PART 2A

GUIDE

Reading guidance

This is Part 2a of the publication entitled “Life cycle assessment: An operational guide to the ISO standards”. The entire publication consists of three parts:

- Part 1 (“LCA in perspective”) is a short introduction describing in broad terms the purpose, role, applications and limitations of life cycle assessment. Its main intended readership consists of people who have to commission the execution of LCAs and who will use the results of such analyses.
- Part 2 consists of two parts: 2a (“Guide”) and 2b (“Operational annex”). Its target audience is those concerned with the actual execution of LCAs. Depending on the context and the complexity, this may be one person or an entire research team with diverging backgrounds, such as process technology, product design, end-of-pipe solutions, ecotoxicology and so on.
- Part 3 (“Scientific background”) provides the foundations and arguments for certain methodological choices, the alternative options available, and much more. It is intended to stimulate scientific debate and progress and to function as a reference book for those who wish to learn more about the rationale behind the Guide’s rules.

The working method for LCA is structured along a framework that has become the subject of world-wide consensus and that forms the basis of a number of ISO standards. This framework divides the entire LCA procedure into four distinct phases:

- Goal and scope definition
- Inventory analysis
- Impact assessment
- Interpretation

The present Guide has chapters corresponding to each of these four phases. In addition, an opening chapter on procedures for managing LCA projects has been included, bringing the total number of chapters to five.

Chapter 1 presents rules that should be kept in mind during the organisation, assignment and progress of LCAs. Chapters 2 to 5, which are devoted to the four LCA phases, each consist of four sections:

- Topic, describing briefly the role and function of this phase.
- Starting points, summarising the main methodological considerations for this phase.
- Recipe, providing detailed instructions for carrying out this phase.
- Results, describing results that will be obtained from this phase.

Within each of the four phases, there are several steps (like characterisation) and elements (like a flow diagram). Because the elements also involve steps to be taken (like constructing the flow diagram), only the term "step" will be used in the remainder of this document. These steps are presented as individual subsections in the Recipe section of each phase. Their treatment is almost invariably as follows:

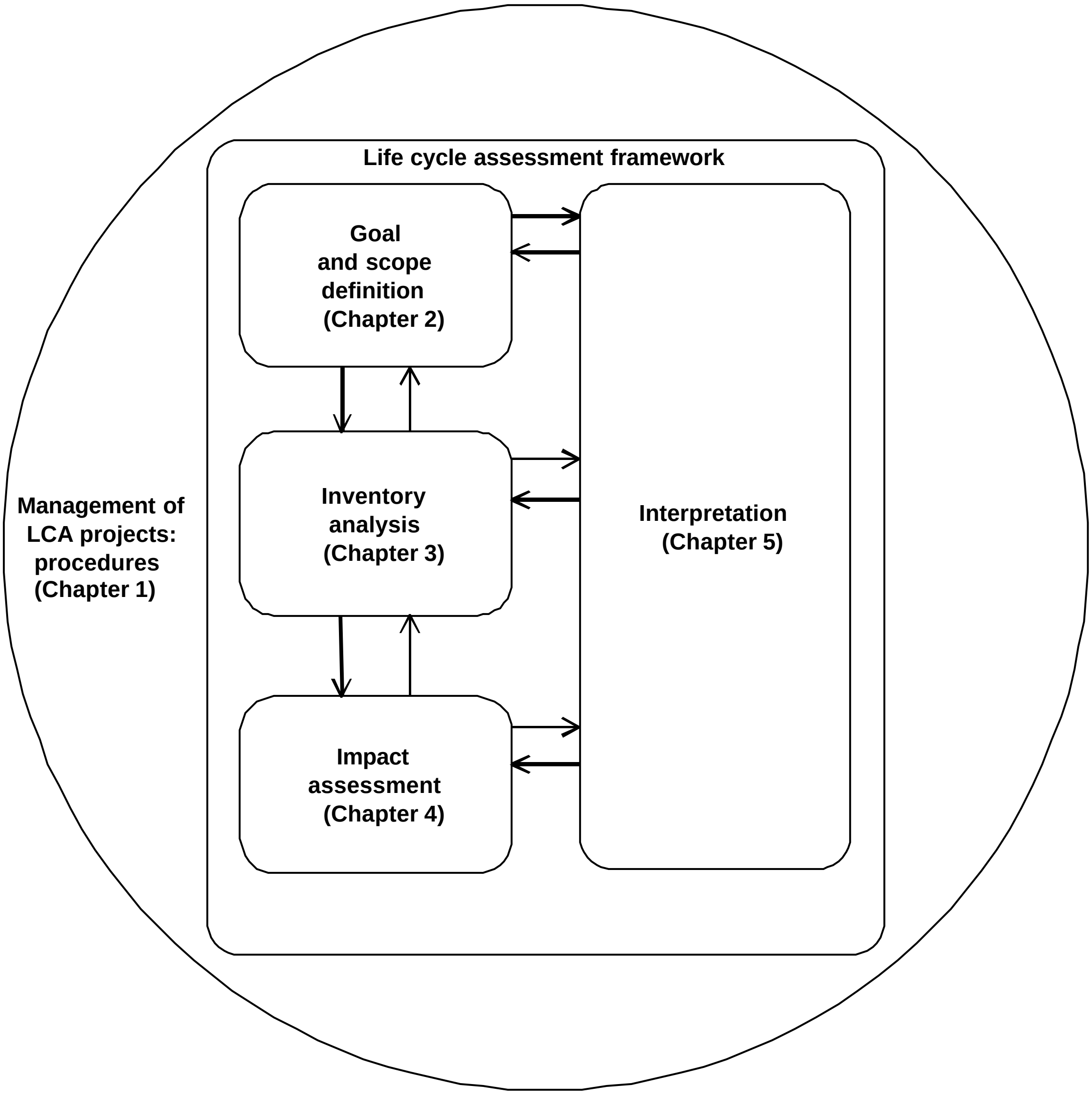
- Topic, describing briefly the role and function of this particular step.
- Main choices, summarising the basis for implementation of this step.
- Guidelines, providing detailed instructions for this step.
- Example, using a hypothetical situation to illustrate[1] the application of the guidelines.

[1] It should be understood that a strict application of the guidelines would mean that the examples for certain steps would require 50 pages or more. Therefore, we have chosen to give the examples an illustrative function only, without pretending to be purist. Furthermore, most – though not all – examples are based on a simple hypothetical system, the data for which is provided with the CMLCA software.

Since an LCA can be conducted at various degrees of sophistication, the guidelines distinguish between the baseline detailed level, a simplified level, and possible extensions to the detailed level. Note that in a detailed LCA, certain steps may be conducted at the simplified level, or that it is possible to choose, even within one step, to apply detailed guidelines for some unit processes or impact categories and simplified guidelines for others. Note also that a simplified LCA is not simple in the sense of being easy.

The guidelines for simplified LCA are largely in line with the ISO standards, but not entirely. For example, the allocation procedure recommended for simplified LCA does not comply with the stepwise procedure described in ISO 14041. The guidelines for detailed LCA comply fully with the various ISO standards, however, although they are elaborated here at a more operational level. Many of the optional extensions do not fit into the ISO framework.

Application of the guidelines requires detailed working instructions and data. All data, and especially all extensive tables with substance-specific factors, and all instructions that extend beyond a few lines have been included in the operational annex (Part 2b). To ensure proper correspondence with the step to which they belong, the numbering of chapters and sections is the same for Parts 2a and 2b.



Contents

1. Management of LCA projects: procedures

1.1 Designing an LCA project

An LCA project is more than just a study. The results of the project could be used in decision-making by industry, government and non-governmental organisations. They could guide decisions on investment, policy issues or strategy determination. So it is best to consider an LCA project as an organisational process, which can be carried out in several ways.

This process approach is based on the idea that the results of an LCA will only be considered authoritative if the most important stakeholders have been involved in the analysis. This has to be done in a proper and correct way, necessitating a process design which should define:

- the parties and the individuals who will be involved in the LCA project;
- the tasks and responsibilities of parties/individuals involved;
- the points at which the parties/individuals involved can exercise their influence (decision points);
- how decision-making will work at these points;
- the arrangements for dealing with ‘bottlenecks’ during the process;
- the actual planning and management of the process.

The execution of an LCA and the accompanying process should be carefully attuned to its ultimate goal. This requires that both the LCA client and other possible stakeholders reflect upon this goal. Meanwhile, the LCA researchers themselves should also keep the goal firmly in mind, considering how this could affect the conditions and constraints of the project itself. The LCA client also needs to consider the design, the organisational set-up and the management of the accompanying process.

A suitable process design can be defined as a set of rules agreed on by the parties involved; these cover who is involved, and also when and how the process is to be carried out. A proper and transparent process can only be realised by a design that maximises all potential advantages, whilst keeping the risks of the process approach to a minimum.

The advantages of the process approach are that a qualitatively better LCA is realised, and that broader support for the results from the parties involved is more likely to be achieved. After all, the stakeholders are far more likely to support the results of an LCA project if they themselves have been actively involved in the execution of the analysis.

Further advantages of the process approach include:

- the opportunity to educate stakeholders and shape their views;
- better quality of the data and other information used in the LCA;
- improved transparency of the LCA report;
- better quality of execution of the LCA.

However, the process approach does carry some risks – mainly of improper manipulation by stakeholders or researchers of the study itself, the results of the analysis or the decision-making process.

The process design must be clear in its objectives, which means that a distinct starting point and a distinct endpoint of the process must be defined. An optimised interaction between the execution of the LCA as such and the practical use of the LCA's results should be arranged.

In general, four steps can be distinguished in LCA-based decision-making processes:

- assignment of the research;
- execution of the LCA;
- presentation of the LCA's results with conclusions;
- implementation based on the LCA's results.

All parties involved can influence the procedure and choices in these four steps. A process design should indicate who can make decisions, when they should be made, and what can be decided in each step.

1.2 Context of an LCA project

The organisational set-up and execution of the decision-making process should be attuned, as far as possible, to the specific nature of this kind of decision-making and to the process context. For instance, making a decision on whether to replace long-life products by disposables might require more process regulation than decision-making on product innovation, especially where there are sharply diverging views among interested parties.

What determines the type of process design and development is, first of all, the nature and number of parties with diverging interests. Secondly, the possible effects of the intended use of the LCA's results also determine the extent and manner of regulation of the development process. Part 1 (Section 2.6) distinguished six different process situations and stated that LCAs are conducted to obtain results that can be used in:

- global exploration of options (the LCA study is conducted to get a first impression of the environmental effect of certain options);
- company-internal innovation (the LCA study is conducted 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, although in a formal organisation representing a branch or chain of companies, it can be regarded as an internal activity);
- strategy determination (the LCA study is conducted to assess the environmental impact of strategic scenarios);
- comparison (the LCA study is conducted to assess whether a product or system meets certain environmental standards, or whether it is more environmentally sound than another product or system);
- comparative assertion disclosed to the public (environmental claim regarding the superiority or equivalence of one product versus a competing product which performs the same function).

It is self-evident that in a situation of global exploration or company-internal innovation, there is, in general, less need for process regulation than in a situation involving disclosure or justification to the public. For process situations in between these two extremes it is important to realise what impact the LCA's results can have for the parties involved. In such situations, there may be potential interests which could be important for long-term strategies, but one or more of the parties could also be affected by more short-term interests.[1]

Note that determining the decision situation in advance of the execution of the LCA study does not imply that the decision to be taken is already fixed. It only implies that a certain decision is aimed for and that a number of procedural arrangements may be necessary.

With respect to the process context, four categories can be defined by making distinctions on grounds of diverging interests and on the relative potential impact of the LCA's results on the

[1] Part 1 (Section 2.3) also mentioned another evolving type of LCA application: LCA as a management tool on a more continuous basis, as in benchmarking. This type of application has not been given any specific attention during the work on procedures described here.

stakeholders. In the case of global exploration of options, there are generally few diverging interests, and there is a weak impact. In such a situation, a process approach is unnecessary. In the remaining three cases, process design needs to be attuned to the various process contexts. These are described below:

- process context I: few diverging interests, potentially strong impact;
- process context II: many diverging interests, potentially weak impact;
- process context III: many diverging interests, potentially strong impact.

Figure 1.2.1 helps to determine the process context that is applicable.

You are going to execute an LCA and you have determined how you will use the LCA's results after completion of the LCA. Answer the following questions:
1. Will there be many parties involved in the use of the LCA's results ?
2. In your opinion, are the interests of these parties widely divergent?
3. Can the results of the LCA have important consequences for one of these parties ?
4. Do the other parties share your views on the interests of the parties ?

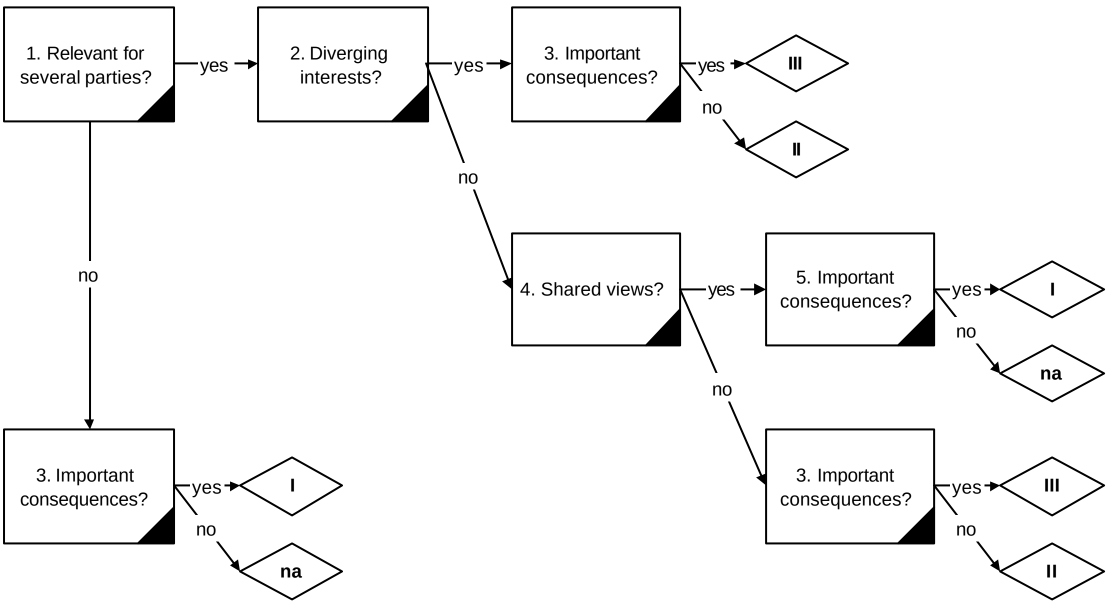


Figure 1.2.1. Decision tree for determining the process context of a given decision situation.

1.3 Process management in LCA

Many LCAs are conducted as company-internal matters. They may be restricted to a general exploration of the environmental burden associated with specific options, in which case the procedural approach to the LCA project can remain a purely internal affair. But the results of LCA projects often have more far-reaching implications, in that policy choices, investments and other important decisions may be driven by them.

Realisation of a correct and transparent process involves shaping the execution of the process in accordance with the process design, as arranged by the various parties involved. In the case of processes in context III (above), the appointment of an independent process manager is recommended.

The next chapters of this Guide provide procedural guidelines for the process management of the separate phases of LCA. In the meantime, the following general principles can be given:

Process rules according to the decision situation

All procedural guidelines for the specific LCA phases are given for the three distinct types of process context. In general, context III is the most complex and requires the most detailed rules.

Process rules based on guidelines for LCA phases

The exact definition of the guidelines does not depend on the complexity of the LCA itself, but rather on the complexity of the interests of the parties involved. It is possible, for instance, that a relatively simple LCA will require a detailed LCA process – because of the varied interests of those involved. This implies that the procedural guidelines only provide a general basis for detailed process rules, which themselves have to be designed by the parties involved in a given situation.

Process design based on general guidelines

The following nine guidelines can form the basis for process design:

- Entry guideline
  The following parties should be invited to be part of the decision-making process: all who have an interest in the results of the LCA and those who could influence or block the purpose of the LCA.
  This basic rule will need to be worked out in each specific context. It may be necessary to involve more parties – because of policy considerations – or to restrict the number, in the interest of management considerations.
- Consensus guideline
  The most important guideline for decision-making is to have decisions made by consensus, and to use a majority of votes, arbitration, or another previously determined procedure for decision-making only if there is no other alternative. The reason is that those who find themselves in the minority a few times may lose commitment to the process and so to the final result.
- Minority gets a say
  It is important that minority wishes should be granted if they do not run counter to the majority view. For example, a minority party may want a supplementary analysis to be conducted. Granting such a wish is sensible, because it will increase the authoritativeness of the final result of the LCA. If the wish is not granted, the minority may dissociate itself from the final conclusions.
- Test of professionalism
  When parties negotiate the formulation of an assignment or an interim report, they may, in the interest of consensus, produce an assignment or statement that turns out not to be up to scientific standards in terms of content. For instance, the formulation of the assignment could contradict the core scientific content of this LCA Guide. In such cases, the investigators should test the content of the parties' statements and report explicitly when they find a statement debatable in scientific terms.
- Reporting in the case of a conflict between investigators and stakeholders
  In such cases, the investigators' opinions should be explicitised in the LCA report. This allows the investigators to keep their professional integrity intact, while stimulating the stakeholders to revise their opinion.
- Explicitness
  Stakeholders may have conflicting opinions about, for example, the formulation of an assignment, about the quality of the result of an investigation or about the analysis of such results. The rule of explicitness ensures that the stakeholders make such differences of opinion explicit. They must indicate – preferably in writing – what they understand the difference of opinion to be.

- External test rule (critical review or peer review)
  This rule states that there should be external testing of certain aspects of an LCA project during the process by independent critical review. ISO10404 states that the critical review shall ensure that:
  - the methods used to carry out the LCA are consistent with the ISO standards on LCA;
  - the methods used to carry out the LCA are scientifically and technically valid;
  - the data used are appropriate and reasonable in relation to the goal of the study;
  - the interpretations reflect the limitations identified and the goal of the study;
  - the study report is transparent and consistent.

  A critical review could, for instance, be applicable to an interim LCA report, or to specific issues giving rise to conflict between investigators and stakeholders, or to conflict between stakeholders. But it may be useful to have a critical review carried out in any case, by way of overall error check, and to justify the reasonableness of assumptions, the appropriateness of data and the correctness of methods.
- Reporting in the case of a conflict between stakeholders
  This second reporting rule allows for unresolved conflicts between stakeholders to be described in the final report. In such cases, one or more stakeholders may dissociate themselves from the results because they feel the LCA guidelines have not been properly applied. The reporting rule requires that a judgement by the research institute and a critical reviewer be added to the stakeholders' opinions. On the one hand, this does justice to minority opinions, since these are noted in the final report. On the other hand, strategic behaviour is exposed, since it will become evident if minority views cannot stand up to a critical appraisal of their content.
- Iteration rule
  One or more stakeholders may require iteration, particularly in the last two process steps. If all parties agree, there is no problem, but if a minority group wants iteration, a conflict may arise. Other parties may wish to end the investigation. The iteration rule says that if a minority wants iteration of the last two steps, this should be allowed.

It should be realised that a process involving many parties cannot be driven by rules alone, and that the way the process is managed is equally important. Can the process manager create sufficient confidence that all parties will participate in all consultations arising from the LCA project?

This is important, since each guideline can be used by uncooperative parties for their own ends, particularly to slow down the whole process. It is up to the process manager to make it clear that everyone profits from a proper application of the rules – and that they all suffer if the rules are abused. There is much to be gained if the manager can make this clear to all concerned.

1.4 Organisation and assignment

Before the start of the executive work in the first phase of LCA (the Goal and scope definition; see Chapter 2), the organisational set-up needs to be established. The following points have to be taken into consideration.

Selection of stakeholders

Selection of the interested parties should be based on the entry guideline described above. ISO 14040 identifies a number of possible categories of participants in the example of a 'comparative assertion that is disclosed to the public' requiring a critical review.

Assignment

The actual execution of the first phase of a study should follow a clearly formulated assignment procedure. In LCA, this formulation should not be regarded as merely a necessary preparatory activity, but rather as an important first step and as part of the execution itself and the underlying process. The execution of the first phase (the Goal and scope definition) is so closely connected to the formulation of the assignment that intensive interaction between the LCA client and the LCA researchers will be necessary.

In practice, it has been noted that lack of foresight at the assignment stage creates certain risks. Unjustifiable simplifications must be avoided - as must extrapolation of the LCA results. For instance, if the analysis aims at a general comparison of two types of product systems, it is insufficient to merely compare a few specific cases.

The process design also needs to describe how the assignment might be revised in the light of new information, such as changes in the intended use of the LCA, the involvement of stakeholders, LCA quality requirements, and so on.

Project organisation

Revising important principles, the formulation of the assignment, and/or process planning should all be avoided during the actual execution of an LCA. Therefore, a well-planned process design and management are essential. This is best done by focusing attention on the following key points:

- views on assignment, process planning and process management;
- selection criteria for parties to be involved in the process;
- possible choice of an independent process manager;
- description of the intended use of the LCA results in the assignment, and the feasibility of that use in terms of the budget and limitations of the LCA;
- description of the intended quality of the LCA results in the assignment;
- intentions with respect to the execution of one or more critical reviews (under ISO it is possible to choose a critical review and/or panel review);
- intentions with respect to the extent of transparency of the report, regarding principles, data, assumptions, choices and so on;
- methods of obtaining an independent validation of non-public data and/or data delivered by interested parties (critical review);
- other process principles, process intentions and intended procedures required to achieve the proper course of the process;
- possible departures from the guidelines during the course of the process and the motivation for such deviations.

The organisational set-up of a properly carried out LCA project requires the initiator to pay particular attention to the first steps, followed by a common approach shared by the stakeholders. From the start, the competencies of all parties should be established, with respect to both the set-up and the other four phases.

1.5 Reporting an LCA project

Reporting is a crucial issue in LCA. A technically excellent LCA without a transparent and unambiguous report will be of very limited value. This applies not only to external studies but also to internal studies. The requirements for external studies are clear: claims made to the public, the use of results by governments and all other applications which involve third parties will require that these third parties can see which choices and assumptions have been made, which parts of the life cycle have been excluded, which data have been used, and so on. For internal studies there is not primarily a need with regard to third parties, but third parties may become involved over time, as experience has shown that company-internal innovation studies sometimes come to be used outside the company. Even for purely internal purposes, however, clear reporting is of prime interest. An LCA may often spawn product or process improvements, and after a year or so there may be an update study which builds on the original one. Moreover, the steps involved are complicated and there are many points at which data are needed and assumptions and choices have to be made. The baseline quality of an LCA can only be guaranteed if all steps undertaken are clearly reported. It is therefore only natural that a Guide for LCA should include guidelines for setting up a clear report.

