste management strategy.
- Assessment of the environmental benefits of different types of biomass use (including thinning wood), for instance in the production of electricity or paper.
- Strategic comparison between different modes of freight transport (road, rail, water) as a basis for public investment in new infrastructure.
- The 'greening' of the building industry. In the Netherlands, for instance, new houses must in the future meet minimum environmental requirements. In addition to energy consumption, this specifically includes requirements on the environmental burdens imposed by all materials used in the building of a house, to be based upon quantitative LCA.

The difference between the two areas distinguished here, that relating to products and the wider applications, is in fact merely one of degree. For instance, the first and the last example mentioned above, that of the choice for one-way packaging and of LCA in the building industry, offers the potential of 'greening' every aspect of the industries involved. At the same time, it could also be seen as an example of product policy, where the product is unusually large – a whole building.

Convergence between the requirements of LCA in product policy and wider applications is also seen in eco-design. For instance, LCA is used in the design of new cars in the German automotive industry. The design process itself allows only simple criteria to be used. However, once a car has been completed, a full LCA is performed on the end product. The results of this analysis provide the basis for the establishment of – again simple – new design criteria. This process implies a ‘learning curve’.

This also points at yet another type of application. In all of the above applications, LCA is used on a project basis: the goal of the project is defined, the study is performed and the conclusions are drawn. But the scope of LCA practice can also be further widened, by using LCA rather as a management tool, on a more continuous basis. In this case, criteria are derived from a more extensive LCA study, which are then used for the ongoing monitoring of the management process. A specific example concerns benchmarking of business and governmental activities.

2.4 Limitations of LCA

The core characteristic of LCA is its 'holistic' nature, which is both its major strength and, at the same time, its limitation. The broad scope of analysing the complete life cycle of a product can only be achieved at the expense of simplifying other aspects.

First of all, LCA cannot address localised impacts. It is possible to scale down some of the results and to identify the regions in which certain emissions take place, after which differences in the sensitivity of these regions can be taken into account in the context of LCA. But LCA does not provide the framework for a full-fledged local risk assessment study, identifying which impacts can be expected due to the functioning of a facility in a specific locality.

The same is true for the time aspect. LCA is typically a steady-state, rather than a dynamic approach. However, future technological developments are increasingly taken into account in more detailed LCA studies.

The LCA model focuses on physical characteristics of the industrial activities and other economic processes; it does not include market mechanisms or secondary effects on technological development.

In general, LCA regards all processes as linear, both in the economy and in the environment. Again, some progress is being made in reducing this limitation, but at heart, LCA is a tool based on linear modeling.

Furthermore, LCA focuses on the environmental aspects of products, and says nothing about their economic, social and other characteristics. The environmental impacts are often described as "potential impacts" (see also the ISO definition), because they are not specified in time and space and are related to an (often) arbitrarily defined functional unit.

Although LCA aims to be science-based, it involves a number of technical assumptions and value choices. An important role is played by the ISO standardisation process, which helps to avoid arbitrariness (see below). An important aim is to make these assumptions and choices as transparent as possible; this is also an important element for embedding LCA in procedures (see also Part 2a).

A further limitation can lie in the availability of data. Indeed, databases are being developed in various countries, and the format for databases is being standardised (see below). But in

practice, data are frequently obsolete, incomparable, or of unknown quality. More in particular, data are generally available at the level of building blocks, i.e., for combinations of processes such as 'electricity production' or 'aluminium production', rather than for the individual constituting processes themselves.

Finally, a more fundamental characteristic concerns the nature of LCA as an analytical tool. As such, it provides information for decision support. LCA cannot replace the decision making process itself. One cannot say: 'The LCA study has proved that this decision must be made,' but rather 'Based on an LCA study and other evidence, the following decision has been made.' This last aspect calls for a clear view of the procedural aspects of the use of LCA, a point given ample attention in this Guide.

2.5 LCA as part of a tool box

The above limitations of LCA can be addressed by extending the analysis and/or bringing in other analytical tools to given decision situations.

For instance, a product can be analysed using LCA and, at the same time, a Risk Assessment (RA) can be performed for a number of core processes in the chain, in which the emphasis is on the local environmental impacts. Both types of data may well be relevant for decision making.

Another useful approach is the complementary use of LCA and Substance Flow Analysis (SFA). This is particularly appropriate if one specific substance dominates the product, such as cadmium in rechargeable batteries or phosphates in detergents. For a single substance, market mechanisms might then also become part of the analysis.

Of course, the complementary use of various tools is imperative if one is interested in other aspects of a new product, such as the wider environmental implications or social and economic aspects. Such aspects include public health and safety (e.g., the quality of food products) animal welfare and the use of child labour in the production stage of a product.