The chapters below provide many guidelines indicating how specific issues (choices, assumptions, data, calculation rules, results, conclusions) are to be reported. But there are also certain general principles for reporting LCA. There are three main guiding principles:

- all issues should be reported;
- all issues should be reported in a transparent way;
- all issues should be reported explicitly.

However, if we adhere to these main principles, reporting on an LCA becomes an extremely time-consuming activity, and LCA reports become huge documents. Fortunately, the present Guide and related documents have “pre-digested” a large number of choices and data, and a simple reference to this Guide and the related texts will often suffice. For instance, Part 2b of this Guide contains dozens of pages with characterisation factors. If these are used in a case study, a proper reference may replace the retyping of these tables. Note, though, that a proper reference is still needed at the appropriate place. What holds for data also holds for argumentation. ISO’s requirement to justify the environmental relevance of the choice of impact categories in an Impact assessment, for instance, can be addressed by referring to the discussion in specific chapters of Part 3 of this Guide.

Nevertheless, reporting on an LCA requires a careful planning and is likely to result in a main report of 20-80 pages, accompanied by annexes with process data and specific characterisation factors, comprising some 50-500 pages, depending on the goal and scope of the LCA. The main report in particular is something that should be planned. Again, the present Guide may assist in the process of writing such a report. It provides certain sample tables that may serve as blueprints for the tables in the main report. This is also true of the structure of the present Guide. It is strongly recommended to have separate chapters for the different phases of an LCA. A blueprint for a report could look as follows:

- Summary
- Introduction
- Procedures
- Goal and scope definition
- Inventory analysis
- Impact assessment
- Interpretation
- Final conclusions

Moreover, many of the steps identified in this Guide should preferably be included in such a report, e.g., economy-environment system boundary, flow diagram, etc. Some of these steps (e.g., calculation method, classification) may only require a short text, while other steps (e.g., data collection and relating data to unit processes, sensitivity analysis and uncertainty analysis) may require a large number of pages, including tables, figures and annexes.

Reporting quantitative results poses special requirements. The following issues need attention.

- Figures that represent quantities, such as mass or volume, are figures relating to units. The units agree with the dimensions of the quantities, and should always be explicitly reported. The guidelines below recommend the use of SI units.

- Figures should never suggest greater precision than is appropriate. For instance, pocket calculators and computer programs often produce results in 8 digits, but only a few of them are significant. Thus, 1/3 should be written as 0.3, not as 0.33333333.
- Figures suggest precision, even if the number of significant digits is limited. When standard errors are available, these may be added, indicated by"±". In other cases, ranges may be available.
- Use a table to present large sets of figures.

In some cases, graphic representation may be useful. However, the design of good graphs is not without its problems. Some issues include the following.

- Add labels for the quantity represented, its unit and the numerical values for at least some of the marks of the axes.
- Be cautious about using one graph to display different quantities at the same time.
- Be cautious about using logarithmic axes.
- Do not limit figure captions to a mere "Figure 12: Results of the characterisation"; expand them to include explanatory material.

As will be clear from the text below on procedures for the various phases of LCA, there will in general be a draft interim report and a final report after revision. It is also emphasized in many places that LCA is an iterative process, which includes regular checks to see whether the choices made are consistent with the goal and scope of the study. It follows that reporting LCA is also an iterative process. It is not a matter of defining procedural steps, gathering data, making calculations and then writing a report. Procedural issues are everywhere in the LCA process, and good decisions by clients, stakeholders, LCA researchers and critical reviewers can only be made on the basis of written documentation, like a draft interim report.

The initialising phase of defining the goal and scope is crucial in this respect. Many choices are made here, relating to purpose, intended application, product alternatives, scope of the analysis, and so on. It also points out where data gaps can be expected, which pitfalls may show up, how much time will be needed for the rest of the LCA, what additional information may be needed, and so on. In practice, a fairly complete report on the Goal and scope definition often serves as a milestone in the LCA project. It provides a good point for rethinking the goal and scope, for allocating budget, for appointing additional reviewers and for deciding whether to continue the project at all. As such, a so-called Goal and scope report plays an important role. One should realise that a Goal and scope report in this sense may be quite different from the chapter on Goal and scope definition in the final complete report, precisely because the Goal and scope report may induce a focus for the goal, a change in scope, or some other major modification of the final LCA plan. Moreover, a Goal and scope report will, in principle, include all of the chapters of the final report (see the list above), although most chapters (Inventory analysis, Impact assessment, Interpretation) will not yet include any results, but only outline the main choices to be made during these phases.

1.6 Example (case history)

Since the late 1980s, Unilever has conducted many LCA-type studies for almost all its major product groups, including margarine, ice cream, detergent and shampoo. Both in the UK and in the Netherlands, various specialists have developed the necessary skills, and have built up a substantial database.

Thanks to this expertise, they have been able to explore improvement options in all parts of the process chain of their products. Unilever has also conducted in-house environmental and market-economic comparisons between one-way and multiple-way packaging for several of its products. These studies were part of the Dutch Packaging Covenant, and have contributed to the formal decision-making process in the Netherlands, involving the government, NGOs, academia and the business community.

Its extensive experience has also enabled the company to conduct a so-called Overall Business Impact Analysis, which formed the basis of its 1998 Environmental Report. This study estimated the combined environmental impact related to the generation of all raw materials, the manufacturing of all products and the use of those products, and related this to Unilever's economic contribution. The outcome of this study has led Unilever to formulate three main environmental focus areas, viz. sustainable agriculture, sustainable fishing and clean water stewardship.

As a consequence of these initiatives, life cycle thinking has become common practice in many places within the company. Although full-scale LCA studies are rarely being conducted anymore, the expertise which has been built up helps to formulate improvement options and to monitor the improvement process.

The next chapters of this part of the Guide describe competencies and responsibilities, together with brief guidelines for handling potential bottlenecks in the various LCA phases by making arrangements that will guarantee the smooth progress of the whole project.

2. Goal and scope definition

2.1 Topic

The Goal and scope definition is the phase in which the initial choices which determine the working plan of the entire LCA are made. The goal of the study is formulated in terms of the exact question, target audience and intended application. The scope of the study is defined in terms of temporal, geographical and technological coverage, and the level of sophistication of the study in relation to its goal. Finally, the products (or product) that are the object of the analysis are described in terms of function, functional unit and reference flows.

2.2 Starting points

The general starting points for the LCA as elaborated in this Guide are as follows.

- There is a focus on change-oriented, structural decisions, that is, the method is mainly intended to support decisions with respect to changing a situation, for instance from one material to another, and for decisions that are assumed to be effective for an indefinite time.
- There is a focus on the main function of a product; possible other functions are identified but ignored or carried over through an allocation step.
- There is no specific focus on particular processes, chemicals, environmental impacts, countries, years and so on. In principle, the analysis covers all processes (cradle-to-grave), taking place at all locations and throughout the entire life cycle period, and includes extractions of natural resources, releases of chemicals, use of land, and all impacts resulting from these interventions.

We have made ISO 14040/14041 the general starting point of the Goal and scope definition and Inventory analysis phases. The ISO requirements have since been made operational through the work of the SETAC Working Group on Inventory Enhancement and many individual projects. The steps for Inventory analysis laid out in the next chapter of this Guide are copied from ISO 14041, with a few adaptations. For a justification and explanation of these adaptations, see Part 3 of this Guide. The requirements of ISO 14041 have been closely followed, with certain additions or further specifications. These are:

- the distinction between two modes of analysis – descriptive and change-oriented;
- a clearer distinction between reporting the main choices to be made in the Inventory analysis, Impact assessment and Interpretation parts of Scope Definition, and in the Inventory analysis, Impact assessment, and Interpretation phases themselves;
- the implementation of an analysis of the data quality in the section on key issues for sensitivity analysis; the latter is conducted as part of the Interpretation phase;
- the choice between actual, standard and recommended performance of products has been shifted to the Inventory analysis phase.

Further information about the individual steps within the Goal and scope definition phase can be found in Part 3.

2.3 Recipe

2.3.1 Procedures

Topic

The procedural organisation should allow for a common treatment of all general and specific subjects that the parties involved will want to discuss during this first LCA phase. Attention should particularly be given to the following issues:

- normative choices to be made prior to defining the goal and scope;
- choices with respect to details of the construction of product systems and scenarios that will be analysed and/or compared;
- choices with respect to the reliability, validity and sensitivity of LCA input and output;
- possibilities for adjusting the details of the assignment and/or LCA process design;
- intentions for the approach to be used in the subsequent phases (including allocation and weighting);
- further LCA process planning and LCA process management.

Main choices

- The procedures in the LCA study must be laid down right from the start of the Goal and scope definition phase. First, a supervision process must be set up. The project initiator should carry out the first steps, while the stakeholders arrange the organisational set-up of the project.
- During this initial phase of the LCA, the supervision process must be set up with due regard to the authoritativeness of the study results. Input from the stakeholders must not be ignored. There must be interaction between all parties involved on topics that are relevant to the goal and scope of the study.

Guidelines

☞ Determine the LCA process context by means of the decision tree in Chapter 1 (Figure 1.2.1).
☞ Determine the competencies and responsibilities of the LCA research scientists, critical reviewers (if any), the LCA clients and other interested parties, using Table 2.3.1.
☞ Address potential bottlenecks in the LCA process by making arrangements on the basis of Table 2.3.2 to ensure the orderly progress of the project.

Table 2.3.1. Overview of the competencies of the various actors during the LCA process for the different process contexts.

Item	Description	Process context		
		I	II	III
1a	first instructions with respect to fulfilment of LCA assignment	C	C or S	S
1b	first instructions with respect to fulfilment of the assignment of a critical reviewer	–	C or S	S
2a	written response to instruction on LCA	L	L + R	L + R

Item	Description	Process context		
		I	II	III
	assignment			
2b	written response to instructions on assignment of a critical reviewer[1]	–	R	R
3a	possible revision of the first instructions on LCA assignment	C	C or S	S
3b	possible report on incompatible opinions on LCA assignment	L	L	L
4	presentation of draft interim report (= draft text of Goal and scope definition)	L	L + R	L + R
5	written reaction to draft interim report on Goal and scope definition	C	C or S	S
6	possible revision of draft report on Goal and scope definition	L	L + R	L + R
7	possible report on incompatible opinions arising during the goal and scope definition	L	L	L
8	final opinion on final interim report on Goal and scope definition	C	C or S	S

Legend

Process context I = few diverging interests, potentially strong impact
Process context II = many diverging interests, potentially weak impact
Process context III = many diverging interests, potentially strong impact
C = first LCA client(s)
S = stakeholders (including C)
L = LCA research scientists
R = critical reviewer

Table 2.3.2 Overview of the arrangements that can be made between the various actors for the different process contexts.

Item	Description	Process context		
		I	II	III
a	widening/supplementation of the study (on request)	o	r	r
b	validation by an independent expert (on request)	o	r	r
c	binding advice on contentious issues by the critical reviewer	o	r	r
d	final decision-making by the largest possible majority, arbitration or another previously determined procedure	o	o	r
e	quantification of the influence of incompatible opinions in the final report	o	r	r

Legend

Process context I = few diverging interests, potentially strong impact
Process context II = many diverging interests, potentially weak impact
Process context III = many diverging interests, potentially strong impact
r = recommended
o = option

[1] The actual implementation of all guidelines in this Guide should be checked in a critical review.

Example (case history)

No example.

2.3.2 Goal definition

Topic

The first step in the Goal and scope definition phase involves stating and justifying the goal of the LCA study, explaining the goal (aim or objective) of the study and specifying the intended use of the results (application), the initiator (and commissioner) of the study, the practitioner, the stakeholders[1] and the intended users of the study results (target audience).

Main choices

- The goal, application, initiator, stakeholders and commissioners must always be defined as unambiguously as possible.
- A special case is that of the so-called comparative assertions disclosed to the public. LCAs reporting on such studies have been a source of controversy in quite a few instances in the past, and therefore require special care.

Guidelines

☞ State the goal(s) of the study unambiguously and transparently, not only in terms of what is to be done (e.g., comparing systems A and B, carrying out a cradle-to-gate or cradle-to-grave analysis, hot-spot identification, etc.), but also in terms of the reasons for executing the study. The intended application(s) and decision(s) to be supported should be defined as precisely as possible.

☞ Determine whether the goal meets the definition[2] of “Comparative assertion disclosed to the public”.

☞ List the parties involved:
- those undertaking the study (the researchers) and their affiliations and LCA experience;
- the LCA commissioner (the client and/or the funding body);
- the target audience (or users) and other interested parties;
- the members of the steering committee or any other supervising committee;
- the expert reviewer(s) and/or members of an expert review panel.

☞ Determine whether LCA is the most appropriate tool to answer the specific research question, or whether other instruments may be more suitable for the goal defined. State the possibilities and limitations of LCA clearly, and clarify the potential value of the use of other tools in addition to LCA (see Part 1 for limitations and other tools).

☞ Check and report whether the general starting points for all phases of the LCA (Goal and scope definition, Inventory analysis, Impact assessment, Interpretation) as described in Sections 2.2, 3.2, 4.2 and 5.2 have been followed. Any deviations from these starting points should be reported and justified. See the general reporting issues (Section 1.5) for the preferred way to report these issues.

☞ Check the formulation of the goal(s) (in relation to the limitations of LCA as stated before). Consider whether adjustments of the goal are necessary or whether there are issues that have to be analysed further in the Interpretation phase. The thoroughness of the check

[1] Referred to in ISO 14040 (1997E) as “interested parties”.

[2] An environmental claim regarding the superiority or equivalence of one product versus a competing product which performs the same function.

and the extent of the adjustments can vary from minor for a simplified LCA to major for a detailed LCA.

☞ If product alternatives are to be compared, determine which differences in results are large enough to allow the conclusion that a certain product alternative is more environmentally sound than another.

Example (hypothetical)

"The goal of the LCA is to identify options for improving the environmental performance of the material polyethylene in disposable bread bags. The results of this LCA will be used for product and process development. The plastic bag manufacturer wants to be able to analyse the effects of changes in its processes, in terms of technology, inputs and product composition, on the total environmental impact. This information, in turn, can be used to prioritise different measures that can be taken to improve the environmental performance. This LCA does not aim at a public comparative assertion.

The study is conducted by Pro-Duct Consultancy Ltd, a moderate-sized private engineering bureau. The commissioner is Bag-Away, a large producer of plastic disposable bags. Interested parties are mainly the plastics industry, bakeries and shops. A steering committee with representatives of the producer, the ministry of the environment and academia will be formed. Finally, an expert review will be carried out at NILCAR, the National Institute for LCA Research."

2.3.3 Scope definition

Topic

The Scope Definition step establishes the main characteristics of an intended LCA study, covering such issues as temporal, geographical and technology coverage, the mode of analysis employed and the overall level of sophistication of the study. A so-called Goal and scope report (see Section 1.5) may also be drafted for the sake of critical review and comments from interested parties. This report should justify all the main choices with respect to the step "Function, functional unit, alternatives and reference flows" and the phases of Inventory analysis, Impact assessment and Interpretation.

Main choices

- The guidelines given in this Guide are basically intended for change-oriented, structural decisions.
- The emphasis in the guidelines is on detailed LCA, in which simplified guidelines have been derived from the detailed ones, and extended guidelines have been designed as add-ons to the detailed ones.
- Guidelines are for so-called cradle-to-grave analysis, although partial analyses, such as cradle-to-gate analyses may largely follow the same guidelines; deviations for cradle-to-gate analysis are specified.
- Guidelines for Impact assessment are based on so-called mid-point effects: somewhere between total mass loadings and mortality increase (see Part 3, Section 4.2). Furthermore, impacts on the environment are the primary focus in defining impact categories. Thus, energy in MJ is not a category, while depletion of resources (including energy carriers) in certain well-defined terms is one.

Guidelines

- ☞ Determine, justify and report the temporal coverage of the study in relation to its goal. This will be a reference point for other choices, e.g., that of the base-period for data collection and the reference period for normalisation. Consider the desired age of the data and the time period over which they have been collected (e.g., one year).
- ☞ Determine, justify and report the geographical coverage of the study in relation to its goal. This will also be a reference point for other choices, e.g., the base-area for the choice of system alternatives in a comparison and the reference area for specifying reference flows (performance characteristics).
- ☞ Determine, justify and report the technology coverage of the study, e.g., weighted average of the actual process mix, best available technology or worst-operating unit, in relation to the goal of the study. A baseline choice for the average level of technology currently installed in the specified geographical area (i.e., modal-modern technology) will suffice for many structural, change-oriented decisions.
- ☞ Determine, justify and report the coverage of economic processes (activities) in relation the goal of the study (= initial system boundaries).
- ☞ Determine, justify and report the coverage of environmental interventions in relation to the goal of the study. All relevant emissions and extractions must be included in the study. The researcher can use the list of interventions given in Part 2b, section 4.4, which summarises all interventions covered by the baseline Impact assessment methods (described in Section 4.3.3), as a checklist. The researcher's level of experience and knowledge of the economic processes concerned and their possible interventions are equally important.
- ☞ Determine, justify and report the coverage of environmental impacts in relation to the goal of the study. All relevant impact categories must be included in the study. The researcher can use the baseline list of impact categories given in Section 4.3.2, which summarises all impact categories covered by the baseline Impact assessment methods (described in Section 4.3.3), as a checklist. The researcher's level of experience and knowledge of on the economic processes concerned and their possible impacts on the environment are equally important.
- ☞ Interventions and/or impact categories which are deemed important but which are unlikely to be quantified during the analysis should be given a separate status ('flags').
- ☞ Determine, justify and report whether the mode of analysis (change-oriented, structural decisions) which is the starting point for this Guide is appropriate to the goal of the study.
- ☞ Determine, justify and report the appropriate level of sophistication (simplified, detailed, and possible options for extensions) in relation to the goal of the study and the decision situation at hand. Keep in mind that this choice means choosing a baseline level of sophistication, and that it is always possible to deviate from this choice for specific steps, unit processes, impact categories and so on, provided that such deviations are justified and reported.
- ☞ In the case of a comparison, determine whether it is useful to restrict the LCA to a difference analysis, in which parts of the life cycle that are qualitatively and quantitatively identical (or almost identical) are omitted from the analysis. If it is decided to conduct a difference analysis, justify and report this, along with a list of the life cycle stages and/or unit processes that have been omitted.
- ☞ The scope of the study should be defined sufficiently comprehensively and in sufficient detail to enable the study to address the stated objectives.
- ☞ Note that LCA is an iterative technique, and not a purely sequential process. This guideline should be kept in mind along the entire LCA process, as the need to revise and reiterate previous steps may arise at any stage.

Example (hypothetical)

"An LCA is carried out to identify hot spots for the improvement of processes in the Netherlands, so data should be representative of the present state of technology in that country. The study uses the most recent data available, mainly from 1999.

The purpose is in agreement with the scope of structural, change-oriented LCA, and simplified guidelines will suffice for most steps.

The total size of the study is 8 person-months. A large proportion of this time will be devoted to the collection of representative data of the most important production, recycling and upgrading processes."

2.3.4 Function, functional unit, alternatives and reference flows

Topic

In this step, the function, functional unit, alternatives and reference flows are defined. The functional unit describes the primary function(s) fulfilled by a product system, and indicates how much of this function is to be considered in the intended LCA study. It will be used as a basis for selecting one or more alternative product systems that might provide these function(s). The functional unit enables different systems to be treated as functionally equivalent and allows reference flows to be determined for each of them. For instance, one could define a functional unit for wall painting in terms of the area to be covered, the type of wall, the ability of the paint to cover the underlying surface and its useful life. In a real example, then, the functional unit of a wall covering would be "20 m^2 of wall covering with a thermal resistance of 2 m^2 K/W, with a coloured surface of 98% opacity, not requiring any other painting for 5 years."

On the basis of the functional unit, a number of alternative product systems can be declared functionally equivalent and reference flows will be determined for these systems. The reference flow is a measure of the outputs from processes in a given product system which are required to fulfil the function expressed by the functional unit. For example, the above functional unit of wall covering might be fulfilled by 20 m^2 of wall covered with paint A, and this is therefore the reference flow for the product system that corresponds to paint A. The fact that 10 litres of paint are needed for this purpose is not a part of the goal definition, but rather of the process data (Section 3.3.6).

Main choices

- Functions must be defined as closely as possible to the end-use
- Depending on the goal and application, the actual, standard or recommended use should guide the definition of the reference flows.
- Alternatives should be selected on the basis of functional equivalence in the context of the study, but additional considerations may play a role as well.
- SI units (or SI-derived or SI-based units) must be used to define the functional unit and the reference flows.
- The size of the functional unit may be chosen arbitrarily (e.g., protecting a 10 square metre wall), or derived from the actual annual size (e.g., protecting 225,000 square metres of wall).
- The choice of using the actual, standard or recommended performance of products is discussed in section 3.3.6 of the Inventory analysis phase, although most authors, including ISO, discuss it in the context of the present step.

Guidelines

Guidelines for simplified LCA[1]

Follow a stepwise procedure.

- ☞ Step 1: Identify the functions to be analysed, formulating them in terms of the final use function(s) of a specific product system, or from a final need or goal. For cradle-to-gate analyses, identify the functions to be analysed, formulating them in terms of physical output (e.g., covering a floor or producing a certain amount of floor covering material).
- ☞ Step 2: Determine and describe the function to be analysed or, in the case of more than one function, select the primary function and
  - decide to allocate (see Section 3.3.9) all economic flows and environmental interventions between the primary function and possible additional functions not included in the analysis; or
  - ignore all additional functions and document these ignored functions (e.g., the primary function is that of covering the floor, and the colour and softness have been ignored).
- ☞ Step 3: Define the functional unit.
  - Determine the key parameters for the system's functioning (e.g., surface to be covered, lifespan of a product, mass etc.) and the units in which they can be expressed; use SI-derived or SI-based units whenever possible (e.g., $m^2 \cdot yr$; see Part 2b, Section 2.4).
  - Define the function of the system in terms of these key parameters as accurately as possible and unambiguously, since this will determine the number of alternative systems that can be considered.
  - Take an arbitrary amount of this function to quantify the amount of function analysed (e.g., 20 $m^2 \cdot yr$).
- ☞ Step 4a: Select equivalent alternative product systems meeting the requirements of the functional unit (e.g., carpets, wooden floors).
  - Ensure that the product or service systems selected are consistent with the goal of the study.
  - Justify and explain, if relevant, why certain product or service systems are considered while others have been omitted from the assessment, although they obviously fulfil the same function or service. Describe the consequences of not considering certain functionally comparable systems for the validity of the study's results and conclusions .
  - Make sure that the alternatives selected are real substitutes (see also under step 4b).
  - If a reference system is to serve as the baseline for comparisons (e.g., to see whether a particular alternative system means an improvement or not, or one for which all results will be put to 1), justify the choice of this reference system in relation to the goal of the study; select the reference system in such a way that the data qualities of the reference system in particular are reasonably consistent in relation to the other systems.
  - Document and justify in a transparent manner the "future" assumptions made if the product systems selected include systems that are yet to be developed or do not feature on the current market.
- ☞ Step 4b: Determine the reference flows needed to fulfil the function defined by the functional unit (e.g., 20 $m^2 \cdot yr$ of floor covered with carpet, 20 $m^2 \cdot yr$ of floor covered with wood), based on standard or recommended use tests. Make sure that the reference flow of every alternative system is a real substitute for the reference flows of the other alternatives (e.g., are we comparing 100 g of steak with 100 g of cutlets or an average

[1] From this step on, separate guidelines will be offered for the different levels of sophistication: simplified, detailed and extended, subdivided, where relevant, for various applications.

portion of steak (100 g) with an average portion of cutlet (150 g)?[1] This step should be done in iteration with the definition of the primary function.

☞ Check the function, functional unit, alternative product systems and reference flows that have been selected and defined.
- Has the function been selected in accordance with the goal(s) defined?
- Are the units and quantity determined for the functional unit consistent and comprehensive in relation to the goal(s) defined?
- Functional equivalence: are the product systems selected on the basis of the functional unit really functionally comparable?

☞ Report every step that is carried out properly and unambiguously.
- Give a brief description of the product (or product group) or service studied.
- Clearly state the relevant function(s) selected as the basis for the LCA study.
- State any additional functions that have been excluded from the comparison.
- State the functional unit(s) defined in the proper and unambiguous terms.
- Justify the product systems selected and describe the main characteristics (trip rate, life span etc…) of these systems.
- Describe the reference flows properly and unambiguously.
- In the case of a comparative assertion, it is mandatory to provide a description of the equivalence of the systems being compared in terms of performance, system boundaries, data quality, allocation procedures, decision rules on evaluating inputs and outputs and Impact assessment, in accordance with ISO 14040, Clause 5.1.2.4.
- In the case of a comparative assertion, comment on relevant alternatives not covered by the study or list them in the report. If no relevant alternatives exist, it is equally important to state this.

Guidelines for detailed LCA and optional extensions

Follow a stepwise procedure.

☞ Step 1: As for simplified LCA.

☞ Step 2: Select the relevant function(s) in relation to the goal of the study.
- If there is only one function at stake, use this as the basis for the definition of the functional unit.
- If various functions are important, the formulation of the functional unit depends on the goal of the study.
- Formulate a single primary function (e.g., floor covering),
  - preferably by physically separating the functions and allocating (see Section 3.3.9) all economic flows and environmental interventions between the primary function and possible additional functions not included in the analysis; or
  - if functions cannot be separated physically, by selecting the primary function and documenting the omitted other additional functions.
- Or formulate an integrated function of the system in terms of all important functions (e.g., floor covering that is soft and blue).

☞ Step 3: Define the functional unit as in a simplified LCA, except for the following:
- Use the actual amount to quantify the amount of function analysed; if not possible, use an arbitrary amount.

☞ Step 4a: Select equivalent product systems fulfilling the functional unit as in a simplified LCA.

☞ Step 4b: Determine the reference flows.
- Make sure that the reference flow of every alternative system is a real substitute for the reference flows of the other alternatives. (E.g., are we comparing 100 g of steak with 100 g of cutlets or an average portion of steak (100 g) with an average portion of

[1] Observe that the choice of comparing equal portions versus comparing average portions is closely related to the question of choosing actual, standard or recommended performance. This is a choice that has to be made for many (foreground) processes, and is therefore discussed in Section 3.3.6.

cutlets (150 g)?) This step should be done in iteration with the definition of the primary or integrated function, especially in multifunction situations.

☞ All other guidelines for checks and reporting mentioned for a simplified LCA must also be applied to detailed LCAs and optional extensions.

Example (hypothetical)

"The function studied in the LCA is that of washing dyed clothes in a household situation. The functional unit has been defined as cleaning 100 kg of dyed clothes in a standard washing machine, in such a way that an independent panel judges the clothes to be sufficiently clean.

The alternatives which are supposed to meet the requirements imposed by the functional unit are:

- Clean-em-all at a temperature of 60ºC;
- Small-Clean at a temperature of 60ºC;
- Cold-Wash at a temperature of 40ºC.

The reference flows belonging to these alternatives are:

- 20 cycles of the washing machine with the recommended dose of Clean-em-all;
- 30 cycles of the washing machine with the recommended dose of Small-Clean;
- 20 cycles of the washing machine with the recommended dose of Cold-Clean."

2.4 Results of Goal and scope definition

The results of the Goal and scope definition phase consist of a clear specification of the goal of the study, the functional unit, and the reference flows for the various alternative product systems. In addition, the scope of the study will guide further choices in subsequent phases. These results form the input for the next phase of the LCA, the Inventory analysis.

3. Inventory analysis

3.1 Topic

The Inventory analysis is the phase in which the product system (or product systems if there is more than one alternative) is defined. In this context, defining includes setting the system boundaries (between economy and environment, with other product systems, and in relation to cut-off), designing the flow diagrams with unit processes, collecting the data for each of these processes[1], performing allocation steps for multifunctional processes and completing the final calculations. Its main result is in an inventory table listing the quantified inputs from and outputs to the environment associated with the functional unit, in terms of kgs of carbon dioxide, mgs of phenol, kgs of iron ore, cubic metres of natural gas, etc.

3.2 Starting points

ISO 14040/14041 has been our general starting point for this phase, as it was for the previous Goal and scope definition phase. As before, the ISO requirements have been made operational through the work of the SETAC LCI group and many individual projects.

The inventory steps laid out in this Guide have been copied from ISO 14041, with a few modifications. For a justification and explanation of these adaptations, see Part 3 of this document, Chapter 1.

The Inventory analysis phase follows the requirements of ISO 14041, with some additions or further specifications, as described below.

- Modifications have been made to bring the method in line with the choice of change-oriented, structural decisions.
- ISO's preference order for co-product allocation has been further specified, in that a clearer distinction is made between avoiding allocation by more detailed modeling and using real allocation where it cannot be avoided by such modeling.
- A quality analysis has been shifted to the Interpretation.

All additional main methodological choices, including references to all ISO steps, are addressed in the section on main choices; the subsequent sections discuss guideline steps - which sometimes deviate from the ISO steps - for the actual performance of LCA studies. Furthermore, this Guide provides advice on mandatory and optional steps for a number of LCA applications.

[1] For the sake of brevity, unit processes are often simply referred to as processes below. In compound terms, the term unit has always been omitted, as for instance in process data and foreground process.

From the general set-up, some general starting points have been derived for the Inventory analysis phase in this Guide.

- The underlying model for the Inventory analysis phase in this Guide is based on steady-state equilibrium modeling. This implies, for one thing, that it is primarily to be used to assess the long-term consequences of a decision, i.e., including newly established market equilibriums.
- The method used in this Guide ignores non-linearities in the relationships between inputs and outputs and flows and effects in industrial and ecologic systems.
- The method developed ignores details regarding the temporal distribution of activities, emissions, and effects. Emissions are specified as total time-integrated releases, and a similar procedure is used for environmental impacts. At the same time, however, sensitivity analyses allow for finite time horizons, e.g., for landfill processes.
- The method ignores spatial details as well. For instance, pollutants are assumed to be released to the water, without indicating to which water. Certain site-dependent additions, however, are available.
- Most economic, socio-cultural and technological mechanisms are either grossly simplified or completely excluded.

3.3 Recipe

3.3.1 Procedures

Topic

The procedural organisation should ensure identical treatment of all general and specific subjects that the parties involved want to discuss in the Inventory analysis phase. Attention should be given to the following issues:

- normative choices made prior to modeling the product system;
- the choice of data sources and data quality requirements (possibly validation) to be enforced;
- enforcement of the accounting rules;
- choices with respect to the processing of data (for example, scaling) into 'useful' specifications;
- the LCI calculation method, including validation of software programs;
- researchers and calculations to be used for the purpose of the significance analysis;
- the type of presentation of the LCI results;
- possible conclusions based on the LCI results;
- further process planning and process management.

Main choices

- In the course of this LCA phase, the supervisory process should be arranged so as to preserve the authoritativeness of the results. The potential input from stakeholders should also be used to improve the quality of the LCA. In this situation of 'mandated science', this implies that, depending on the specific process context, there should be room for interaction between the parties involved on topics that are relevant to the definition of system boundaries, cut-off and allocation rules, data quality and so on.

Guidelines

Guidelines for simplified and detailed LCA and optional extensions

- ☞ Determine the competencies and responsibilities of the LCA research scientists, any critical reviewers, the LCA clients and other interested parties, using Table 3.3.1.
- ☞ Address potential bottlenecks in the LCA process by making arrangements in line with Table 3.3.2 to ensure the orderly progress of the project.

Table 3.3.1 Overview of the competencies of the various actors during the LCA process for the various process contexts.

Item	Description	Process context		
		I	II	III
1a	first instructions with respect to fulfilment of LCA assignment	C	C or S	S
1b	first instructions with respect to fulfilment of assignment of critical reviewer	–	C or S	S
2a	written response to instructions on LCA assignment	L	L + R	L + R
2b	written response to instructions on assignment of critical reviewer[1]	–	R	R
3a	possible revision of the first instructions on LCA assignment	C	C or S	S
3b	possible report on incompatible opinions on LCA assignment	L	L	L
4	presentation of draft interim report (= draft text of Inventory analysis)	L	L + R	L + R
5	written response to draft report on Inventory analysis	C	C or S	S
6	possible revision of draft report on Inventory analysis	L	L + R	L + R
7	possible report on incompatible opinions arising during the Inventory analysis	L	L	L
8	final opinion on report on Inventory analysis	C	C or S	S

Legend

Process context I = few diverging interests, potentially strong impact
Process context II = many diverging interests, potentially weak impact
Process context III = many diverging interests, potentially strong impact
C = first LCA client(s)
S = stakeholders (including C)
L = LCA research scientists
R = critical reviewer

Table 3.3.2 Overview of arrangements that can be made between the various actors for the different process contexts.

Item	Description	Process context		
		I	II	III
a	widening/supplementation of the study (on request)	o	r	r

[1] The actual implementation of all guidelines of this guide should be checked in a critical review.

Item	Description	Process context		
		I	II	III
b	validation by an independent expert (on request)	o	r	r
c	binding advice on decision points by the critical reviewer	o	r	r
d	final decision-making by the largest possible majority, arbitration, or another previously determined procedure	o	o	r
e	quantification of the influence of incompatible opinions in the final report	o	r	r

Legend

Process context I = few diverging interests, potentially strong impact
Process context II = many diverging interests, potentially weak impact
Process context III = many diverging interests, potentially strong impact
r = recommended
o = option

<u>Example (case history)</u>

In order to develop a sound response to the various lists of environmentally preferable materials, the Dutch building materials sector started the so-called MRPI project in 1996. The umbrella organisation for this sector (NVTB) initiated and co-ordinated the MRPI project with the objective of providing the building sector with “reliable information on environmental aspects of building materials, building products or building elements, delivered at the initiative of the producer or his representative by means of LCA”.

Since the interpretation of the LCA output and the use of LCAs to generate environmentally relevant information on products (= MRPI data) turned out to be an important item, the building materials sector is making extensive efforts to educate its members on this issue. The Dutch Concrete Association, for example, developed an LCA training course focusing on the collection and processing of relevant data and the handling of information. This LCA training course characterises the collection of data as the bottleneck ‘pièce de résistance’, necessitating orientation on data concerning processes outside the company, i.e., elsewhere in the product chain. But: ”In practice the suppliers of semi-products and raw materials are a little bit reluctant still when it comes to supplying environmental data. Everybody seems to be afraid of being compared to his competitors. At the same time people in the business chain together have the key in their hands to reach a fundamental break-through in reducing the environmental load.”

Nevertheless, the Dutch building materials sector succeeded in implementing the MRPI project; currently, 80 MRPI licences have been issued, in about 20 building sectors. All MRPI data are based on LCAs and all data have been verified by independent organisations. At present (2000) the sector is trying to develop a structural embedding, by providing regular updates to the MRPI data.

3.3.2 Economy-environment system boundary

<u>Topic</u>

In LCA, each and every flow should be followed until its economic inputs and outputs have all been translated into environmental interventions. The term ‘environmental interventions’ refers to flows entering the product system (for example, natural resources, but also land use) which have been drawn from the environment without prior human transformation, or flows of materials leaving the product system which are discarded into the environment without subsequent human transformation. Environmental interventions are thus flows crossing the boundary between the economy (= product system) and the environment. To create a clear distinction between the product system and the environment and between elementary and other flows, the economy-environment boundary should be explicitly defined.

Whenever a system is studied, system boundaries are needed to separate the system from the rest of the world. An LCA Inventory analysis distinguishes three types of boundaries:

- the boundary between the product system and the environment system;
- the boundary between processes that are relevant and irrelevant to the product system (cut-off);
- the boundary between the product system under consideration and other product systems (allocation).

The first of these will be discussed here, while the second is addressed under the heading "Cut-off and data estimation" (Section 3.3.8) and the third under the heading "Multifunctionality and allocation" (Section 3.3.9).

Main choices

- Human control over processes is the main criterion for regarding a process as a unit process and hence including it in the economic system.

Guidelines

Guidelines for simplified LCA

☞ Use the definition of system boundaries that is applied in existing databases and literature sources.

☞ Take note of possible inconsistencies between the various data sources used and of possible deviations from the advice given in this Guide for detailed LCA and optional extensions.

Guidelines for detailed LCA and optional extensions

☞ Determine the boundary between the product system[1] studied and the (natural) environment by applying the definitions for elementary flows (see the Appendix on terms and definitions). In particular:

- Controlled landfills should be regarded as economic processes from which emissions take place (emissions of organics should be integrated over 200 years, emissions of inorganics like heavy metals ad infinitum); uncontrolled landfills should be regarded as part of the environment system. Partially controlled landfills should be treated as a mixture of these two extremes.
- Wastewater treatment should be regarded as an economic process. This implies that releases to a sewage system are not considered as emissions into the environment, but that only the releases of the treated wastewater after sewage treatment is considered as such. Because process data for wastewater treatment are sometimes difficult to obtain, one will in practice sometimes exclude wastewater treatment from the flow diagram. The latter should, however, be clearly reported and justified as a flow that has not been followed to the system boundary.
- Agriculture and forestry are regarded as economic processes, although agricultural and forestry soils are part of the environment system. Further, the harvested part of a

[1] When two or more alternative product systems are being studied, the economy-environment system boundary should be determined for each of these alternatives.

crop should be regarded as a part of the economic system, while the non-harvested part belongs to the environment system. This means that pesticides on the harvested part of a crop do not show up in the LCA, unless they enter the environment at a later stage, for instance when the crops are washed before cooking and the water used for washing is released to the environment.
  - Treatment of mining tips should be similar to that of landfills.
- ☞ Distinguish, if relevant, between "positive" and "negative" emissions and extractions.
  - Dredging for specific uses (water transport; clay for bricks or dykes) should be included as a negative emission (from the environment), and as a positive emission when it is returned to the environment (particularly to another environmental compartment).
  - In agriculture, and particularly in forestry, sequestering of CO_2 in biomass should be regarded as a negative emission, while CO_2 or CH_4 released during waste processing of the agricultural product should be considered a positive emission.
- ☞ Justify the reasons for possible deviations from the baseline advice given above.
- ☞ Ensure that system boundaries are defined consistently throughout the LCA study and also beyond the study, with respect to the characterisation factors and normalisation factors used.
- ☞ Check that the economy-environment system boundary defined is consistent with the scope of the study and with these guidelines.
- ☞ In the case of a comparison, check whether the economy-environment system boundary is handled consistently over the various product systems that are being compared.
- ☞ For studies on agricultural products and landfill systems, check whether there are defensible alternative choices with respect to the definition of the economy-environment system boundary.
- ☞ Report the following issues:
  - systems and system boundaries for all stages of the product system life cycle, including inputs, processing routes and spatial and temporal considerations;
  - a justification of the final system boundaries in relation to the goal of the study;
  - inputs and outputs of the system as elementary flows.

Example (hypothetical)

"In the LCA, agriculture for the production of biofuels has been included in the product system, just like the controlled landfilling of waste. Disposal of sludge into rivers, however, has been categorised as belonging to the environment system. Uptake of carbon dioxide by crops is counted as a negative emission."

3.3.3 Flow diagram

Topic

The flow diagram provides an outline of all the major unit processes to be modeled, including their interrelationships. It is helpful in understanding and completing a system to describe the system using a process flow diagram.

Main choices

- Appropriately constructed flow diagrams are important for understanding the product systems
- Drafting flow diagrams can be done at different levels of complexity, also in relation to the level of sophistication (detailed, simplified), the most complete being a diagram in terms of unit processes

Guidelines

Guidelines for simplified LCA

- ☞ For each alternative product system studied, draft an initial flow diagram at the level of aggregated processes for each life cycle stage. Start from the reference flow, the process producing the reference flow and adjacent processes, up to and including the processes producing the main materials and those managing the main waste flows.
- ☞ It is convenient to use boxes for unit processes (or aggregated processes) and arrows for the economic flows linking them. Environmental interventions are often omitted from the flow diagram, because the main function of the flow diagram is to illustrate the structure of the product system and the relationships between the unit processes. Text labels in boxes should clearly indicate the names of the unit processes, and text labels attached to arrows show the names of the economic flows.
- ☞ Use arrows primarily to indicate the physical direction of flows. For instance, use an arrow from consumption to waste treatment to indicate the flow of disposed products, and not the other way around to indicate the flow of the waste treatment service. However, it is often more convenient to indicate service-providing activities in a different way. Thus, a cleaning process does not absorb dirt, but provides a cleaning service.
- ☞ Indicate clearly which of the boxes refers to a unit process and which to a partial flow diagram with aggregated unit processes.

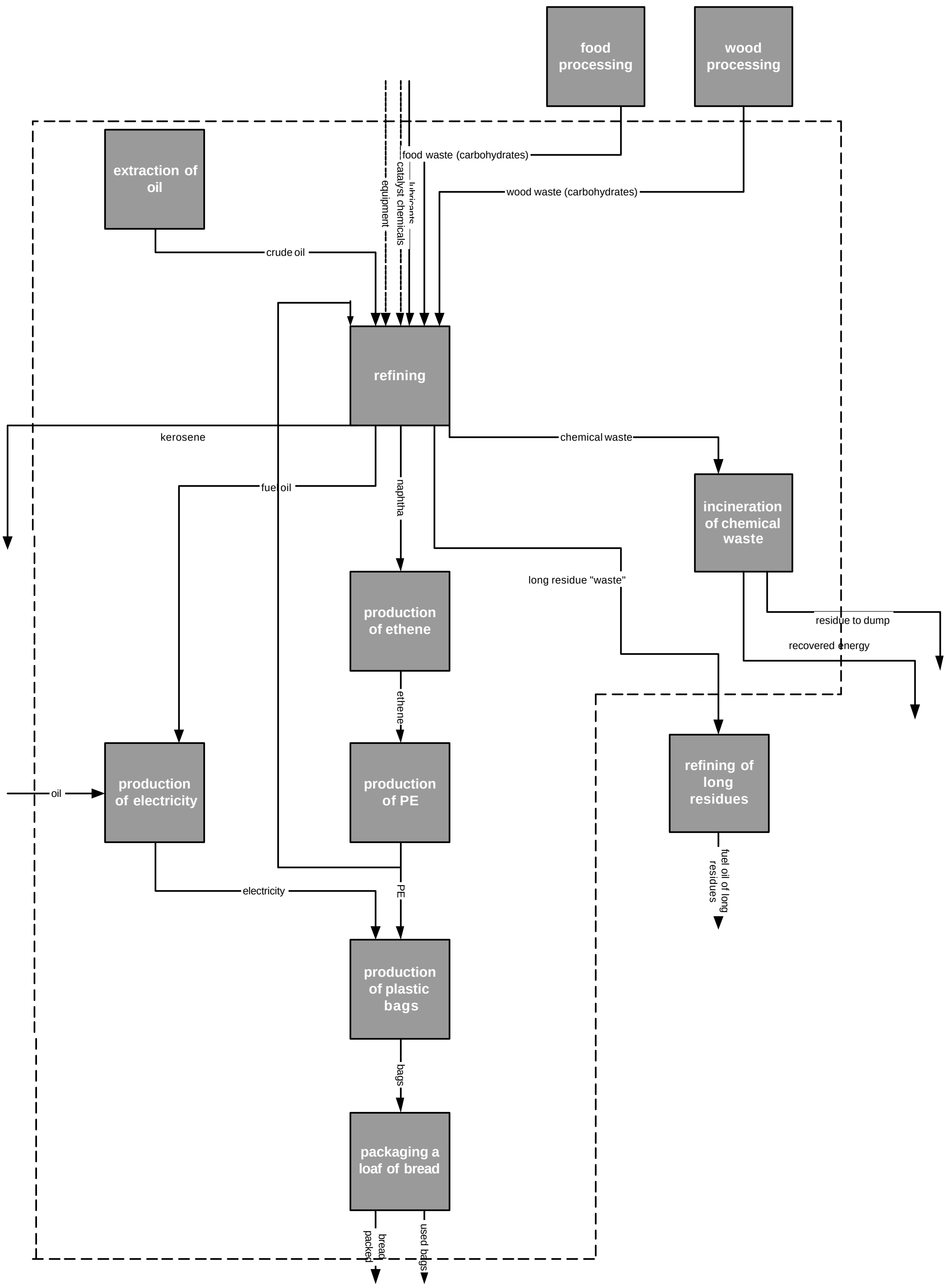
Guidelines for detailed LCA and optional extensions

These are the same as for a simplified LCA, but with the following additional guidelines.

- ☞ Draft a detailed flow diagram in iteration with the data collection step (see Section 3.3.6), starting from the initial flow diagram.
- ☞ Solve the problem of huge numbers of unit processes and complex interrelationships by zooming in from the initial flow diagram to the underlying unit processes in partial flow diagrams.
- ☞ Check whether the number of flows for which estimated data must be collected in relation to the number of flows for which specific data have been collected is consistent with the goal(s) and scope of the study and the guidelines given.
- ☞ Check whether the flow diagram is complete.
- ☞ In the case of a comparison, check whether there are any inconsistencies between the flow diagrams of the systems being compared.
- ☞ Report process flow diagrams describing the complete system under study.
- ☞ Include system boundaries, major inputs, products and co-products in the process flow diagrams. The process flow diagrams should include the main production sequence, ancillary materials and energy/fuel production.

Example (hypothetical)

“The flow diagram for the investigated system of PE disposable bags is visualised below. The environmental inflows and outflows have been omitted for the sake of readability.