Where economic aspects are concerned, there is the Life Cycle Costing (LCC) approach for evaluating the economics of the life cycle of a product. LCC can be expected to become a standard addition to LCA applications.

The aim is to provide a tool box which offers opportunities for different types of analysis, in line with the requirements of the given decision situation. The limitations described in the previous section not only refer to the state of the art of the various tools, but also to the availability of correct data. Such a tool box is therefore a long-term goal, rather than one to be achieved in the short term. Nevertheless, the aim of combining the use of different tools in one decision situation is certainly valid.

2.6 Management of LCA projects: procedures

LCA studies can be performed in a whole range of different decision-making situations, ranging from mere internal use to public comparative use. These different situations also impose different requirements on the type of decision procedure which has to be followed.

The present Guide distinguishes the following decision situations (see Box).

Global exploration of options	The LCA study is performed to get a first impression of the environmental effect of certain options.
Company-internal innovation	The LCA study is performed to assess the environmental impact of company-internal product improvements, product development or technical innovations.
Sector-driven innovation	Similar to the above, except that it is sector-oriented (in a formal organisation representing a branch of chain of companies, it can be regarded as an internal activity).
Strategic planning	The LCA study is performed to assess the environmental impact of strategic scenarios.
Comparison	The LCA study is performed to assess whether a product or system meets certain environmental standards, or whether it is environmentally sounder than another product or system.
Comparative assertion disclosed to the public	The LCA study aims to provide an environmental claim regarding the superiority or equivalence of one product versus a competing product which performs the same function.

These six situations are subsequently grouped into three categories: situations with few diverging interests and with potentially strong impact; situations with many diverging interests and with potentially weak impact; and situations with many diverging interests and with potentially strong impact. Guidelines have to be set particularly for how to deal with assignment, critical reviews, process planning and management and with stakeholder participation. These procedural guidelines become stricter as one goes from the first to the third group of decision situations.

3 International developments

LCA is a core topic in the field of environmental management. Its history goes back to the early seventies, though in the past, it went by different names such as Resource and Environmental Profile Analysis (REPA), Energy Analysis or Product Ecobalance. Here we review the role of a number of international bodies that have been – and are – concerned with the development and application of LCA.

3.1 SETAC

SETAC (the Society of Environmental Toxicology and Chemistry) was the first international body to act as an umbrella organisation for the development of LCA. It is a scientific organisation with its roots in academia, industry and government and, as such, has been able to offer a science-based platform for the coherent development of LCA as a tool. SETAC's aims are scientific development in specific areas of research and application of the results in the field of environmental management.

SETAC's involvement with LCA dates from 1989, when its first workshop was held in Smugglers Notch, Vermont. A year later this was followed up with a workshop in Leuven, Belgium. These workshops set the scene for the emergence of two different schools of LCA development in North America and Europe, which have dominated the scene for many years.

The main activities of SETAC's LCA section are:

- annual scientific meetings both in North America and Europe, which are a regular part of SETAC's meetings calendar and include sessions focusing on LCA methodology development;
- an annual Case Studies Symposium, held in Brussels, focusing on the application of LCA in different branches of industry;
- since 1996, a number of working groups which deal with different aspects of LCA methodology and application, both in Europe and North America.

The European working groups have regarded the development and harmonisation of LCA methodology as their main aim, while the North American groups have focused on analysing the limitations of LCA and warning against its unwarranted use.

Despite the differences between the two SETAC branches (North America and Europe), there are also major areas of co-operation. A major example has been the development of a 'Code of Practice' for LCA. This was an important step towards harmonisation of the tool, as it presented the first internationally accepted technical framework for LCA. It may be hard to recall, from today's standpoint, but even the term LCA was not generally accepted in the late 1980s – the tool was still being called by a number of alternative names. The Code of Practice pointed out that, besides science, LCA also involves procedural aspects and value choices. Indeed, this Code of Practice was the forerunner of the activities which are now performed under ISO.

3.2 ISO

ISO (the International Organization for Standardization) is a world-wide private organisation, including national bodies from both industrialised and developing countries, which aims to standardise a wide range of products and activities. One of its key activities is the development of the 9000 series of standards, which is aimed at the integration of quality aspects into business practice.

The 14000 series of ISO standards includes the standard 14001 on Environmental Management Systems, as well as a series of standards relating to LCA (the 14040 series). These ISO activities began in 1994 and aim to produce the first complete series of LCA standards.