3.3.4 Format and data categories

<u>Topic</u>

A key task of the Inventory phase is the collection of process data. This usually involves large quantities of data in electronic form, retrieved in part from databases set up by others. To render these comparable and mutually consistent, a standard data format must be developed. All the various data categories should be assigned a specific place in this format and a general description given of each to facilitate and guide data entry and retrieval.

Main choices

- Choice of data categories should be made in relation to the impact categories and characterisation factors included.
- Using a transparent format is important.
- Conformity with a data exchange standard is important. The so-called SPOLD format provides such a standard.
- Adaptations of this standard may be required in relation to choices made in other steps, like terminology and definitions of data categories.

Guidelines

Guidelines for simplified and detailed LCA and optional extensions

☞ Use the SPOLD format as much as possible for the collection of data for foreground processes; for background processes, use the format applied in the database or literature source used for data on these background processes, or if possible, convert these data to the SPOLD format too. See Part 2b, Section 3.4 for references to further information.

☞ Use the headings of the SPOLD format as the main data categories. However, adaptations are needed; see Part 2b, Section 3.4 for a list of data categories.

☞ Treat energy inputs and outputs like any other economic input and output to an LCA.

☞ Use the list of elementary flows for which Impact assessment data are available (see Part 2b, Section 4.3) as a reference list to specify these main data categories. Use the CAS number where possible and relevant. Distinguish emission compartments, where relevant, into
- air;
- fresh water;
- seawater;
- agricultural soil;
- industrial soil.

☞ In addition to the reference list provided above, include data on some more relevant inventory items. Depending on the goal and scope of the study and on the choice of impact categories, inventory items of interest may be:
- land occupation;
- land transformation;
- emissions of waste heat;
- casualties;
- sound.

☞ Report decisions about data categories and details about individual data categories.

Example (hypothetical)

No example.

3.3.5 Data quality

Topic

For LCA models, like any other model, it holds that "garbage in = garbage out". In other words, data quality has a major influence on results, and proper evaluation of data quality is therefore an important step in every LCA. Even if the quality of individual datasets is high, however, such data can still yield erroneous results if used to answer questions on which they have limited or no bearing. The data used in a given case study should, for instance, be representative of that particular study. Quality requirements thus refer to both the reliability and the validity of process data. Since validity depends on the application in question, it is not validity requirements as such that are specified here but the data needed to assess that validity.

Main choices

- Since fully operational models for assessing the influence of data quality on output validity are lacking, a partial qualitative data quality assessment is provisionally proposed, based on suggestions from ISO 14041.
- Although a full quantitative assessment of every dataset is not feasible, one should not neglect to include quantitative data quality information (meta-data) for those items for which this is available.

Guidelines

Guidelines for simplified and detailed LCA

☞ Data quality should be specified in terms of:
- collection from specific sites versus general data;
- being measured, calculated or estimated;
- precision, as a measure of the variability of the data values for each data category expressed (e.g., variance);
- completeness, as a percentage of locations reporting primary data from the potential number in existence for each data category in a unit process;
- representativeness, as a qualitative assessment of the degree to which the dataset reflects the true population of interest (i.e., geographical, time period and technology coverage);
- consistency, as a qualitative assessment of the degree of uniformity with which the study methodology is applied to the study serving as the data source;
- reproducibility, as a qualitative assessment of the extent to which information about the methodology and data values allows an independent practitioner to reproduce the results reported in the study serving as the data source;
- justification of the choice of data sources selected in relation to the goal of the study and particularly to scope issues such as temporal, geographical and technology coverage;
- reliability of different data sources in qualitative terms;
- completeness of the data provided (for instance, if there are unreported emissions);
- correctness of the mass and energy balances;
- agreement between the data sources used and other data sources.

☞ If possible, ask for opinions of technical (non-LCA) experts.

☞ If a comparison is being made, check whether:
- the data quality requirements and the choice between marginal and average data are consistently elaborated between the product systems compared;

- there are any major differences between the product systems being compared, with respect to the ratio between background and foreground data;
- the estimated importance of the flows for which specific data are lacking differs considerably between the various systems being compared.

☞ In the case of a comparative assertion, report on the assessment of the precision, completeness and representativeness of the data used.
☞ Justify and report maximum baseline data quality requirements.
☞ The report must clearly establish and define data quality goals, as well as any variability of data considered in the study.
☞ Identify clearly all data sources for the study and reference them. Key indicators of data quality should be reported, so that choices are justified and transparent, including:

- age of data;
- frequency of collection;
- spatial and temporal considerations;
- any other relevant factors.

☞ The quality assessments may be reported as a Pedigree Matrix per process (see Part 2b, Section 3.5).
☞ If data are presented in aggregate form (e.g., for reasons of confidentiality), is the aggregation procedure fully described? A sensitivity analysis of key data sets should be included.

Guidelines for optional extensions

All guidelines provided above for simplified and detailed LCA apply here.
☞ Consider developing a new method for data quality assessment. If so, document and justify comprehensively and transparently the method developed and the choices and assumptions made.

Example (hypothetical)

See example under Section 3.3.6.

3.3.6 Data collection and relating data to unit processes

Topic

This step of the Inventory analysis phase involves the collection of all relevant data on the unit processes and quantifying all flows connected to the unit processes in accordance with the format specified above (Section 3.3.4). The reference flow(s) (see Section 2.3.4) defined in the Goal and scope definition phase of the study form(s) the starting point for data collection.

The process data available to the practitioner may be structured in any number of ways. In LCA databases, process data are often organised around unit processes, relating a given economic output to economic inputs and environmental inputs and outputs. Process data provided by companies are often also organised around unit processes, but given in terms of inputs and outputs per unit of time, e.g., emission of 5 tonnes of CO_2 per year, input of 1000 tonnes of wood per year, etc. In existing LCA databases, process data are almost always quantified in relation to some physical (reference) flow (e.g., one kg of material or 1 MJ of electricity).

Main choices

- The ISO step labeled "Relating data to unit processes" has been integrated with ISO's "Data collection" step, since the activity of relating data to unit processes has too little

substance to make it a separate element, and since it is inextricably linked with the activity of data collection.
- If possible, conversion of the data should be minimised and, if necessary, clearly documented.
- A distinction will be made between foreground and background processes, although various definitions of these terms are in use, and an unambiguous partitioning of processes into these two sets may be impossible. In this Guide, foreground processes are those unit processes for which case-specific primary data are used, while background processes are those unit processes for which more general information is used.

Guidelines

Guidelines for simplified LCA

☞ Determine a small number of foreground processes, i.e., processes for which primary data will be collected. The remainder of processes are treated as background processes for which secondary data sources, such as generic databases, literature or IOA data (see Section 3.3.8 on data estimation) may be used.

☞ With respect to data collection for foreground processes, the following guidelines apply.
- Collect process data, preferably in flow-per-time figures, and relate the data to one of the flows through scaling factors, using time as a dimension, if the software allows for this (see Section 3.3.10 on calculation method).
- SI units (or SI-derived or SI-based units) should be used wherever possible in collecting data for all economic and environmental flows. For suggested units in the various data categories, see Part 2b, Section 2.4.
- Consider to what extent market mixes should form the basis for the data on a particular unit process. For instance, a study on bottles for the European market will probably involve many bottle producers, so that a market mix, proportional to the market shares, is more representative than a choice of one particular bottle producer. If a market mix is to be used, the average level of currently installed technology in the relevant geographical area (i.e., modal vs. modern technology) will in many cases be a good choice.
- Justify and document procedures used for data collection.
- Describe each of the unit processes initially to define where the unit process begins (in terms of the receipt of raw materials or intermediate products and the nature of the transformations and operations that occur as part of the unit process) and where it ends (in terms of the destinations of the intermediate or final products).
- For the unit process from which the reference flow emanates (usually the use process), determine whether actual, standard or recommended performance is the best option in relation to the goal of the study. Consider whether this choice is also relevant to other foreground processes. For these processes:
  - if geographical context is relevant, adapt standard or recommended use to the specific geographical circumstances;
  - if temporal context is relevant, adapt standard or recommended use to the specific temporal circumstances;
  - check whether the options that are being compared have the same performance;
  - present the result of a performance measurement.

☞ With respect to data collection of background processes, the following guidelines apply.
- Where data are collected from published literature, specify the source.
- The practitioner must realise that the choice of secondary data sources may significantly influence the outcome of the study and limits the opportunities for choosing different allocation rules or cut-off criteria and conducting sensitivity and uncertainty analyses. The practitioner must explicitly justify that the data source(s)

selected for the background processes are representative with respect to the specification of the goal and scope of the study.
- A list showing a number of commonly used databases with process data is included in Part 2b, Section 3.6.

☞ Avoid the use of group parameters (such as CxHy, PAH, heavy metals, AOX) as much as possible[1]. If some process emissions are specified as a group parameter:
- split up the group parameter into its individual chemical constituents;
- convert the group parameter using generic conversion factors like those included in Part 2b, Section 3.6; if this is not possible, report original data, conversion methods and converted data.

☞ For those emissions for which the characterisation tables in Part 2b, Section 4.3 require this, specify, where possible, the emission compartment:
- air;
- water, divided for certain substances into fresh water and seawater;
- soil, divided for certain substances into agricultural soil and industrial soil.

☞ If such a specification is not known, assign the emissions to the most plausible emission compartment, and report what has been done. Some example guidelines include the following.
- Emissions of volatile substances can be assigned to the air compartment.
- Emissions of substances to water can be assigned to the freshwater compartment.
- Emissions of pesticides and fertilizers to the soil can be assigned to the agricultural soil compartment.
- Emissions of industrial processes to the soil can be assigned to the industrial soil compartment.

☞ Interventions that are not assigned to any impact category or that lack appropriate characterisation factors should not be omitted from the Inventory analysis.

☞ The use of data from pre-allocated databases is to be restricted to simplified LCA.

Guidelines for detailed LCA and optional extensions

All guidelines provided above for simplified studies also apply here, except for the first.

☞ The first guideline, stating that data must be obtained for a small number of foreground processes, is replaced by the following guideline: determine a large number of foreground processes, i.e., processes for which primary data will be collected.

In addition, the following guidelines apply for detailed and extended studies:

☞ Assess all primary data collected by the data quality requirements defined in Section 3.3.5.

☞ Whenever possible (e.g., in the case of consumer products), determine the data for the unit process from which the reference flow emanates (usually the use process). Based on the relevant performance test, the following hierarchy of preference can be used:
- actual use, e.g., based on behaviour surveys, consumer enquiries or market studies;
- standard use in combination with consumer behaviour studies;
- recommended use in combination with consumer behaviour studies.

☞ Specify all secondary data collected from databases, literature, etc., as well as the published literature which supplies details about the relevant data collection process, about the time when data have been collected and about further data quality indicators. Perform this step in iteration with the contribution and perturbation analyses (see Sections 5.3.4 and 5.3.5).

☞ Include estimated process data (see Section 3.3.8), and indicate these as such.

☞ Include details of the calculation procedure used for the energy systems in the report. In particular, specify whether country-specific or average energy has been used for

[1] Note: group parameters are only legitimate parameters if measured as such, not if calculated from measurements of individual chemicals.

materials and processing, the use of high or low calorific values, the approach used for feedstock energy and the conversion of electricity into primary energy.

☞ Try to avoid the use of data from pre-allocated databases.

Example (hypothetical)

“The table below presents the fictitious process data for the unit process of ethylene production.

Item	Value
general information	
name	production of ethylene
code	Z-23-4f
author	CML
date	14 May 2001
source	Jones (2000): The Handbook of Life Cycle Data
status	based on average of measurements from 23 representative plants
precision	not specified, but there seems to be little variation across the individual plants
temporal representativeness	mid-nineties
geographical representativeness	average for Western Europe
economic outputs	
ethylene	950 kg
economic inputs	
naphtha	1000 kg
emissions to air	
benzene	$8.5 \cdot 10^{-5}$ kg
ethylene	$8.21 \cdot 10^{-3}$ kg
emissions to fresh water	
benzene	$2.7 \cdot 10^{-9}$ kg
cadmium	$3.1 \cdot 10^{-10}$ kg
phenol	$1.2 \cdot 10^{-6}$ kg

3.3.7 Data validation

Topic

This step involves checking the validity of the process data collected. Various tools are available for this purpose, including mass balances, energy balances and comparison with data from other sources (e.g., comparative analysis of emission factors). Any data found to be inadequate during the validation process should be replaced. Similarly, missing data should be identified in this step and a decision made on how these gaps are to be filled.

Main choices

Not applicable.

Guidelines

Guidelines for simplified LCA

- ☞ Validate data collected for the foreground processes, and for all background processes significant for the conclusions of the study, by establishing mass and energy balances and by comparative analysis of the different data sources used. A contribution analysis (see Section 5.3.4) can be used to point out this class of data.
- ☞ Address missing data and gaps in the foreground data and significant background data by means of one of the following:
  - a non-zero data value which is justified;
  - a zero data value, if justified;
  - a calculated value based on values reported for similar technology, or another type of estimate (see the Section 3.3.8 on data estimation).
- ☞ Document and justify the criteria used for determining the "correct" data values from such validation procedures.

Guidelines for detailed LCA and optional extensions

In addition to the above guidelines for simplified LCA, the following also apply.

- ☞ Report anomalies in foreground data, and wherever possible also in significant background data, to the reporting location (i.e., internal company experts) or reporting source to determine their validity. Obvious anomalies in the data appearing from such validation procedures must result in alternative data values, which comply with the data quality requirements established in Section 3.3.5.

Example (hypothetical)

No example.

3.3.8 Cut-off and data estimation

Topic

In principle, an LCA should track all the processes in the life cycle of a given product system, from the cradle to the grave. In practice this is impossible, however, and a number of flows[1] must be either roughly estimated or cut off[2] and subsequently ignored. The root problem behind the cut-off issue is the lack of readily accessible data, implying disproportionate expenditure of funds and effort on data collection. Cut-off can substantially influence the outcome of an LCA study, however, which means that 'easy' LCAs come at a price. The cut-off problem can be formulated as a problem of having to quantitatively estimate the environmental interventions associated with flows for which no readily accessible data are available.

Main choices

- Cut-off is necessary mainly for reasons of lack of data, in combination with lack of time and money.

---

[1] In the cut-off discussion, the term "flows" refers specifically to all economic input flows and the output flow "waste to be treated".

[2] One important additional situation in which a cut-off may be introduced is a difference analysis (see Section 2.3.3).

- The problem comes up after data collection, when it turns out that production processes for some inflows and waste treatment processes for some outflows are unknown or undocumented.
- Cut-off is interpreted as more than simply ignoring certain parts. More importantly, the estimation of lacking data is an essential element in this Guide.
- Cut-off comprises two distinct aspects: dealing with missing unit processes and dealing with missing interventions from the unit processes included.

Guidelines

Guidelines for simplified LCA

☞ In a difference analysis (see Section 2.3.3), cut-off of flows that are qualitatively and quantitatively identical across the various alternative product systems considered may provide an attractive shortcut.
☞ Try to avoid cut-off as much as possible. Several estimation procedures are available for this purpose; see under *Guidelines for detailed LCA and optional extensions* below.
☞ In practice, however, time and budget will not allow the application of these estimation procedures for most of the data gaps. Cut-off will then be achieved by putting flows explicitly to zero.

Guidelines for detailed LCA and optional extensions

☞ In a difference analysis (see Section 2.3.3), cut-off of flows that are qualitatively and quantitatively identical across the various alternative product systems considered may provide an attractive shortcut.
☞ Avoid cut-offs as much as possible by collecting process-specific data.
☞ If this is not possible, estimations must, whenever reasonably possible, be made of the significance for the remainder of processes for which specific data cannot be found by
  - environmental input-output analysis at the sectoral level[1] (see Part 2b, Section 3.8);
  - approximation of the process by a similar process (for instance estimating HDPE production by LDPE production);
  - comparing the flow for which data are lacking with a reasonably similar flow for which data are known (see Part 2b, Section 3.8), and justify whether cutting off is reasonable or whether specific process data should be gathered after all.

☞ If estimation is not possible, try to estimate the potential quantitative and qualitative significance of the flow for which specific data are lacking.
☞ If all of the above options are not feasible, cut off only those flows for which data are lacking, by putting them to zero, and report these flows clearly (see also Section 4.3.3.18).
☞ After each of the above-mentioned estimation steps, it should be decided – and the decision should be justified – whether or not the estimations give cause for additional collection of specific process data after all.
☞ Report:
  - criteria for initial inclusion of inputs and outputs;
  - description of criteria and assumptions used for estimating or ignoring missing flows;
  - estimated effect of estimation or omission on the results;
  - in the case of a comparative assertion: analysis of material flows to justify their inclusion or exclusion in a comparative context;
  - sensitivity analysis to refine the system boundaries;
  - omissions of life cycle stages, processes or economic and/or environmental flows;

[1] As noted in Parts 2b and 3, input-output analysis cannot be applied to the use and waste management phases.

- estimated process data along with primary and secondary process data, indicating clearly which data items have been estimated, and which estimation principles have been used (in Section 3.3.6).

Example (hypothetical)

"In the example system, several inputs and outputs are cut off. These cut-offs have not all been included, for the sake of clarity. As an example, the potential contributions of the refinery facility and a catalyst, e.g., platinum, are estimated by Input-Output Analysis. The analysis uses the MIET model (see Part 2b, Section 3.8). See the table below for results.

	catalyst chemicals	equipment
resources		
crude oil	0.023 kg	0.0034 kg
emissions to air		
1-butene	–	–
benzene	$6.4{\cdot}10^{-10}$ kg	$2.4{\cdot}10^{-8}$ kg
carbon dioxide	0.054 kg	0.021 kg
dioxins (unspecified)	–	–
ethylene	$1.8{\cdot}10^{-6}$ kg	$9.9{\cdot}10^{-8}$ kg
nitrogen oxides	0.00016 kg	$6.4{\cdot}10^{-5}$ kg
sulphur dioxide	0.00020 kg	$7.3{\cdot}10^{-5}$ kg
emissions to water		
benzene	$3.6{\cdot}10^{-10}$ kg	$5.2{\cdot}10^{-11}$ kg
cadmium	$1.6{\cdot}10^{-11}$ kg	$2.9{\cdot}10^{-12}$ kg
lead	$5.1{\cdot}10^{-11}$ kg	$6.9{\cdot}10^{-11}$ kg
mercury	$9.1{\cdot}10^{-12}$ kg	$3.4{\cdot}10^{-13}$ kg
phenol	$5.8{\cdot}10^{-10}$ kg	$2.3{\cdot}10^{-10}$ kg

In addition, cut-offs have been used for the input of lubricants for refining, the outputs of residue to dump from the incineration of chemical waste, and the output of used bags from the use process (packaging a loaf of bread). Finally, the co-product of "recovered energy from incineration of chemical waste" has not been allocated, but just ignored for the sake of simplicity. This can be justified by acknowledging that the revenues from energy recovery are negligible compared to those of waste incineration."

3.3.9 Multifunctionality and allocation

Topic

Most industrial processes are multifunctional. Their output generally comprises more than a single product, and raw material inputs often include intermediates or discarded products. LCA practitioners are thus faced with the problem that the product system or systems under study provide more functions than that which is investigated in the functional unit of interest. An appropriate decision must therefore be made as to which of the economic flows and environmental interventions associated with the product system under study are to be allocated to the functional unit produced by that system. Decisions on the specifics of allocation will obviously be determined by the precise nature of the system boundaries as previously defined (see Section 3.3.2), since these determine which inputs and outputs are to be regarded as associated with the function of interest. An appropriate allocation procedure is thus required to partition the inputs and outputs of all relevant processes to the appropriate product systems.

Main choices

- Allocation is the result of the multifunctionality of one or more unit processes, and is performed at the unit process level.
- The use of data from allocated databases is to be restricted to simplified LCAs; for detailed LCAs, this is to be avoided as much as possible.
- The ISO preference order for dealing with allocation is more clearly specified with regard to the application of the different options in simplified and detailed LCAs and in possible extensions, with regard to more detailed modeling and actual allocation, and with regard to operational aspects.
- Co-production, combined waste treatment and recycling are treated on the basis of the same allocation principles.

Guidelines

Guidelines for simplified LCA

☞ If possible, avoid allocation by modeling within the Inventory analysis. Possible methods are the following, in order of preference.
  - Use single-function (cradle-to-gate databases) as a basis, such as ETH or BUWAL (see Part 2b, Section 3.6 for references to these databases). In this case all multifunction processes are already allocated by the maker.
  - Treat open-loop recycling as closed-loop recycling, using a quality factor indicating the lower value of the recycled material.
  - Use existing physical-causal waste management models.

☞ If allocation cannot be avoided, possible allocation methods are:
  - economic allocation based on the value of all resulting functions, where feasible (see Part 2b, Section 3.9.1);
  - substitution with pre-allocated cradle-to-gate database data;
  - allocation based on indicators of economic value, such as mass, volume, or energy content;
  - quick and dirty last resort methods, based on very rough estimations, such as 50-50%, prices of similar products etc., or allocating all flows to the function investigated.

☞ Justify and describe the methods used to avoid allocation and the methods used to allocate.

☞ Check the following issues and, where relevant, use them to make recommendations for further analysis in the Interpretation.
  - Are any other simplified allocation keys possible?
  - In the case of a comparison, are there important differences in the allocation situations between the various systems compared?

☞ A decision should be taken as to whether and how the influence of different allocation methods will be further analysed in the Interpretation phase.

Guidelines for detailed LCA

☞ If possible, avoid allocation by modeling within the Inventory analysis. Possible methods are the following, in order of preference.
  - Split up processes that are not really multiple. In practice, this means that more detailed process sheets or databases are consulted, or that more detailed measurements are made.
  - Model long-term technical-physical relations in waste processing, in addition to existing models.

☞ If allocation cannot be avoided, allocate using economic allocation based on the market value or constructed market value of all the resulting functions (see Part 2b, Section 3.9.1).

- ☞ If the above-mentioned methods cannot be applied, use one of the possible methods for allocation mentioned under simplified LCA as a last resort.
- ☞ Justify and describe the methods used to avoid allocation and the methods used to allocate, giving special attention to the situations where a last resort method had to be used.
- ☞ Check the following issues.
  - Are any other allocation keys possible?
  - In the case of a comparison, are there major differences in the allocation situations between the various systems compared?
- ☞ The influence of the allocation methods used should be further analysed in the Interpretation phase in the form of a sensitivity analysis. If last resort methods have been applied, they must be given special attention in the sensitivity analysis in Section 5.3.6.

Guidelines for optional extensions

All guidelines provided above for detailed LCA apply here. In addition to the first guideline on avoiding allocation by means of modeling within the Inventory analysis, the following guideline is given.

- ☞ If relevant and possible, apply market analysis for main co-products (= system expansion) to avoid allocation.
- ☞ If relevant and possible, make a linear programming optimisation model for one main process to avoid allocation. We advise the LCA practitioner to do this only if (s)he is familiar with optimisation models (see the various papers by Azapagic and Clift referenced in Part 3 for more details).
- ☞ If relevant and possible, apply symmetrical substitution as an allocation method in addition to economic allocation (see Part 2b, Section 3.9.2)

Example (hypothetical)

"The refinery process is a multifunctional process. The allocation is based on sales (= quantity $\times$ price) of the products. The proceeds of the six products as produced by the installation are summarised in the table. The share of each product in total proceeds is the allocation factor for that product.

product	quantity (10^6 kg)	price (€/kg)	proceeds (10^3 €)	allocation factor
1: fuel oil (good)	10	0.15	1500	0.25
2: naphtha (good)	9	0.20	1800	0.30
3: kerosene (good)	3	0.10	300	0.05
4: long residue "waste" (good)	4	0.05	200	0.03
5: food waste (service)	4	0.15	600	0.10
6: wood waste (service)	2	0.80	1600	0.27
Total	32	–	6000	1.00

The resulting six mono-functional processes are tabulated below.

	production of fuel oil	production of naphtha	production of kerosene	production of long residue "waste"	treatment of food waste	treatment of wood waste
economic outflows (kton)						
fuel oil	10	0	0	0	0	0
naphtha	0	9	0	0	0	0
kerosene	0	0	3	0	0	0
long	0	0	0	4	0	0

residue "waste"						
chemical waste	0.5	0.6	0.1	0.06	0.2	0.54
economic inflows (kton)						
food waste	0	0	0	0	4	0
wood waste	0	0	0	0	0	2
PE (ton)	0.0025	0.003	0.0005	0.0003	0.0001	0.0027
lubricants	5	6	1	0.6	2	5.4
emissions to air (g)						
CO2	2125	2550	425	255	850	2295
SO2	80	96	16	9.6	32	864
NOx	6	7.2	1.2	0.72	2.4	6.5
emissions to water (g)						
Cd	7	8.4	1.4	0.84	2.8	7.6
Hg	0.07	0.084	0.014	0.0084	0.028	0.076
benzene	0.7	0.84	0.14	0.084	0.28	0.76

3.3.10 Calculation method

Topic

Collection of process data yields a database of processes. The act of quantitatively relating these processes to one another, scaled to the reference flow following from the functional unit, is referred to here as the calculation method. The calculation result is a set of linked and scaled processes, each with scaled environmental interventions, which are usually aggregated.

Main choices

- Matrix-based calculations are preferred because they easily allow for recursive relationships.
- The calculation of inventory results includes an aggregation of all interventions over all unit processes, but there are also unaggregated results, which serve all types of purposes, like the contribution analysis (see Section 5.3.4)

Guidelines

Guidelines for simplified LCA

☞ For each alternative product system, calculate the inventory table by scaling all processes in relation to the reference flow of that product system. This means that, within each product system, each unit process should be scaled in such a way that it delivers the quantity of product or service that is necessary for the reference flow.
- Use software based on matrix inversion.
- If this is not possible, use other software.
- Document explicitly any software used for the calculation, if possible along with the calculation procedures involved.

☞ If the final calculation shows that the system delivers not only the desired functional unit but also another function or functions, further allocation must take place. Check which unit process delivers the "extra" function(s) and allocate this process (see Section 3.3.9). After this, recalculate the inventory table.

☞ Report the inventory table and all economic flows not followed to the system boundary together. It may be convenient to report the results for the different alternatives in one table. An example form for completion is provided in Part 2b, Section 3.10.

Guidelines for detailed LCA and optional extensions

Guidelines for simplified LCA also apply here, but the first guideline is replaced by the following set of guidelines.

☞ For each alternative product system, calculate the inventory table by scaling all processes in relation to the reference flow of that product system. This means that, within each product system, each unit process should be scaled in such a way that it yields the quantity of product or service that is necessary for the reference flow.
- Use software based on matrix inversion.
- If this is not possible, use other documented software, or specify the algorithm or algebra used for the calculations, and specify whether the outcomes are compatible with the outcomes of matrix inversion.
- Document explicitly any software used for the calculation, along with the calculation procedures involved.

☞ If a sequential[1] calculation technique is applied:
- check whether there are any loops within the systems studied;
- in the case of a comparison, check whether the number of loops differs for the various product systems studied.

☞ Check how loops have been treated in the literature and in the reference databases used, and, in the case of a comparison, whether the number of loops differs for the background processes of the various product systems studied.

☞ If deficits are identified, these can be adjusted directly by using a different calculation method. If this is not possible for practical reasons, assess the influence that ignoring loops might have on each of the systems studied, by means of a sensitivity analysis in the Interpretation phase[2].

Example (hypothetical)

"In the example of PE bags, all processes have been scaled using a matrix-based algorithm. The scaling factors are as listed.

unit process	scaling factor
refining; allocated to fuel oil	$6.1 \cdot 10^{-8}$
refining; allocated to naphtha	$1.3 \cdot 10^{-6}$
extraction of oil	$1.3 \cdot 10^{-6}$
incineration of chemical waste	8.1
production of ethylene	0.0008
production of PE	0.01
production of plastic bags	0.01
production of electricity	$2.4 \cdot 10^{-5}$
packaging a loaf	1000

[1] In a product system there may be internal loops, for instance when the extraction of coal requires electricity and the production of coal requires electricity. In a matrix method, the calculation takes this accurately into account, while in a sequential method, the solution is only an approximation, and the accuracy depends on the number of times the loop is passed. Depending on the software used, the number of passes may be one, a fixed number (e.g. 5), or it may depend on the size that each additional pass adds to the results.
[2] This may be a qualitative sensitivity analysis for detailed LCA and a quantitative sensitivity analysis modeling the loops concerned, as an optional extension.

The interventions of each process have been scaled accordingly and aggregated over the entire system. This produces the following results.

intervention	product system
resources	
crude oil	8.1 kg
emissions to air	
1-butene	7.8E–7 kg
benzene	9.9E–7 kg
carbon dioxide	2.2 kg
dioxins (unspecified)	8.1E–14 kg
ethylene	1.2E–4 kg
nitrogen oxides	3.7E–3 kg
sulphur dioxide	2.0E–2 kg
emissions to water	
benzene	1.2E–9 kg
cadmium	4.4E–8 kg
lead	3.0E–9 kg
mercury	2.8E–9 kg
phenol	2.4E–8 kg
economic inflows not followed to the system boundary	
lubricants	2.4 kg
economic outflows not followed to the system boundary	
used plastic bags	1000
residue to dump	0.08 kg
recovered energy	0.0008 MJ

Notice that these results exclude the estimates of the IOA."

3.4 Results of Inventory analysis

The main result of this phase, which is the input of the next phase – Impact assessment – is the inventory table; see above for an example. But of course, there is a host of additional information, like aspects that could not be quantified, information related to data quality, and so on. These other forms of information are especially useful in the Interpretation phase.

4. Impact assessment

4.1 Topic

Life Cycle Impact Assessment (LCIA) is the phase in which the set of results of the Inventory analysis – mainly the inventory table – is further processed and interpreted in terms of environmental impacts and societal preferences. To this end, a list of impact categories is defined, and models for relating the environmental interventions to suitable category indicators for these impact categories are selected. The actual modeling results are calculated in the characterisation step, and an optional normalisation serves to indicate the share of the modeled results in a worldwide or regional total. Finally, the category indicator results can be grouped and weighted to include societal preferences of the various impact categories.

4.2 Starting points

ISO 14042 has been the general starting point for this phase. The ISO requirements have subsequently been made operational through the work of the SETAC Working Group on Impact Assessment and many individual projects.

The Impact assessment steps described in this Guide have been copied from ISO 14042, with a few adaptations. For a justification and explanation of these adaptations, see Part 3, chapter 1. The requirements of ISO 14042 have been closely followed, with the following additions or further specifications:

- The list of impact categories and best available models drawn up by the SETAC-Europe Working Group on Impact Assessment has been taken as the basis for the baseline impact categories and category indicators. In this method, the impact indicators focus on the so-called midpoints of the cause-effect chain, and the method is referred to below as the problem-oriented approach.
- Quality analysis has been implemented in the section on key issues for sensitivity analysis; the latter is conducted as part of the Interpretation.

All additional main methodological choices, including references to all ISO steps, are addressed in the following sections on main choices; recipe steps are given, sometimes deviating from ISO 14042.

Instead of the baseline Impact assessment approach, entirely different approaches towards Impact assessment could be chosen. Eco-indicator 99 provides such an approach, with partly different impact categories and category indicators. EPS is another example.

4.3 Recipe

4.3.1 Procedures

Topic

Procedural organisation should involve a common treatment of all general and specific subjects that the parties involved wish to discuss in this Impact assessment phase. Attention should be given to the following issues of this phase.

- The choice of impact categories to be taken into consideration (whether or not quantified)
- The choice (and/or development) and use of the characterisation method(s)
- The choice of process groups/substance groups to be taken apart from calculation and presentation
- The calculation of effect scores per impact category (including a validated software program)
- The presentation of the quantitative results of the Impact assessment per impact category
- An account of non-quantified but relevant environmental aspects
- The execution of the normalisation step
- The execution of the weighting step
- The execution of a sensitivity analysis
- The presentation of results, including marginal notes and possible (preliminary) conclusions
- Intentions with respect to the approach to be used in the following phases (especially that of Interpretation)
- Further process planning and process management

Main choices

- In the course of this LCA phase, the supervisory process should be arranged so as to preserve the authoritativeness of the results. The potential input from stakeholders should also be used to improve the quality of the LCA. In this situation of 'mandated science', this implies that, depending on the specific process context, there should be room for interaction between the parties involved on topics that are relevant to the selection and definition of impact categories, characterisation methods, normalisation references, weighting principles and so on.

Guidelines

Guidelines for simplified and detailed LCA and optional extensions

☞ Determine the competencies and responsibilities of the LCA research scientists, any critical reviewers, the LCA clients and other interested parties, using Table 4.3.1.
☞ Address potential bottlenecks in the LCA process by making arrangements in line with Table 4.3.2 to ensure the orderly progress of the project.

Table 4.3.1. Overview of the competencies of the various actors during the LCA process for the different process contexts.

Item	Description	Process context		
		I	II	III
1a	first instructions with respect to fulfilment of LCA assignment	C	C or S	S
1b	first instructions with respect to fulfilment of assignment of critical reviewer	–	C or S	S
2a	written response to instruction on LCA assignment	L	L + R	L + R
2b	written response to instructions on assignment of critical reviewer[1]	–	R	R
3a	possible revision of the first instructions on LCA assignment	C	C or S	S
3b	possible report on incompatible opinions on LCA assignment	L	L	L
4	presentation of draft interim report (= draft text of Impact assessment report)	L	L + R	L + R
5	written response to draft interim report on Impact assessment	C	C or S	S
6	possible revision of draft report on Impact assessment	L	L + R	L + R
7	possible report on incompatible opinions arising during the Impact assessment	L	L	L
8	final opinion on final interim report on Impact assessment	C	C or S	S

Legend

Process context I = few diverging interests, potentially strong impact
Process context II = many diverging interests, potentially weak impact
Process context III = many diverging interests, potentially strong impact
C = first LCA client(s)

[1] The actual implementation of all guidelines in this Guide should be checked in a critical review.

S = stakeholders (including C)
L = LCA research scientists
R = critical reviewer

Table 4.3.2 Overview of the arrangements that can be made between the various actors for the different process contexts.

Item	Description	Process context		
		I	II	III
a	widening/supplementation of the study (on request)	o	r	r
b	validation by an independent expert (on request)	o	r	r
c	binding advice on decision points by the critical reviewer	o	r	r
d	final decision-making by the biggest possible majority, arbitration or another previously determined procedure	o	o	r
e	quantification of the influence of incompatible opinions in the final report	o	r	r

Legend
Process context I = few diverging interests, potentially strong impact
Process context II = many diverging interests, potentially weak impact
Process context III = many diverging interests, potentially strong impact
r = recommended
o = option

Example (case history)

In the spring of 2000, the Waste Department of the Dutch Ministry of Environmental Affairs finished the OMA project, which aimed to develop an instrument for comparing the total environmental load of different waste policy options. This project was started in 1999, because of doubts about the general validity of the standard order of preference with respect to waste disposal (prevention, product reuse, materials recycling, incineration with energy recovery, dumping). The way this problem was addressed in practice was found to be problematic: “In those cases where it was decided to execute of an LCA, there have been differences in scope, environmental aspects taken into account and weighting methods. There is no systematic approach to the use of integral environmental analyses in waste policy.”

A project group of staff members of the Waste Department addressed the problem in a few workshops together with selected staff members of other departments of the Ministry of Environmental Affairs. They discussed the results of a number of relevant LCA studies, focusing on key supplies and environmental aspects that were of overriding importance for the comparison of different waste disposal options.

For the sake of communication and manageability, it was deemed desirable to restrict the number of environmental aspects to be taken into account. Important criteria for achieving a justifiable simplification turned out to be the size of the differences in the scores of the alternatives and the size of the contribution to the national environmental load. The staff members concluded that in the case of waste policy, the analysis could be restricted to three main environmental aspects: greenhouse effect, dumped waste and dispersion of hazardous substances. In the near future, this approach will be used to address a number of actual waste topics and to prepare the National Waste Plan.

4.3.2 Selection of impact categories

Topic

In the Impact assessment phase, the results of the Inventory analysis are translated into contributions to relevant impact categories, such as depletion of abiotic resources, climate change, acidification, etc. To this end, relevant impact categories must be identified. To facilitate the work of practitioners, a default list of impact categories has been elaborated, distinguishing between 'baseline' impact categories, 'study-specific' impact categories and 'other' impact categories. In this step of the LCA, then, practitioners have to select those categories relevant to the goal of their particular study, supported by the preliminary selection made in this Guide.

Main choices

- The list of best available practice impact categories drawn up by the SETAC Working Group on Impact Assessment has served as a basic list. This choice is referred to below as the problem-oriented approach, because it is driven by environmental problems (the so-called mid-point of the cause-effect chain), rather than by damage (the end-point of this chain).
- Three sets of impact categories are distinguished (see Table 4.3.3), depending on the environmental relevance in relation to LCA and the availability of adequate characterisation methods[1] (see Section 4.3.3).
  - Group A, “Baseline impact categories”, comprises those categories for which a baseline characterisation method is selected in Part 2b, and which are included in almost all LCA studies.
  - Group B, “Study-specific impact categories”, comprises categories that may merit inclusion, depending on the goal and scope of the LCA study and whether appropriate data are available, and for which a baseline and/or alternative characterisation method is proposed in Part 2b.
  - Group C, “Other impact categories”, comprises several categories for which no baseline characterisation method is proposed in this Guide, although alternative characterisation methods may be available. These impact categories require further elaboration before they can be used in LCA studies, with research still in progress.

Table 4.3.3: Overview of baseline and other impact categories in relation to the availability of baseline characterisation methods.

Impact category	Single baseline characterisation method available in the Guide?	Other characterisation method(s) available in the Guide?
A. Baseline impact categories		
Depletion of abiotic resources	yes	yes
Impacts of land use		
land competition	yes	yes
Climate change	yes	yes
Stratospheric ozone depletion	yes	yes
Human toxicity	yes	yes

[1] The characterisation method for a given impact category comprises a category indicator, characterisation model and characterisation factors derived from the model.

Impact category	Single baseline characterisation method available in the Guide?	Other characterisation method(s) available in the Guide?
Ecotoxicity		
freshwater aquatic ecotoxicity	yes	yes
marine aquatic ecotoxicity	yes	yes
terrestrial ecotoxicity	yes	yes
Photo-oxidant formation	yes	yes
Acidification	yes	yes
Eutrophication	yes	yes
B. Study-specific impact categories		
Impacts of land use		
loss of life support function	no	yes
loss of biodiversity	no	yes
Ecotoxicity		
freshwater sediment ecotoxicity	yes	yes
marine sediment ecotoxicity	yes	yes
Impacts of ionising radiation	yes	yes
Odour		
malodourous air	yes	no
Noise	yes	no
Waste heat	yes	no
Casualties	yes	no
C. Other impact categories		
Depletion of biotic resources	no	yes
Desiccation	no	no
Odour		
malodourous water	no	no
...	...	...

Note: the list is restricted to the impact categories. The results of the characterisation and normalisation steps require reporting of the calculated values for the selected impact categories, as well as information on interventions not included in the model (Section 4.3.3.17) and economic flows not followed to the system boundary (Section 4.3.3.18), and additional qualitative information.

Guidelines

Guidelines for simplified LCA

- ☞ Use the problem-oriented approach with impact categories defined at mid-point level (see the glossary at the end of this Part). If not, document and justify any other approach chosen. As an option for a sensitivity analysis, application of an endpoint-oriented approach such as Eco-indicator 99 or EPS is suggested. See references in Part 2b, Section 3.2.
- ☞ Include all or a selection of the baseline impact categories (group A) from Table 4.3.3.
- ☞ If a selection is made, justify this selection in relation to the goal of the study. Note that it is better to have "empty" impact categories than omissions. For instance, do not leave out the impact category of stratospheric ozone depletion for products that are "ozone-friendly", but show only zeroes in the classification and characterisation.
- ☞ Be flexible in including additional impact categories if the goal and scope of the study demands this (e.g., always include the additional effects of the land use subcategories of

"loss of life support" and "loss of biodiversity" in a study on wood applications or studies involving forestry).

- ☞ Practitioners can refer to this Guide for a description and justification of the choice of impact categories as required to meet ISO 14042 standards.
- ☞ If it is relevant to the study, the energy carriers extracted from the environment (coal, oil and gas) can be transformed into one total amount of extracted energy in MJ. See Part 2b, Table 4.3.1.5 for a list of upper and lower heating values for a number of energy carriers. This amount should then be given as a separate "impact" category.
- ☞ As an issue for the Interpretation phase, check whether the selection of impact categories is appropriate for the product(s) investigated, and if it is balanced in the case of a comparison.
- ☞ If no Impact assessment has been carried out, the reasons for this should be detailed.
- ☞ In the case of a comparison, select the same impact categories for each of the alternative product systems.

Guidelines for detailed LCA

All guidelines provided above for simplified studies apply here as well. In addition, the following guideline is given.

- ☞ From Table 4.3.3, include baseline impact categories (group A) and any study-specific impact categories (group B) relevant to the goal and scope of the study.

Guidelines for optional extensions

All guidelines provided above for detailed studies apply here as well. In addition, the following guideline is given.

- ☞ Consider whether it is justifiable, in relation to the goal and scope of the study, to add impact categories from group C or to add a new impact category. If so, document and justify comprehensively and transparently all requirements listed in Part 3, Section 4.1.

Example (hypothetical)

"This LCA includes all baseline impact categories (group A), as well as freshwater and marine sediment toxicity, because the emission of toxics is generally felt to be one of the major problems for this product."

4.3.3 Selection of characterisation methods: category indicators, characterisation models and factors

Topic

The interventions recorded in the inventory table are quantified in terms of a common category indicator. To this end, characterisation models are used, from which characterisation factors are derived for individual pollutants and so on. For a given impact category, a characterisation method comprises a category indicator, a characterisation model and characterisation factors derived from the model. The impact categories distinguished in this Guide (see 4.3.2) are treated individually in Sections 4.3.3.1 to 4.3.3.18, below, discussing the models, factors and indicators available for the category in question.

Main choices

- Category indicators are chosen at mid-point level, since the end-point level is not comprehensive enough and is still being developed.
- The list of best available practice category indicators and characterisation models by the SETAC Working Group on Impact Assessment has served as a basic list.

- In the selection of characterisation methods for every impact category, a distinction has been made into:
  - a baseline characterisation method, i.e., the method recommended here as the current best available practice for the impact category in question;
  - alternative characterisation methods, which may be adopted instead of the baseline method if duly justified and documented, or may be used in tandem with the baseline method, as a sensitivity analysis;
  - additional characterisation methods, which may be applied like the alternative methods but require additional effort (e.g., collection of additional data, development of additional models);
  - variant characterisation methods, which start from entirely different principles, and which are referred to in Part 3, but not tabulated in Part 2b.

Guidelines

Guidelines for simplified and detailed LCA

☞ Use the baseline characterisation method for each of the selected impact categories for which such a method exists.[1]

☞ For certain impact categories, consider using one of the methods from the group of alternative methods. Justify this selection.

☞ Practitioners can refer to this Guide for a description and justification of the choice of these characterisation models and their related category indicators, as required to meet ISO 14042 standards.

☞ If an Impact assessment has been carried out, the methodology used should be clearly described in the report. Practitioners can refer to this Guide for a description and justification (as required to meet ISO 14042 standards) of the methods recommended as the baseline methods in this Guide. If other methods are used, these must be documented and justified in the report.

☞ In the case of a comparison, check whether the Impact assessment has been conducted consistently between the various systems compared and whether the validity and reliability of the data sources used for Impact assessment is not too different for the various systems studied.

☞ Give a justification of the scientific and technical validity and environmental relevance of the category indicators and characterisation models used in the study. Practitioners can refer to this Guide for a description of the methods reviewed in this Guide.

☞ If other methods are used, reports must pay attention to the following topics.
  - Can the choice of data sources for characterisation factors be justified in relation to the goal of the study and particularly to scope issues like temporal and geographical coverage? For instance, is the use of a particular model of acidification suitable and not designed for other regions than those where the bulk of the acidifying depositions will occur?
  - What is the reliability of different data sources in qualitative terms?

[1] The choice of baseline characterisation methods in the next twenty sections is based on the assumption that the problem-oriented approach has indeed been chosen, with the associated set of impact categories (see Section 4.3.2). If Eco-indicator 99 and/or EPS has been chosen, the set of impact categories is considerably different from those discussed below. For a subset of impact categories, however, there is an overlap between the problem-oriented approach that is the default choice of this Guide and the alternative approaches (Eco-indicator 99, EPS). Many of the basic models used in Eco-indicator 99 and EPS, e.g. the fate and exposure model for the toxicity categories and the GWP model for climate change etc., are basically the same as those of the problem-oriented approach. Due to recent updates, however, this is as yet not the case, which may lead to ‘unnecessary’ inconsistencies.

- Are the sets of characterisation factors used complete? For instance, are any characterisation factors missing for interventions that are suspected to contribute to a given impact category?
- In the case of a comparison: are the above-mentioned issues not too different for the various systems studied?

☞ Include a description and justification of any new category indicators or characterisation models used for the Impact assessment, including all assumptions and limitations and all value choices made. Discuss their influence on the results, conclusions and recommendations

☞ Derive characterisation factors for the group parameter at stake, based on the arithmetic means of the individual species within that group for which characterisation factors are known. If, for example, only emission data on hydrocarbons are known, group POCPs can be derived as the arithmetic means of the POCPs of individual hydrocarbons.

☞ Include a statement as to whether or not international acceptance exists for the selected category indicators.