The ISO LCA standards concern the technical as well as organisational aspects of an LCA project. The organisational aspects mainly focus on the design of critical review processes, with special attention to comparative assertions disclosed to the public. They also cover matters such as the involvement of stakeholders

The following general standards and technical reports have been or are being produced by ISO in the 14040 series (Environmental management - Life cycle assessment) :

- ISO 14040: A standard on principles and framework. 1st Edition 1997
- ISO 14041: A standard on goal and scope definition and inventory analysis. 1st Edition 1998
- ISO 14042: A standard on life cycle impact assessment. 1st Edition 2000
- ISO 14043: A standard on life cycle interpretation. 1st Edition 2000
- CD 14047: A draft technical report presenting examples for ISO 14042 on life cycle impact assessment (in preparation)
- CD 14048: A draft standard on data format (in preparation)
- TR 14049: A technical report presenting examples for ISO 14041 on the life cycle inventory phase. 1st Edition 1999.

In addition, other ISO activities also bear a relationship to the ISO series on LCA. One example concerns the technical report TR 14025 on so-called Type III environmental declarations, which require a life cycle approach, including formal LCA. Another example concerns TR 14062, a technical report which is still in preparation, dealing with guidelines to integrate environmental aspects into product development, and also involving life cycle aspects.

Scientific activities within SETAC have greatly enhanced the quality of work in ISO. At the same time, ISO has played a major role in bringing together the different schools of LCA, by requiring agreement on every single word of the different standards. The choice of wording in terms of 'may', 'should' or 'shall' – the three normative vehicles of any standard – was a particularly good example. The international standards and additional technical reports have also greatly enhanced the acceptance of LCA as a tool for decision support by both industry and government.

It is to be expected that after the completion of the first full series of the 14040 standards and technical reports, a second, revised series will be compiled, taking account of new developments in LCA methodology.

3.3 UNEP

A third international player in the field of LCA is UNEP (the United Nations Environmental Programme), represented by its Department of Technology, Industry and Economics in Paris. UNEP's focus is mainly on the application of LCA, particularly in developing countries. An important contribution was the publication in 1996 of UNEP's user-friendly and easy-to-read guide to LCA, entitled *Life Cycle Assessment: What it is, and what to do about it*. A second publication of interest is *Towards Global Use of Life Cycle Assessment*, published in 1999. Furthermore, a series of international workshops dealing with various aspects of LCA are being organised by the Environmental Protection Agency of the US (US-EPA) and CML in the Netherlands, under the auspices of UNEP.

SETAC and UNEP are now co-operating in a major new task, concerning the identification of best available practice in the field of life cycle assessment, on the initiative of a SETAC-Europe working group. The task involves the identification of best available practice in establishing a database for the life cycle inventory phase, and a list of environmental impact categories and accompanying factors to address these impact categories.

4 Guiding principles for the present Guide

The following guiding principles were used in the preparation of the present Guide.

- It had to be based on up-to-date science, as developed within the scientific community of SETAC and its working groups.
- It had to operationalise the ISO standards in a 'cookbook' format, being as compatible as possible with the ISO standards on LCA and indicating explicitly where the present Guide goes beyond ISO.
- It had to be unambiguous, specifying best practice. In places, other LCA methods, leading to different outcomes, are presented. This has been done in such a way that they can easily be incorporated into a sensitivity analysis.
- It had to be relevant to various types of applications. This involved having a baseline practice specified, differentiating between a simplified and a detailed method. Possibilities for extensions aimed at specific applications are also considered.

- It had to be a practical Guide, aiming for precise guidelines for use in practice. These are presented separately from the descriptions of operational methods and data and from the description of the scientific background. They are illustrated by a number of examples.
- It had to present the guidelines in the framework of a number of possible decision situations, specifying the relevant procedural steps to be taken.

5. Reading guide

The present Guide consists of the following Parts.

Part 1, the part in front of you, gives a general overview of LCA in perspective: the reasons for developing a new Guide, the main characteristics of LCA, the main international developments and the guiding principles for the present Guide. The main target audience of this part is those who use the results of LCA, for instance policymakers and corporate managers.

Part 2 is the Guide itself, which itself consists of two parts. Part 2a deals with process management and procedural guidelines, and contains an overall description of the technical guidelines. Part 2b offers an operational annex, including elements for all LCA phases but emphasising modeling rules for the inventory phase and factors for the impact assessment phase. This part is mainly intended for those carrying out life cycle assessments.

Part 3 offers an overview of the scientific background for the guidelines presented in Part 2a. Its main intended readership is scientists working on the further development of LCA and persons carrying out LCAs or using the results of LCAs who wish to understand why certain methodological choices have been made, which other options could be considered, and why the possibilities and limitations of LCA are as they are.

Additional reading guides for Parts 2 and 3 are provided within these documents.