☞ In the case of a comparison, check whether the validity and reliability of the data sources used for Impact assessment is not potentially too different for the various systems studied.

Guidelines for optional extensions

All guidelines provided above for simplified and detailed studies apply here as well. In addition, the following optional guidelines are given.

☞ Use characterisation methods from the group of additional methods, where relevant.

☞ Where relevant, use or develop other characterisation methods and describe these according to ISO 14042. Furthermore, an appropriate indication should be given of how the category indicator results have been, or are to be, calculated.

☞ Calculate, estimate or extrapolate characterisation factors for interventions which might be important for the case in hand but for which no characterisation factors are given in Part 2b of this Guide. The new factors could be calculated based on the baseline method (see the next sections), or estimated or extrapolated based on known characterisation factors for interventions which are comparable to the new interventions.

☞ Try whether, in addition to the superficial qualitative assessment of reliability mentioned under simplified and detailed LCA, more extensive qualitative and/or quantitative assessments of reliability can be made.

Example (hypothetical)

"In this LCA we have used the baseline characterisation methods developed by Guinée et al. (2001) for all selected impact categories."

4.3.3.1 Depletion of abiotic resources

Topic

"Abiotic resources" are natural resources (including energy resources) such as iron ore, crude oil and wind energy, which are regarded as non-living. Abiotic resource depletion is one of the most frequently discussed impact categories and there is consequently a wide variety of methods available for characterising contributions to this category. To a large extent, these different methodologies reflect differences in problem definition. Depending on the definition, this impact category includes only natural resources, or natural resources, human health and the natural environment, among its areas of protection. Note that the debate on the characterisation of depletion-related impact categories is not settled.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	based on ultimate reserves and extraction rates	4.3.1.1
alternative 1	based on economic reserves and extraction rates	4.3.1.2
alternative 2	based on ultimate or economic reserves only	4.3.1.2
alternative 3	based on exergy content	4.3.1.3 4.3.1.4
additional	–	–
variant	–	–

Example (for baseline)

impact category	abiotic depletion
LCI results	extraction of minerals and fossil fuels (in kg)
characterisation model	concentration-based reserves and rate of de-accumulation approach
category indicator	depletion of the ultimate reserve in relation to annual use
characterisation factor	abiotic depletion potential (ADP) for each extraction of minerals and fossil fuels (in kg antimony equivalents/kg extraction)
unit of indicator result	kg (antimony eq)

4.3.3.2 Depletion of biotic resources

Topic

"Biotic resources" are material resources (including energy resources) regarded as living, e.g. rainforests, elephants. Depending on the precise definition adopted, this impact category has only natural resources, or natural resources, human health and the natural and the man-made environment as areas of protection.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	–	–
alternative	–	–
additional	based on reserves and deaccumulation rate	–
variant	–	–

Example (for baseline)

Depletion of biotic resources has been excluded, in line with the baseline recommendation.

4.3.3.3 Impacts of land use

Topic

The category "Impacts of land use" covers a range of consequences of human land use. A distinction has been made between use of land with impacts on the resource aspect and use of land with impacts on biodiversity, life support functions, etc.

4.3.3.3.1 Land competition

Topic

This subcategory of land use impacts is concerned with the loss of land as a resource, in the sense of being temporarily unavailable. The areas of protection are natural resources and the man-made environment.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	unweighted aggregation	–[1]
alternative	–	–
additional	–	–
variant	–	–

Example (for baseline)

impact category	land competition
LCI results	land use (in $m^2 \cdot yr$)
characterisation model	unweighted aggregation
category indicator	land occupation
characterisation factor	1 for all types of land use (dimensionless)
unit of indicator result	$m^2 \cdot yr$ (land use)

4.3.3.3.2 Loss of biodiversity

Topic

In this impact category, the problems defined are the effects on biodiversity resulting from interventions such as harvesting biotic resources, or the destruction or alteration of land. Notice that the discussion on characterisation of land-use-related impact categories is far from settled.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	–	–
alternative 1	based on a statistical measure of species density	–
alternative 2	based on a statistical measure of plant species density	–
additional	–	–
variant	–	–

Example (for baseline)

Loss of biodiversity has been excluded, in line with the baseline recommendation.

[1] Characterisation factor is 1 throughout.

4.3.3.3.3 Loss of life support function

Topic

In this impact category, the problems defined are the effects on life support function resulting from interventions such as harvesting biotic resources, or the destruction or alteration of land. Notice that the discussion on characterisation of land-use-related impact categories is far from settled.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	–	–
alternative	based on Net Primary Production	–
additional	–	–
variant	–	–

Example (for baseline)

Loss of life support function has been excluded, in line with the baseline recommendation.

4.3.3.4 Desiccation

Topic

Desiccation refers to a group of related environmental problems caused by water shortages due to groundwater extraction for industrial and potable water supply, enhanced drainage and water management (i.e. manipulation of the water table). This may lead to a lowered water table, reduced seepage, introduction of water from other areas and (consequently) changes in natural vegetation. The area of protection is the natural environment.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	–	–
alternative	–	–
additional	–	–
variant	–	–

Example (for baseline)

Desiccation has been excluded, in line with the baseline recommendation.

4.3.3.5 Climate change

Topic

Climate change is defined here as the impact of human emissions on the radiative forcing (i.e. heat radiation absorption) of the atmosphere. This may in turn have adverse impacts on ecosystem health, human health and material welfare. Most of these emissions enhance radiative forcing, causing the temperature at the earth’s surface to rise. This is popularly referred to as the ‘greenhouse effect’. The areas of protection are human health, the natural environment and the man-made environment.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	GWP_{100}	4.3.5.1
alternative 1	GWP_{20}	4.3.5.2
alternative 2	GWP_{500}	4.3.5.2
alternative 3	upper limit of net GWP	4.3.5.3
alternative 4	lower limit of net GWP	4.3.5.3
additional	–	–
variant	–	–

Example (for baseline)

impact category	climate change
LCI results	emissions of greenhouse gases to the air (in kg)
characterisation model	the model developed by the Intergovernmental Panel on Climate Change (IPCC) defining the global warming potential of different greenhouse gases
category indicator	infrared radiative forcing (W/m^2)
characterisation factor	global warming potential for a 100-year time horizon (GWP100) for each greenhouse gas emission to the air (in kg carbon dioxide equivalent/kg emission)
unit of indicator result	kg (carbon dioxide eq)

4.3.3.6 Stratospheric ozone depletion

Topic

Stratospheric ozone depletion refers to the thinning of the stratospheric ozone layer as a result of anthropogenic emissions. This causes a greater fraction of solar UV-B radiation to reach the earth's surface, with potentially harmful impacts on human health, animal health, terrestrial and aquatic ecosystems, biochemical cycles and materials. Stratospheric ozone depletion thus impinges on all four areas of protection: human health, the natural environment, the man-made environment and natural resources.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	ODP_{∞}	4.3.6.1
alternative 1	ODP_5	4.3.6.2
alternative 2	ODP_{10}	4.3.6.2
alternative 3	ODP_{15}	4.3.6.2
alternative 4	ODP_{20}	4.3.6.2
alternative 5	ODP_{25}	4.3.6.2
alternative 6	ODP_{30}	4.3.6.2
alternative 7	ODP_{40}	4.3.6.2
additional	–	–
variant	–	–

Example (for baseline)

impact category	stratospheric ozone depletion
LCI results	emissions of ozone-depleting gases to the air

characterisation model	the model developed by the World Meteorological Organisation (WMO), defining the ozone depletion potential of different gases
category indicator	stratospheric ozone breakdown
characterisation factor	ozone depletion potential in the steady state (ODP steady state) for each emission to the air (in kg CFC-11 equivalent/kg emission)
unit of indicator result	kg (CFC-11 eq)

4.3.3.7 Human toxicity

Topic

This impact category covers the impacts on human health of toxic substances present in the environment. The health risks of exposure in the workplace are also sometimes included in LCA. These latter risks are often included in a wider impact category encompassing more than exposure to toxic substances (e.g. accidents at work). In this Guide, no further consideration is given to the impacts of exposure to toxic substances in the workplace. The area of protection for this impact category is human health. Notice that the discussion on characterisation of toxicity-related impact categories is far from settled.

Main choices and guideline

Method status	Characterisation method/factor	Table in Part 2b
baseline	$HTP_{\infty,global}$	4.3.7.1
alternative 1	$HTP_{20,global}$	4.3.7.2
alternative 2	$HTP_{100,global}$	4.3.7.1
alternative 3	$HTP_{500,global}$	4.3.7.2
alternative 4	$HTP_{\infty,continental}$	4.3.7.2
additional	–	–
variant	see Part 3	–

Example (for baseline)

impact category	human toxicity
LCI results	emissions of toxic substances to air, water and soil (in kg)
characterisation model	USES 2.0 model developed at RIVM, describing fate, exposure and effects of toxic substances, adapted to LCA
category indicator	acceptable daily intake /predicted daily intake
characterisation factor	human-toxicity potential (HTP) for each emission of a toxic substance to air, water and/or soil (in kg 1,4-dichlorobenzene equivalent/kg emission)
unit of indicator result	kg (1,4-dichlorobenzene eq)

4.3.3.8 Ecotoxicity

Topic

This impact category covers the impacts of toxic substances on aquatic, terrestrial and sediment ecosystems. The area of protection is the natural environment (and natural resources). Notice that the discussion on characterisation of toxicity-related impact categories is far from settled.

4.3.3.8.1 Freshwater aquatic ecotoxicity

Topic

Freshwater aquatic ecotoxicity refers to the impacts of toxic substances on freshwater aquatic ecosystems.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	$FAETP_{\infty,global}$	4.3.8.1
alternative 1	$FAETP_{100,global}$	4.3.8.2
alternative 2	$FAETP_{20,global}$	4.3.8.3
alternative 3	$FAETP_{500,global}$	4.3.8.4
alternative 4	$FAETP_{\infty,continental}$	4.3.8.5
additional	–	–
variant	see Part 3	–

Example (for baseline)

impact category	freshwater aquatic ecotoxicity
LCI results	emissions of toxic substances to air, water and soil (in kg)
characterisation model	USES 2.0 model developed at RIVM, describing fate, exposure and effects of toxic substances, adapted to LCA
category indicator	predicted environmental concentration/predicted no-effect concentration
characterisation factor	freshwater aquatic ecotoxicity potential (FAETP) for each emission of a toxic substance to air, water and/or soil (in kg 1,4-dichlorobenzene equivalents /kg emission)
unit of indicator result	kg (1,4-dichlorobenzene eq)

4.3.3.8.2 Marine aquatic ecotoxicity

Topic

This impact category covers impacts of toxic substances on marine aquatic ecosystems.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	$MAETP_{\infty,global}$	4.3.8.1
alternative 1	$MAETP_{100,global}$	4.3.8.2
alternative 2	$MAETP_{20,global}$	4.3.8.3
alternative 3	$MAETP_{500,global}$	4.3.8.4
alternative 4	$MAETP_{\infty,continental}$	4.3.8.5
additional	–	–
variant	see Part 3	–

Example (for baseline)

impact category	marine aquatic ecotoxicity
LCI results	emissions of toxic substances to air, water and soil (in kg)
characterisation model	USES 2.0 model developed at RIVM, describing fate, exposure

	and effects of toxic substances, adapted to LCA
category indicator	predicted environmental concentration/predicted no-effect concentration
characterisation factor	marine aquatic ecotoxicity potential (MAETP) for each emission of a toxic substance to air, water and/or soil (in kg 1,4-dichlorobenzene equivalent/kg emission)
unit of indicator result	kg (1,4-dichlorobenzene eq)

4.3.3.8.3 Terrestrial ecotoxicity

Topic

Terrestrial ecotoxicity refers to impacts of toxic substances on terrrestrial ecosystems.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	$TAETP_{\infty,global}$	4.3.8.1
alternative 1	$TAETP_{100,global}$	4.3.8.2
alternative 2	$TAETP_{20,global}$	4.3.8.3
alternative 3	$TAETP_{500,global}$	4.3.8.4
alternative 4	$TAETP_{\infty,continental}$	4.3.8.5
additional	–	–
variant	see Part 3	–

Example (for baseline)

impact category	terrestrial ecotoxicity
LCI results	emissions of toxic substances to air, water and soil (in kg)
characterisation model	USES 2.0 model developed at RIVM, describing fate, exposure and effects of toxic substances, adapted to LCA
category indicator	predicted environmental concentration/predicted no-effect concentration
characterisation factor	terrestrial ecotoxicity potential (TETP) for each emission of a toxic substance to air, water and/or soil (in kg 1,4-dichlorobenzene equivalents/kg emission)
unit of indicator result	kg (1,4-dichlorobenzene eq)

4.3.3.8.4 Freshwater sediment ecotoxicity

Topic

Freshwater sediment ecotoxicity refers to impacts of toxic substances on the sediment of freshwater ecosystems.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	$FSETP_{\infty,global}$	4.3.8.1
alternative 1	$FSETP_{100,global}$	4.3.8.2
alternative 2	$FSETP_{20,global}$	4.3.8.3
alternative 3	$FSETP_{500,global}$	4.3.8.4
alternative 4	$FSETP_{\infty,continental}$	4.3.8.5

Method status	Characterisation method/factor	Table in Part 2b
additional	–	–
variant	see Part 3	–

Example (for baseline)

impact category	freshwater sediment ecotoxicity
LCI results	emissions of toxic substances to air, water and soil (in kg)
characterisation model	USES 2.0 model developed at RIVM, describing fate, exposure and effects of toxic substances, adapted to LCA
category indicator	predicted environmental concentration/predicted no-effect concentration
characterisation factor	freshwater sediment ecotoxicity potential (FSETP) for each emission of a toxic substance to air, water and/or soil (in kg 1,4-dichlorobenzene equivalents/kg emission)
unit of indicator result	kg (1,4-dichlorobenzene eq)

4.3.3.8.5 Marine sediment ecotoxicity

Topic

Marine sediment ecotoxicity refers to impacts of toxic substances on the sediment of sea water ecosystems.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	$MSETP_{\infty,global}$	4.3.8.1
alternative 1	$MSETP_{100,global}$	4.3.8.2
alternative 2	$MSETP_{20,global}$	4.3.8.3
alternative 3	$MSETP_{500,global}$	4.3.8.4
alternative 4	$MSETP_{\infty,continental}$	4.3.8.5
additional	–	–
variant	see Part 3	–

Example (for baseline)

impact category	marine sediment ecotoxicity
LCI results	emissions of toxic substances to air, water and soil (in kg)
characterisation model	USES 2.0 model developed at RIVM, describing fate, exposure and effects of toxic substances, adapted to LCA
category indicator	predicted environmental concentration/predicted no-effect concentration
characterisation factor	marine sediment ecotoxicity potential (MSETP) for each emission of a toxic substance to air, water and/or soil (in kg 1,4-dichlorobenzene equivalents/kg emission)
unit of indicator result	kg (1,4-dichlorobenzene eq)

4.3.3.9 Photo-oxidant formation

Topic

Photo-oxidant formation is the formation of reactive chemical compounds such as ozone by the action of sunlight on certain primary air pollutants. These reactive compounds may be injurious to human health and ecosystems and may also damage crops. The relevant areas of protection are human health, the man-made environment, the natural environment and natural resources.

Photo-oxidants may be formed in the troposphere under the influence of ultraviolet light, through photochemical oxidation of Volatile Organic Compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NO_x). Ozone is considered the most important of these oxidising compounds, along with peroxyacetylnitrate (PAN). Photo-oxidant formation, also known as summer smog, Los Angeles smog or secondary air pollution, contrasts with winter smog, or London smog, which is characterised by high levels of inorganic compounds, mainly particles, carbon monoxide and sulphur compounds. This latter type of smog causes bronchial irritation, coughing, etc. Winter smog, as far as considered in this Guide, is part of human toxicity.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	high NOx POCP	4.3.9.1
alternative 1	MIR	4.3.9.2
alternative 2	MOIR	4.3.9.2
alternative 3	EBIR	4.3.9.2
alternative 4	low NOx POCP	4.3.9.3
additional	–	–
variant	–	–

Example (for baseline)

impact category	photo-oxidant formation
LCI results	emissions of substances (VOC, CO) to air (in kg)
characterisation model	UNECE Trajectory model
category indicator	tropospheric ozone formation
characterisation factor	photochemical ozone creation potential (POCP) for each emission of VOC or CO to the air (in kg ethylene equivalents/kg emission)
unit of indicator result	kg (ethylene eq)

4.3.3.10 Acidification

Topic

Acidifying pollutants have a wide variety of impacts on soil, groundwater, surface waters, biological organisms, ecosystems and materials (buildings). Examples include fish mortality in Scandinavian lakes, forest decline and the crumbling of building materials. The major acidifying pollutants are SO_2, NO_x and NH_x. Areas of protection are the natural environment, the man-made environment, human health and natural resources.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	average European AP	4.3.10.1
alternative	generic AP	4.3.10.2
additional	region (site) dependent AP	4.3.10.3
variant	see Part 3	–

Example (for baseline)

impact category	acidification
LCI results	emissions of acidifying substances to the air (in kg)
characterisation model	RAINS10 model, developed at IIASA, describing the fate and deposition of acidifying substances, adapted to LCA
category indicator	deposition/acidification critical load
characterisation factor	acidification potential (AP) for each acidifying emission to the air (in kg SO_2 equivalents /kg emission)
unit of indicator result	kg (SO_2 eq)

4.3.3.11 Eutrophication

Topic

Eutrophication covers all potential impacts of excessively high environmental levels of macronutrients, the most important of which are nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In addition, high nutrient concentrations may also render surface waters unacceptable as a source of drinking water. In aquatic ecosystems increased biomass production may lead to a depressed oxygen levels, because of the additional consumption of oxygen in biomass decomposition (measured as BOD, biological oxygen demand). As emissions of degradable organic matter have a similar impact, such emissions are also treated under the impact category “eutrophication”. The areas of protection are the natural environment, natural resources and the man-made environment.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	generic EP	4.3.11.1
alternative	average European EP	4.3.11.2
additional	region (site) dependent EP	4.3.11.2
variant	–	–

Example (for baseline)

impact category	eutrophication
LCI results	emissions of nutrients to air, water and soil (in kg)
characterisation model	the stoichiometric procedure, which identifies the equivalence between N and P for both terrestrial and aquatic systems
category indicator	deposition/N/P equivalents in biomass
characterisation factor	eutrophication potential (EP) for each eutrophying emission to air, water and soil (in kg PO_4 equivalents/kg emission)
unit of indicator result	kg (PO_4 eq)

4.3.3.12 Waste heat

Topic

Emissions of waste heat may increase temperatures on a local scale: in a city or lake, for example. They cannot contribute to global warming on a scale such as that associated with emissions of greenhouse gases. The effects on ecosystems of waste heat emissions to the air are negligible. Depending on local conditions, the discharge of waste heat into surface waters may result in a substantial temperature rise, with a consequent impact on local aquatic ecosystems. In this Guide waste heat is treated as a separate impact category, although it covers only aquatic emissions of waste heat such as cooling water emissions from power stations. The areas of protection are the natural environment and natural resources.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	unweighted aggregation of energy	–[1]
alternative	–	–
additional	–	–
variant	–	–

Example

impact category	waste heat
LCI results	emissions of heat (in MJ) to water
characterisation model	unweighted aggregation
category indicator	heat released
characterisation factor	1 (dimensionless)
unit of indicator result	MJ (heat)

4.3.3.13 Odour

Topic

Odour becomes a problem when a given concentration of odorous substances is experienced as unpleasant. Whether an odour is experienced as stench will depend on the particular individual exposed. Above a certain emission level, however, every individual will experience it as such. Here, the term odour will be used for effects. The area of protection is human health.

4.3.3.13.1 Malodorous air

Topic

This subcategory involves airborne odour.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	inverse OTV	4.3.13.1

[1] Characterisation factor is 1 throughout.

Method status	Characterisation method/factor	Table in Part 2b
alternative	–	–
additional	based on fate model and odour threshold values	–
variant	–	–

Example (for baseline)

impact category	malodorous air
LCI results	emissions of odorous substances (in kg) to the air
characterisation model	reciprocal of odour threshold value in the air
category indicator	volume of air filled to the odour threshold value
characterisation factor	reciprocal of odour threshold value (1/OTV, in m^3/kg)
unit of indicator result	m^3 (air)

4.3.3.13.2 Malodorous water

Topic

This subcategory deals with water-borne odour.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	–	–
alternative	–	–
additional	–	–
variant	–	–

Example (for baseline)

Malodorous water has been excluded, in line with the baseline recommendation.

4.3.3.14 Noise

Topic

Noise, or noise nuisance, refers to the environmental impacts of sound. In principle, these impacts could cover at least human health and ecosystem health, but the environmental mechanisms are complex, non-linear and highly dependent upon local circumstances. Moreover, noise is similar to odour in that a given level of exposure is experienced differently by different individuals. Something considered a nuisance by one person might be appreciated by another, as exemplified by the case of loud music. Hence, whether or not sound waves will lead to 'nuisance' depends partly on the actual situation and partly on the person interviewed.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	unweighted aggregation of sound	–[1]
alternative	–	–
additional	based on DALY	–

[1] Characterisation factor is 1 throughout.

Method status	Characterisation method/factor	Table in Part 2b
variant	–	–

Example (for baseline)

impact category	noise
LCI results	emissions of sound (in $Pa^2 \cdot s$)
characterisation model	unweighted aggregation
category indicator	sound
characterisation factor	1
unit of indicator result	$Pa^2 \cdot s$ (sound)

4.3.3.15 Impacts of ionising radiation

Topic

The impact category 'impacts of ionising radiation' covers the impacts arising from releases of radioactive substances as well as direct exposure to radiation, in building materials for example. Exposure to ionising radiation is harmful to both human beings and animals. The areas of protection are therefore human health, the natural environment and natural resources. Ionising radiation is expressed in terms of the number of atoms disintegrating (or decaying) per unit time. The SI unit of radioactivity is the becquerel (Bq), one Bq corresponding to one disintegration per second. The radioactivity of a substance is expressed in $Bq \cdot kg^{-1}$ or $Bq \cdot l^{-1}$. Radioactivity always declines in the course of time and the time taken for the radioactivity of a given substance to decline by half is known as the half-life of the substance.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	ionising radiation damage factors	4.3.15.1
alternative	screening factors – level I	4.3.15.2
additional	screening factors – level II	–
variant	–	–

Example (for baseline)

impact category	impacts of ionising radiation
LCI results	emissions of ionising radiation to air, water and soil (in kBq[1])
characterisation model	fate and exposure models combined with epidemiological studies and the concept of disability-adjusted life years (DALY)
category indicator	disability-adjusted life years (DALY)
characterisation factor	ionising radiation damage factors for each ionising radiation emission to air, water and/or soil (in yr/kBq emission)
unit of indicator result	yr

[1] Emissions of ionising substances in kg can be converted to Bq or kBq; see Part 2b, Section 3.6.

4.3.3.16 Casualties

Topic

This impact category refers to casualties resulting from accidents. The area of protection is human health.

Main choices and guidelines

Method status	Characterisation method/factor	Table in Part 2b
baseline	unweighted aggregation of victims	–[1]
alternative	–	–
additional	–	–
variant	–	–

Example

impact category	casualties
LCI results	number of victims (dimensionless)
characterisation model	unweighted aggregation
category indicator	number of victims
characterisation factor	1 (dimensionless)
unit of indicator result	dimensionless

4.3.3.17 Interventions for which characterisation factors are lacking

Topic

Many practical cases will involve emissions of toxic chemicals for which no toxicity potentials are listed in the tables with characterisation factors. The same applies to acidifying substances, ionising substances, depletable resources and so on. A general guideline given for extended LCAs is to calculate, estimate or extrapolate missing characterisation factors. This will often be unfeasible, however, for lack of time or knowledge, for instance. In such cases these overlooked items should be discussed in a separate part of the Impact assessment

Main choices

- A distinction should be made between:
  - interventions that are known to contribute to an impact category, for which no characterisation factor is available but for which a factor can be calculated, estimated or extrapolated;
  - interventions that are known to contribute to an impact category, but for which no characterisation factor can be found, calculated, estimated or extrapolated;
  - interventions assumed to be environmentally relevant but not contributing to any of the selected impact categories;
  - interventions assumed not to be environmentally relevant.

[1] Characterisation factor is 1 throughout.

Guidelines

Guidelines for simplified and detailed LCA and optional extensions

- ☞ Include interventions for which a characterisation factor can be calculated, estimated or extrapolated in the environmental profile under the relevant impact category, accompanied by a clear explanation of the divergent status of the characterisation factor and the method used to obtain it.
- ☞ Include interventions for which no characterisation factor can be calculated, estimated or extrapolated but which are known to contribute to one or more impact categories in a separate part of the environmental profile labelled "Interventions for which characterisation factors are lacking", accompanied by all relevant additional information such as:
  - substance name;
  - emission compartment;
  - amount emitted;
  - impact category to which a contribution is suspected;
  - if possible, an indication of the significance of the suspected impact; see Part 2b, Section 4.3.17.
- ☞ Include interventions known to be of environmental relevance but contributing to an impact category that is not selected in the environmental profile in the same way.
- ☞ Interventions expected to be environmentally irrelevant can be excluded from the environmental profile, but this should be transparently justified in the LCA report.

Example (hypothetical)

“The inventory table contains the entry "dioxins (unspecified)". Although dioxins are known to be extremely toxic, this entry does not show up in the list of characterisation factors for the models selected to address human toxicity and ecotoxicity. This could lead to a gross underestimate of the indicator results. In a sensitivity analysis, a worst-case influence can be investigated by replacing it with 2,3,7,8-TCDD (tetrachloride-dibenzo-dioxin), for which characterisation factors are available.

Furthermore, emissions of 1-butene contribute to photo-oxidant formation but not to the impact categories that relate to toxicity. This can be justified because this substance is generally agreed to be non-toxic, although it is very explosive. The latter aspect, however, is outside the scope of LCA, although it should be addressed in a separate analysis of safety.”

4.3.3.18 Economic flows not followed to system boundary

Topic

LCAs may comprise certain flows that are not specified in terms of environmental interventions, either inputs, like energy or materials, or outputs, like solid waste. Every effort should be made to avoid such flows, in the first place by applying the data estimation methods outlined in Section 3.3.8. All economic flows that cannot be followed to the system boundary should then be listed in a separate category: ‘Economic flows not followed to system boundary”. Flows listed in this category should always be described qualitatively (e.g. ‘hazardous waste’ and ‘non-hazardous waste’) and, wherever possible, quantitatively (e.g. 10^{-12} truck).

Main choices

- Economic flows should as much as possible be estimated, rather than cut off. Only if such estimation is not feasible, can a cut-off be applied, and these flows are then to be listed in the present category.

Guidelines

Guidelines for simplified LCA

☞ List economic flows that are not followed to the system boundary qualitatively and quantitatively and as part of the environmental profile as a separate category, labeled "Economic flows not followed to the system boundary".
☞ Discuss these flows in the Interpretation.

Guidelines for detailed LCA

☞ Estimate the possible contribution to the impact categories of flows not followed to the system boundary by applying the procedure described in Section 3.3.8.
☞ If this is not possible, list the flows concerned qualitatively and quantitatively and as part of the environmental profile, and discuss these flows in the Interpretation.

Guidelines for optional extensions

All guidelines provided above for detailed LCA apply here. In addition, the following guideline is given:
☞ Decide and justify whether or not it is important to collect specific process data for a specific flow not followed to the boundary, based on an estimation of the possible contribution to the impact categories. If so, collect specific process data for that flow.

Example (hypothetical)

See the example under Characterisation.

4.3.4 Classification

Topic

In this step the environmental interventions qualified and quantified in the Inventory analysis are assigned on a purely qualitative basis to the various pre-selected impact categories (see Section 4.3.2). For a baseline list of interventions, for which characterisation factors have previously been derived, the classification step involves no actual work as these interventions have already been assigned to the various impact categories in this Guide (see Section 4.4 of Part 2b of this Guide). In the case of other interventions the practitioner will have to adopt an appropriate procedure of his own.

Main choices

- As long as a characterisation step is performed and reported with due attention to the category of "Interventions for which characterisation factors", no explicit implementation or reporting of the classification step is required.
- It may sometimes be important to consider interventions contributing to more than one impact category in more detail. We distinguish the following types:
  - emissions with parallel impacts, i.e., emissions of substances that may theoretically contribute to more than one impact category but in practice contribute

only to one, e.g., an emission of SO_2 which may have either toxic or acidifying impacts;
- emissions with serial impacts, i.e., emissions of substances that may in practice have successive impacts, e.g., emissions of heavy metals which may first have ecotoxicological impacts and subsequently, via food chains, impacts on human health;
- emissions with indirect impacts, i.e., emissions of substances having a primary impact that in turn leads to one or more secondary impacts, e.g., aluminium toxicity induced by acidification, or methane contributing to photo-oxidant formation, with the ozone produced contributing to climate change, which in turn may contribute to stratospheric ozone depletion;
- emissions with combined impacts, i.e., emissions of substances having a mutual influence on each other's impacts, e.g., synergistic or antagonistic impacts of mixtures of toxic substances, or NO_x and VOC, both of which are required for photo-oxidant formation.

Guidelines

Guidelines for simplified and detailed LCA and optional extensions

☞ If the lists of characterisation factors recommended in Section 4.3.3 are observed, no action is required from the practitioners with respect to interventions for which characterisation factors have been defined.
☞ If the study's inventory table includes interventions that lack appropriate characterisation factors (in this Guide), the guidelines specified above in section 4.3.3.17 on "Interventions for which characterisation factors are lacking" lead to additional entries in a classification table.
☞ Interventions with serial and combined impacts are fully assigned to all relevant impact categories in the proposed baseline method.
☞ The partial assignment of interventions with parallel impacts is addressed, as much as possible, by means of fate models in the characterisation models, and does not need to be effected as part of the classification step. Where proper fate treatment is not yet possible, a full assignment to all relevant impact categories is to be made.

Example (hypothetical)

No example.

4.3.5 Characterisation

Topic

In the characterisation step of Impact assessment the environmental interventions assigned qualitatively to a particular impact category in classification are quantified in terms of a common unit for that category, allowing aggregation into a single score: the indicator result. The resulting figure for one particular impact category is referred to as a category indicator result, and the complete set of category indicator results as the environmental profile.

Main choices

- If the choices of impact categories and category indicators are explicitly addressed, characterisation is a technical step, and emphasis can be put on proper reporting of the characterisation results.

Guidelines

Guidelines for simplified and detailed LCA and optional extensions

- ☞ For each alternative studied, calculate the environmental profile by multiplying the interventions of inventory results by their concomitant characterisation factors and aggregating the results of these multiplications for each impact category. See Part 2b, Section 4.3 for specific equations and factors.
- ☞ If a separate "impact" category of energy (in MJ) has been defined (see Section 4.3.3), transform the energy carriers extracted from the environment (coal, oil and gas) into one total amount of extracted energy in MJ by multiplying the amount used by the heating value (see Part 2b, Table 4.3.5.3).
- ☞ Report the category indicator results, the interventions for which characterisation factors and/or methods are lacking, the flows that have not been followed up to the system boundary, and additional remarks in separate tables or in separate sections of one table. It is often convenient to report characterisation results for all alternatives studied in one table. An example form to report characterisation results is provided in Part 2b, Section 4.3.5.

Example (hypothetical)

The results of the Inventory analysis are transformed after characterisation into the environmental profile shown below.

Impact category	Value
indicator results	
depletion of abiotic resources	3.5 kg antimony eq
photo-oxidant formation	$1.2{\cdot}10^{-4}$ kg ethylene eq
climate change	2.2 kg CO2 eq
freshwater aquatic ecotoxicity	0.013 kg 14DCB eq
terrestrial ecotoxicity	$2.6{\cdot}10^{-6}$ kg 14DCB eq
human toxicity	0.0088 kg 14DCB eq
acidification	0.033 kg SO2 eq
eutrophication	$4.8{\cdot}10^{-4}$ kg PO4 eq
interventions for which characterisation factors are lacking	
emission to air: dioxins (unspecified)	$8.1{\cdot}10^{-14}$ kg
economic outflows not followed to system boundary	
used plastic bags	1000
residue to dump	0.08 kg
recovered energy	0.0008 MJ

4.3.6 Normalisation

Topic

ISO 14042 defines normalisation as "calculation of the magnitude of indicator results relative to reference information". The reference information may relate to a given community (e.g., The Netherlands, Europe or the world), person (e.g. a Danish citizen) or other system, over a given period of time. Other reference information may also be adopted, of course, such as a future target situation. The main aim of normalising the category indicator results is to better understand the relative importance and magnitude of these results for each product system under study. Normalisation can also be used to check for inconsistencies, to provide and communicate information on the relative significance of the category indicator results and to prepare for additional procedures such as weighting or Interpretation.

Main choices

- Normalisation is regarded as a strongly recommended step for any LCA.

Guidelines

Guidelines for simplified and detailed LCA

☞ For each alternative studied, calculate a normalised environmental profile by dividing the impact scores for each impact category by their concomitant normalisation factors.

☞ Use normalisation data based on one geographically and temporally well-defined reference system, preferably the world for one year, for all impact categories. The method based on total world interventions (method 1) or that based on the interventions of an average world citizen (method 2) are both applicable. Which one is chosen depends on the goal of the study.

☞ Part 2b, Section 4.6 provides several sets of normalisation factors per impact category for the baseline impact category indicators (see Section 4.3.3).

☞ For other category indicators, use the unaggregated data (interventions per reference area and period) to calculate normalisation factors. This can be done by applying the characterisation factors of an indicator on the interventions and adding them up to category indicator results (see Part 2b, Section 4.6 for references to the unaggregated data).

☞ If other normalisation methods are used (e.g., combining different scales) these should be described and justified in relation to the goal and scope of the study.

☞ If different scales are combined:
- use only per capita normalisation data;
- base the normalisation data for regional impact categories on the regions where the interventions of the relevant LCA study have taken place;
- if grouping or weighting is performed, group or weight the regionally normalised data using regional grouping methods or regional weighting factors;
- pay attention in the Interpretation to the seriousness of the impact categories in the regions concerned.

☞ Normalisation factors do not need to be reported for the baseline normalisation method and impact categories if appropriate reference is made to the data set in Part 2b, including the publication date of the document. Normalisation factors not included in Part 2b should always be reported.

☞ Report normalised indicator results for every impact category. It is often convenient to report normalised indicator results for all alternatives studied in one table. An example form is provided in Part 2b, Section 4.6.

☞ When reporting normalised indicator results, specify the unit. If the result is dimensionless, this must also be stated explicitly. The preferred unit for normalised indicator results is a year.

☞ In the case of a comparison, check whether the validity and reliability of the data sources used to derive reference values for normalisation are not (potentially) too different for the various systems studied.

Guidelines for optional extensions

All guidelines provided above for detailed studies apply here. In addition, the following guidelines are given:

- ☞ Fill (some of the) gaps in existing sets by collecting data on the magnitude of an intervention which is relevant to the study but which is not included in the normalisation data given in this Guide.
- ☞ Assess the reliability of different data sources in qualitative terms:
  - Check whether the sets of normalisation factors which are used are mutually consistent. More specifically, check whether choices with respect to the economy-environment system boundary, cut-off, allocation, characterisation methods, etc. are consistent between normalisation factors and case.
  - Check whether sets of reference values used for normalisation are complete.

Example (hypothetical)

"In this example, the situation in the Netherlands is taken as a reference for all impact categories. This is in line with the goal of the study, which is to identify hot spots in the product system of PE bags in the Netherlands. The reference information used refers to the year 1993, because this was the most recent complete list that was available.

The results of the Inventory analysis after normalisation are shown in the normalised environmental profile below.

Impact category	Value
normalised indicator results	
depletion of abiotic resources	2.2E–11 yr
photo-oxidant formation	2.6E–15 yr
climate change	5.7E–14 yr
freshwater aquatic ecotoxicity	6.7E–15 yr
terrestrial ecotoxicity	6.8E–18 yr
human toxicity	1.8E–16 yr
acidification	1.1E–13 yr
eutrophication	3.7E–15 yr
interventions for which characterisation factors are lacking	
emission to air: dioxins (unspecified)	8.1E–14 kg
economic outflows not followed to system boundary	
used plastic bags	1000
residue to dump	0.08 kg
recovered energy	0.0008 MJ

4.3.7 Grouping

Topic

Grouping is a step of Impact assessment in which impact categories are aggregated into one or more sets. It is an optional element for which two possible procedures are available: sorting and ranking, defined by ISO as follows:

- sorting of the category indicators on a nominal basis e.g. by characteristics such as emissions and resources or global regional and local spatial scales;
- ranking of the category indicators on an ordinal scale, e.g. a given order or hierarchy, such as high, medium and low priority (ranking is based on value-choices).

Main choices

- Grouping is optional; it is allowed within ISO 14042 for comparative assertions

Guidelines

Guidelines for simplified and detailed LCA

☞ Grouping is an optional step in LCA, for which no clear method is available. It is therefore not specifically applicable, except for optional extensions.

Guidelines for optional extensions

☞ Grouping is an optional step in LCA, for which no clear method is available. If this is to be applied, a method, including criteria for grouping, must be developed.
☞ Present the results of the grouping of impact categories as a matrix on the basis of the criteria used.
☞ The following criteria can be used as the starting point for ranking, but the criteria to be used depend on the goal and scope of the study:
  - ecological threat potential;
  - reversibility of the effect;
  - scale of the effect;
  - environmental preference of the population;
  - relationship between current and/or previous pollution and quality goals.

☞ When grouping is applied, describe and justify extensively the method and criteria used to sort or rank the impact categories.
☞ When grouping or ranking is applied, include the following statements in the report.
  - A statement to the effect that conclusions and recommendations derived from grouping are based on value choices and that “The value choices and judgements used in the grouping procedures are the sole responsibility of the commissioner of the study (e.g., government, community, organisation, etc)"
  - A statement to the effect that “The ISO 14042 standard does not specify any specific methodology or support the underlying value choices used to group or rank the impact categories"

Example (hypothetical)

“No grouping has been performed, as the literature provides no clearly described method.”

4.3.8 Weighting

Topic

Weighting is an optional step of Impact assessment, in which the (normalised) indicator results for each impact category assessed are assigned numerical factors according to their relative importance, multiplied by these factors and possibly aggregated. Weighting is based on value choices (e.g. monetary values, standards, expert panel). A convenient name for the result of the weighting step is ‘weighting result’, of which there is generally one for each alternative product system analysed. The term ‘weighting profile’ is used in this Guide for the overall result of the weighting step: a table showing all the weighting results, supplemented by any other relevant information.

Main choices

- Weighting is an optional step for all non-comparative assertions; it is not allowed within ISO 14042 for comparative assertions disclosed to the public.
- There is no best available method, and there is no recommended set of weighting factors.

Guidelines

Guidelines for simplified and detailed LCA

- ☞ Weighting is an optional step in LCA, for which no baseline method is proposed in this Guide. It is therefore not specifically applicable, except for optional extensions.[1]

Guidelines for optional extensions

- ☞ According to ISO 14042, weighting is not allowed for comparative assertions disclosed to the public. One must therefore decide whether to ignore the ISO principles, keep results internal, or refrain from weighting.
- ☞ If a weighting is performed, first formulate the conclusions that can be drawn without weighting.
- ☞ Weighting is an optional step in LCA, for which no clear method is available. If this is to be applied, a method, including weighting factors, must be developed.
- ☞ The results of the environmental profile must in most cases be equalised as to their units before weighting. A possible method for this is normalisation (see Section 4.3.6).
- ☞ If normalisation is performed before weighting and this normalisation is done on different scale levels (combining regional and world scales in one LCA), weighting must also be based on these different scale levels and the regions where the interventions included in the study took place.
- ☞ The preferred method is the use of a complete, nationally or internationally authorised set of weighting factors covering all relevant impact categories. However, as long as such a set does not exist, one might consider developing a case-specific set of weighting factors that is most appropriate to the goal of the study. For this set, consider the following suggestions.
  - Base the weighting factors preferably on a panel method, including all relevant parties, or should be based on publicly revealed preference data.
  - use more than one method to develop weighting factors.
  - Instead of single value weighting factors per impact category, use ranges based on the different views in the consultation panel or the different results of the various methods used.
  - There are technical details that may be quite important, including the composition of the panel, the questions posed to the members of the panel, the degree of interaction between the members of the panel and the possible subdivision of impact categories into subcategories.
  - Avoid the use of an implicit or temporary weighting factor of 1.
- ☞ Report any further procedures that transform the category indicator results and provide a justification of the selected references, weighting factors, etc.
- ☞ If weighting has been undertaken, explain and justify the methodology clearly, both for quantitative and qualitative approaches. Document all advantages and disadvantages and relate them to the goal and scope.
- ☞ Justify the choice of weighting factors in relation to the goal of the study and particularly in relation to scope issues such as temporal and geographical coverage.
- ☞ If weighting has been undertaken, list all interventions and impact categories not included in the weighting directly under the weighting results (including those interventions not characterised).
- ☞ In the case of a comparison, check whether the validity and reliability of the data sources used to derive weighting factors are not (potentially) too different for the various systems studied?

---

[1] Certain other approaches to Impact assessment, such as Eco-indicator 99 and EPS, include operational weighting. If a weighted single result is desired in a simple or detailed LCA, one of these approaches should be selected in Section 4.3.2. We would discourage straightforward application of the weighting factors of Eco-indicator 99 and EPS to this Guide's problem-oriented approach.

Example (hypothetical)

"A social panel approach has been chosen for the weighting. Details on how the panel has been instructed are provided in an appendix. The weighting factors used and the results of weighting are listed below.

Impact category	Weight	Value
weighted indicator results		
depletion of abiotic resources	0.01	2.2E–13 yr
photo-oxidant formation	0.8	2.1E–15 yr
climate change	2.4	1.4E–13 yr
freshwater aquatic ecotoxicity	0.2	1.3E–15 yr
terrestrial ecotoxicity	0.4	3.9E–18 yr
human toxicity	1.1	1.9E–16 yr
acidification	1.3	1.4E–13 yr
eutrophication	1.0	3.7E–15 yr
weighting result		
total	–	5.1E–13 yr
interventions for which characterisation factors are lacking		
emission to air: dioxins (unspecified)		8.1E–14 kg
economic outflows not followed to system boundary		
used plastic bags	–	1000
residue to dump	–	0.08 kg
recovered energy	–	0.0008 MJ

Observe that the weighting result is dominated by three impact categories: depletion of abiotic resources, acidification and climate change."

4.4 Results of Impact assessment

The main results of this phase, which is the input of the next phase, Interpretation, include the environmental profile, the normalised environmental profile and the weighting profile.

5. Interpretation

5.1 Topic

Life Cycle Interpretation is the phase in which the results of the analysis and all choices and assumptions made during the course of the analysis are evaluated in terms of soundness and robustness, and overall conclusions are drawn. The main elements of the Interpretation phase are an evaluation of results (in terms of consistency and completeness), an analysis of results (for instance, in terms of robustness), and the formulation of the conclusions and recommendations of the study.

5.2 Starting points

ISO 14043 has played a central role in the elaboration of this phase. Within this framework, three main categories of activities have been identified:

- evaluation of results;
- analysis of results;
- conclusions and recommendations.

In addition, as in the previous phases, special attention has been given to the procedures for managing the LCA.

Additional starting points for the Interpretation phase in this Guide include the following.

- Interpretation does not replace an external interactive critical review.
- A full error analysis is not feasible for LCA.
- Even a partial Monte-Carlo analysis is currently unachievable for simplified or detailed LCA, and is only mentioned as an extension.

5.3 Recipe

5.3.1 Procedures

<u>Topic</u>

The procedural organisation must ensure the common treatment of general and specific subjects that the parties involved want to discuss during the Interpretation phase. The following procedural issues should be taken into account.

- The choice of assumptions and data to be checked or analysed in the Interpretation phase, especially product specification and system specifications, methodological choices, and the data and calculation models used.
- Execution of sensitivity analysis and uncertainty analysis.

- Quantification of the accuracy of the calculated LCA results, including imprecision due to disregarding and the use of cut-off criteria, data uncertainties and uncertainties arising from deviations in the process situation being analysed.
- Determination of the bandwidth of the LCA results, in relation to the quantification of the accuracy of these results and the adequacy, quality and results of sensitivity analysis.
- Effects of the bandwidth conclusions with respect to possible implications of conclusions based on LCA results, possible adjustment of the goal of the LCA study and possible revision of further progress of the process.
- Intentions with respect to a possible iterative approach to the phases (in terms of allocation and weighting).
- Further process planning and process management.

Main choices

- In the course of this LCA phase, the supervisory process should be arranged so as to preserve the authoritativeness of the results. The potential input from stakeholders should also be used to improve the quality of the LCA. In this situation of 'mandated science' this implies that, depending on the specific process context, there should be room for interaction between the parties involved on topics that are relevant to the selection of topics to be included in consistency checks, sensitivity analyses, final conclusions and so on.

Guidelines

Guidelines for simplified and detailed LCA and optional extensions

☞ Determine the competencies and responsibilities of the LCA research scientists, any critical reviewers, the LCA clients and other interested parties using Table 5.3.1.

☞ Address potential bottlenecks in the LCA process by making arrangements in line with Table 5.3.2 to ensure the orderly progress of the project.

Table 5.3.1. Overview of the competencies of the various actors during the LCA process for the different process contexts.

Item	Description	Process context		
		I	II	III
1a	First instructions with respect to fulfilment of LCA assignment	C	C or S	S
1b	First instructions with respect to fulfilment of assignment of critical reviewer	–	C or S	S
2a	Written response to instruction on LCA assignment	L	L + R	L + R
2b	Written response to instructions on assignment of critical reviewer[1]	–	R	R
3a	Possible revision of the first instructions on LCA assignment	C	C or S	S
3b	Possible report on incompatible opinions on LCA assignment	L	L	L
4	Presentation of draft interim report (= draft text of Interpretation)	L	L + R	L + R
5	Written response to draft interim report on	C	C or S	S

[1] The actual implementation of all guidelines in this Guide should be checked in a critical review.

Item	Description	Process context		
		I	II	III
	Interpretation			
6	Possible revision of draft report on Interpretation	L	L + R	L + R
7	Possible report on incompatible opinions arising during the Interpretation	L	L	L
8	Final opinion on final interim report on Interpretation	C	C or S	S

Legend

Process context I = few diverging interests, potentially strong impact
Process context II = many diverging interests, potentially weak impact
Process context III = many diverging interests, potentially strong impact
C = first LCA client(s)
S = stakeholders (including C)
L = LCA research scientists
R = critical reviewer

Table 5.3.2 Overview of the arrangements that can be made between the various actors for the different process contexts.

Item	Description	Process context		
		I	II	III
a	Widening/supplementation of the study (on request)	o	r	r
b	Validation by an independent expert (on request)	o	r	r
c	Binding advice on decision points by the critical reviewer	o	r	r
d	Final decision-making by the largest possible majority, arbitration or another previously determined procedure	o	o	r
e	Quantification of the influence of incompatible opinions in the final report	o	r	r

Legend

Process context I = few diverging interests, potentially strong impact
Process context II = many diverging interests, potentially weak impact
Process context III = many diverging interests, potentially strong impact
r = recommended
o = option

Example (case history)

“The first Dutch Packaging Covenant stipulated LCA studies for a number of product groups. According to this covenant, disposable packaging systems had to be replaced by refillable packaging systems in all cases where refillable systems produce “clearly less environmental damage”. As a result, an extensive project was organised between 1992 and 1994, to manage the implementation of the LCAs needed and to manage an accompanying process.

The covenant partners did not define the phrase ‘clearly less environmental damage’, nor did they establish which environmental aspects were to be taken into account.

The LCA project was organised by a steering group involving many stakeholders (several business organisations and Dutch consumers' organisations; the environmentalist movement was not willing to participate). At the end of the project, the steering group concluded: “In general, there are no great differences in environmental aspects between disposable and refillable packaging systems, with the exception of the waste aspect.” However, this first conclusion had no consequences: the commission that had to check the implementation of the covenant concluded that the interpretation of the LCA results in terms of “clearly less environmental damage” had not been unambiguously defined, and formulated criteria themselves. However, the commission concluded that further study was required with respect to a number of comparisons.

A good example of this is the comparison between milk in cartons and milk in a refillable polycarbonate bottles. The representatives of the consumers' organisations felt that the LCA had proved the PC-bottle packaging system to be environmentally preferable. The business organisations involved did not endorse to this. In their view, this was not a question of “clearly less environmental damage” because a changeover from cartons to PC bottles would only achieve waste reduction and possibly some reduction of eutrophication.”

5.3.2 Consistency check

Topic

The objective of the consistency check is to determine whether the assumptions, methods, models and data are consistent with the goal and scope of the study, both over a product’s life cycle and across various options. As discussed above, we place this issue at the very start of the Interpretation phase, contrary to ISO 14043. All other analyses of the results and sensitivity analyses are futile if the assumptions and models used in the LCA are inconsistent with the goal and scope of the study, or inconsistent across the various options.

Main choices

Only those included in ISO 14043.

Guidelines

Guidelines for simplified and detailed LCA and optional extensions

- ☞ Conduct a consistency check to determine whether the assumptions, methods, models and data are consistent with the goal and scope of the study. Check for unexpected results
  - based on expert knowledge, and
  - if possible, based on a comparison between the results of the study and results of previous studies on related subjects.
- ☞ In the case of comparisons in particular, check for differences between the options being compared as regards data sources, data accuracy, technical level, temporal aspects, geographical representativeness and functions.
- ☞ If inconsistencies are found:
  - justify them, if they are justifiable;
  - assess their validity and influence;
  - if possible and necessary, reiterate previous steps in the methodology and adapt the study results by removing the inconsistencies found;
  - report any remaining inconsistencies explicitly and justify these together with the results of the study.

☞ In addition to a data-oriented consistency check, analyse and discuss the consistency of the procedures followed.

Example (hypothetical)

“In this example, it has been decided to develop a checklist that will be used to determine whether the model and data choices made in the study are equivalent either within a product’s life cycle or across the various options. The checklist includes the following.

- Differences in data sources. For instance, the information on the production of ethylene may be based on the literature, while the information on PE production is based on primary data.
- Differences in data accuracy. For instance, a highly detailed modularisation might be available for option A, while option B is described as an accumulated black box system.
- Differences in technical level. For instance, data on chemical waste incineration may be based on an experimental process (e.g., a new installation with higher process efficiency at pilot plant level) while electricity production data are based on existing large-scale technology.
- Temporal differences. For example, data on PE production may refer to recently developed technology, while the refining process is described for a mixture of technologies, including recently built and old plants.
- Differences in data age. For instance, data for option A are five-year-old primary data, whereas data for Option B have been recently collected.
- Differences in geographical representativeness; data for option A might represent a mixture of European technologies, while option B is representative of one EU country with a high level of environmental protection or one single plant.
- Differences in the functions performed by the two products or options.

A detailed report on the discrepancies found has been added as an appendix to the LCA report. The overall findings suggest that no serious consistency problems were present.”

5.3.3 Completeness check

Topic

The completeness check ensures that all relevant information and data needed for the Interpretation phase are available and complete. In the error check, the study is checked for false assumptions, model choices and data. Having an expert look at the results of the LCA and how they were generated can uncover errors and incomplete data. An LCA expert could check the methodology used in the different phases of the project and the results and conclusions of the analysis in relation to the goal and scope of the study. Technical experts could also look at the parameters describing the product system and the data used.

Main choices

Only those included in ISO 14043.

Guidelines

Guidelines for simplified and detailed LCA and optional extensions

☞ Conduct a completeness check based on the knowledge of one or more internal or external LCA experts and/or technical expert(s), and, if possible, based on a comparison between the results of the study and results of previous studies on related subjects.

- ☞ Refer to the "Interventions for which characterisation factors are lacking" and the "Economic flows not followed to system boundary"
- ☞ If errors or gaps are found:
  - justify them, if they are justifiable;
  - assess their validity and influence;
  - if possible and necessary, reiterate the previous step in the methodology and adapt the study results by correcting the errors or gaps found;
  - report any remaining issues explicitly and justify these together with the results of the study.
- ☞ Special attention should be given to comparisons. If the completeness of the data differs between alternative systems, the influence of this difference should be estimated (e.g., by way of a contribution analysis, a perturbation analysis or a sensitivity analysis; see the next sections).
- ☞ In addition to a data-oriented completeness check, analyse and discuss, if necessary, the completeness of the procedures followed.

Example (hypothetical)

"A technical expert has assessed the qualitative and quantitative validity of the system, looking at the following questions.
- Is the structure of the process tree correct?
- Are any processes missing?
- Are any economic inputs or outputs missing?
- Are any emissions or extractions missing?
- Is the magnitude of the emission correct?
- Do the mass balances add up to zero?

A detailed report by the technical expert has been added as an annex. The expert did not find any major problems with the validity of the data and the system."

5.3.4 Contribution analysis

Topic

The contribution analysis calculates the overall contribution to the results of the various factors. The contributions are usually expressed as percentages of the total. Contribution analysis answers questions about the contribution of specific environmental flows, processes or impacts to a given environmental score.

Main choices

Only those included in ISO 14043.

Guidelines

Guidelines for simplified and detailed LCA and optional extensions

- ☞ Conduct several contribution analyses by calculating the contributions to the results of:
  - individual processes within the overall process (e.g., pasteurising as a phase within the production of 1000 l of milk);
  - a group of processes within the overall process (e.g., various conservation measures as a phase within the production of 1000 l of milk);
  - a life-cycle stage within the overall process (e.g., the agricultural production of 1000 l of milk);

- the packaging phase within the overall process (e.g., the bottles used to package 1000 l of milk);
- an environmental flow within the overall process (e.g., SO_2 flow in the production of 1000 l of milk);
- specific product properties, e.g., the energy requirement of a refrigerator.

☞ Do this, when applicable, at the level of:
- the inventory results, e.g., emissions or extractions of (groups of) substances;
- the environmental profile;
- the normalised environmental profile;
- the weighting results.

☞ For a description of calculation techniques, see Part 2b, Section 5.5.

☞ Pay special attention to processes and process data whose data quality gives reason for concern (see Section 3.3.5 on data quality) or processes for which the data are based on estimations (see Section 3.3.6 on data collection and Section 3.3.8 on data estimation). If the contribution analysis shows that the contributions of these processes or flows may be substantial, this may be a reason to return to the data collection step to collect more data, or data of a better quality.

☞ Pay special attention to differences in completeness between alternative systems. Are the data missing in one alternative very important contributors in another?

☞ Report and justify the levels (inventory table, environmental profile, etc.; processes, life-cycle phases, elementary flows, etc.) chosen for the contribution analyses.

☞ Compare, if possible, the results of a contribution analysis with those of contribution analyses reported in previous studies on related products.

☞ Report results of the contribution analysis as tables and, if useful, as graphs.

Example (hypothetical)

"A contribution analysis for the emission of cadmium to fresh water yields the following list of contributing processes.

Process	Contribution
Electricity production	56%
Refining; allocated to naphtha	25%
Incineration of chemical waste	19%

Thus, a large part (56%) of the emission of cadmium to surface water is caused by electricity production. Note that the 25% contribution made by the refining process is only the part that is allocated to naphtha production, and that this excludes the production of fuel oil and other co-products. If the emission of cadmium to surface water is a major concern in the study, it is clear that the process data for the electricity production must be checked carefully."

5.3.5 Perturbation analysis

Topic

Perturbation analysis involves the study of the effects of small changes within the system on the results of an LCA.[1] The effects of these small changes are calculated simultaneously for all flows within the system, including economic flows. The analysis can be conducted at different levels of aggregation: inventory table, indicator results, normalised indicator results or weighting results. The main difference between the contribution analysis and the

[1] In the perturbation analysis, all system parameters (process data, characterisation factors, etc.) are successively changed marginally (e.g. 1%), and the resulting change in a system output (emission, category indicator result, etc.) is observed. The ratio between these is the multiplier. Hence, if a 1% decrease in the fuel input of a production process leads to a 3% decrease in the emission of CO_2, the multiplier is said to be 3.

perturbation analysis lies in the fact that it takes into account not only environmental flows but also economic flows between unit processes. This is important, because multipliers of economic flows can exceed unit when internal loops (see also Section 3.3.10) are present. The perturbation analysis may be very important in an improvement analysis and in a sensitivity analysis aimed at identifying important points and refining the LCA study.

Main choices

- Perturbation analysis is a potentially useful addition to the methods mentioned in ISO 14043.

Guidelines

Guidelines for simplified and detailed LCA

☞ Perturbation analysis requires dedicated software routines which are not generally available. Therefore, it may be skipped in many cases. One might consider, however, to use specialised software including a perturbation analysis in selected cases.

Guidelines for optional extensions

☞ Conduct perturbation analyses at the level of:
- the inventory table;
- the environmental profile;
- the normalised environmental profile;
- the weighting results.

☞ For a description of calculation techniques, see Part 2b, Section 5.6.

☞ Pay special attention to processes and process data whose data quality gives reason for concern (see Section 3.3.5 on data quality) or processes whose data were based on estimations (see Section 3.3.6 on data collection and Section 3.3.8 on data estimation). If the perturbation analysis shows that small changes in these processes or flows can have relatively large effects on the results, this may be a reason to go back to the data collection step to collect more data, or data of a better quality.

☞ Pay special attention to differences in completeness between alternative systems. Are the results very sensitive to small changes in the data missing in one alternative?

☞ Report and justify the level (inventory table, environmental profile, etc.) at which perturbation analyses have been conducted.

☞ If possible, compare the results of a perturbation analysis with results of perturbation analyses reported in previous studies on related products;

☞ Report the results of the perturbation analysis as tables and, if useful, as graphs.

Example (hypothetical)

"A perturbation analysis for the emission of benzene to fresh water yields the following:

Process	Flow	Multiplier
production of ethylene	output of ethylene	–1.15
production of PE	input of ethylene	0.92
production of PE	output of PE	0.92
production of plastic bags	input of PE	0.92
production of plastic bags	output of plastic bags	0.92
packaging a loaf	output of loaves packaged	0.92
refining	output of naphtha	0.90
production of ethylene	input of naphtha	0.90
packaging a loaf	input of plastic bags	0.70
rest (19 items)		<0.1

These results should be interpreted as follows: if the output of ethylene from the production of ethylene is increased by one per cent, the emission of benzene to fresh water will decrease by 1.15 per cent. This means, among other things, that the output of ethylene from the process of production of ethylene should be known fairly accurately for a reliable result on emissions of benzene to fresh water. It also means that a technological improvement affecting this coefficient leads to a large reduction in the emission of benzene to fresh water. Finally, it shows that most of the coefficients (19 out of 28) have a negligible influence on this emission."

5.3.6 Sensitivity and uncertainty analysis

Topic

In order to use LCA as a tool for decision-making, information is needed on the robustness of the results. This element of the Interpretation phase assesses the influence on the results of variations in process data, model choices and other variables. In the sensitivity analysis, these changes are deliberately introduced in order to determine the robustness of the results with regard to these variations. The uncertainty analysis uses empirical data on the uncertainty ranges of specific data to calculate the total error range of the results.

Main choices

- Since the required data are often lacking and since most LCA software does not include the possibility to conduct a full sensitivity and uncertainty analysis, such analyses can not be made obligatory. However, it is good practice to implement at least partial sensitivity and uncertainty analyses.

Guidelines

Guidelines for simplified LCA

☞ Select and justify a limited set of issues for sensitivity analysis, based on the results of contribution analysis, perturbation analysis and the subjects identified as issues for Interpretation in the various steps (e.g., influence of future scenarios, effect of data quality, key data sensitivity, possible contribution of missing processes) See Part 2b, Section 5.7 for a checklist of issues for simplified LCA.

☞ Conduct sensitivity analyses on the issues selected, at the level of:

- the inventory table;
- the environmental profile;
- the normalised environmental profile;
- the weighting results.

☞ Report the issues identified for sensitivity analyses.

☞ Report the results of the sensitivity analyses and possible uncertainty analyses conducted in table and, if useful, in graphic format.

☞ If possible, compare the results of a sensitivity and uncertainty analysis with results of such analyses reported in previous studies on related products.

☞ Pay special attention to processes and process data whose data quality gives reason for concern (see Section 3.3.5 on data quality) or processes whose data were based on estimations (see Section 3.3.6 on data collection and Section 3.3.8 on data estimation). If the sensitivity analysis shows that changes in these processes or flows can have important effects on the results of the LCA, this may be a reason to go back to the data collection step to collect more data, or data of a better quality

☞ Pay special attention to differences in completeness between alternative systems. Are the results very sensitive to changes in the data missing in one alternative?

Guidelines for detailed LCA

All guidelines provided above for simplified studies apply here, but the selection of issues in the first guideline should now be comprehensive instead of limited.

Guidelines for optional extensions

All guidelines provided above for detailed studies apply here. In addition the following guideline is given:

☞ Conduct more detailed sensitivity analyses or, if possible, conduct partial uncertainty analysis on the issues selected and on parameters for which uncertainty ranges are known, for instance by Monte Carlo simulations.

Example (hypothetical)

"Since the example LCA is a simplified LCA, the uncertainty analysis is skipped and the sensitivity analysis is confined to an ISO-based checklist, including:

- rules for allocation;
- characterisation method;
- weighting method and data;
- cut-off criteria;
- boundary setting and system definition;
- data;
- normalisation data.

With regard to data uncertainties in a simplified LCA, the focus is on the most important processes and flows in the contribution and/or perturbation analyses. The data for these processes and flows have been checked and a sensitivity analysis on this data has been conducted for data variations.

With regard to allocation rules, a sensitivity analysis has been conducted by comparing the results of economic allocation with those of allocation on the basis of energy content. Results are presented as an appendix to the report. There is no major difference with economic allocation."

5.3.7 Conclusions and recommendations

Topic

In this last step of the Interpretation phase, conclusions are drawn and recommendations are made for the intended audience of the study, based on the information gathered in the previous phases of the LCA and combined with the results of the previous steps of the Interpretation phase.

Main choices

- For the sake of transparency, it is good to separate analysis and opinion, and therefore, to have a separate step in which final conclusions are drawn and recommendations are made.

Guidelines

Guidelines for simplified and detailed LCA and optional extensions

- ☞ Formulate conclusions and recommendations transparently and unambiguously by:
  - giving a summary of key issues;
  - justifying conclusions drawn by means of materials presented in the report and on the basis of the entire report.
- ☞ Formulate conclusions and recommendations in line with the goal and scope of the study and the results found.
- ☞ Take the results of the consistency and completeness checks and the sensitivity and uncertainty analyses on data and models into account in formulating conclusions and recommendations.
  - Inconsistencies, incompleteness and errors must either be corrected or incorporated in the conclusions of the study.
  - Data and parameters to which the conclusions of the study are most sensitive must be mentioned.
- ☞ Check and report whether the limitations of LCA as a tool and the limitations of the models used allow for the conclusions and recommendations intended.
- ☞ If possible and relevant, discuss the results of the study in relation to earlier, related studies.
- ☞ In the case of a comparison, report and justify the significance of the differences in results. Check the concomitant statement made on this in the Goal and scope definition and indicate whether the differences in results are large enough to allow the conclusion that a certain product alternative is more environmentally sound than another alternative.
- ☞ In the case of a comparison, give a summary of key issues. For example, product system A is substantially better with respect to acidification than product system B.

Example (hypothetical)

"Although there a number of data gaps, for instance relating to ancillary inputs, capital equipment, and toxicity parameters for dioxins, it seems that a fairly complete picture of the bread packaging systems has been obtained. The most important results are presented in the tables and figures below. Important contributions are made by several emissions, mainly on impact categories that relate to toxicity, photo-oxidant formation, and acidification; see the table. As the goal was formulated in terms of finding options for product and process improvement, the results of the analysis cannot be used for comparison with alternative packaging systems."

5.4 Results of Interpretation

The results of the Interpretation phase are two-fold. First, there are the results of all forms of consistency and uncertainty analysis, leading to a number of judgements relating to the quality and the robustness of the findings of the Inventory analysis and Impact assessment. Second, there is a description of the final conclusions and recommendations, for instance as to product choice or improvement.

Appendix A: Terms, definitions and abbreviations

This glossary provides definitions of the key terms and abbreviations used in this Guide. Terms marked with an asterisk (*) are defined in accordance with the definitions given in the ISO 1404X series of standards, although not necessarily according to the letter. For reasons explained in the text, several definitions adopted here deviate substantively from those of ISO. In this Glossary these are marked as "adapted from ISO". Cross-references, indicated by an arrow (→), point to the preferred terms used in this Guide.

Terms

abiotic resource
a natural resource (including energy resources) regarded as non-living, e.g. zinc ore, crude oil, wind energy

allocation
→ multifunctionality and allocation

alternative
one of a set of product systems studied in a particular LCA, e.g. for comparison (note: some LCA steps are carried out for all alternatives together (e.g. selection of impact categories), while others are repeated for each alternative (e.g. characterisation)

area of protection
a cluster of category endpoints of recognisable value to society, viz. human health, natural resources, natural environment and man-made environment

average modeling
→ proportional modeling

background system/process
a system or process for which secondary data, viz. databases, public references, estimated data based on input-output analysis, are used in an LCA

baseline method (model, impact category, LCA, etc.)
a method (etc.) recommended in this Guide for operationalising an LCA or methodological step

biotic resource
a natural resource (including energy resources) regarded as living, e.g. rainforests, elephants

casualty
human injury or death due to direct, physical cause, e.g. explosion or traffic collision (but not indirect casualties, e.g. due to toxics)

category endpoint *
an attribute or aspect of the natural environment, human health, natural resources or the man-made environment identifying an issue of concern, e.g. loss of coral reefs or crops, damage to buildings

category indicator *
a quantifiable representation of an impact category, e.g. infrared radiative forcing for climate change

category indicator result *
→ indicator result

cause-effect network
→ environmental mechanism

change-oriented LCA
a type of LCA focusing on the environmental changes resulting from a switch to or from a particular product system or an extra functional unit of a particular product system

characterisation *

a step of Impact assessment, in which the environmental interventions assigned qualitatively to a particular impact category (in classification) are quantified in terms of a common unit for that category, allowing aggregation into a single score: the indicator result; these scores together constitute the environmental profile

characterisation factor *

a factor derived from a characterisation model for expressing a particular environmental intervention in terms of the common unit of the category indicator, e.g. $POCP_{methanol}$ (photochemical ozone creation potential of methanol)

characterisation method

a method for quantifying the impact of environmental interventions with respect to a particular impact category; it comprises a category indicator, a characterisation model and characterisation factors derived from the model

characterisation model

a mathematical model of the impact of environmental interventions with respect to a particular category indicator

characterisation result

→ environmental profile

classification *

a step of Impact assessment, in which environmental interventions are assigned to predefined impact categories on a purely qualitative basis

closed loop recycling *

recycling of material within one and the same product system

combined waste processing

a method of waste processing in which more than one form of waste is processed simultaneously

comparative assertion *

an environmental claim regarding the superiority or equivalence of one product relative to a competing product performing the same function; particular requirements are set by ISO on comparative assertions disclosed to the public

completeness check *

a step of the Interpretation phase to verify whether the information yielded by the preceding phases is adequate for drawing conclusions in accordance with the Goal and scope definition

consistency check *

a step of the Interpretation phase to verify whether assumptions, methods and data have been applied consistently throughout the study and in accordance with the Goal and scope definition

contribution analysis *

a step of the Interpretation phase to assess the contributions of individual life cycle stages, (groups of) processes, environmental interventions and indicator results to the overall LCA result (e.g. as a percentage)

co-product *

any of two or more functional flows from a co-production process

co-production process

a unit process having more than one functional flow, e.g. crude oil refining

critical review *

an expert (internal or external) review of an LCA, designed to ensure validity, consistency, transparency and credibility of results

damage approach

definition of category indicators close to areas of protection

data category *
a heading for classifying data in an LCA, e.g. energy inputs, raw material inputs, ancillary inputs, other physical inputs, products, emissions to air, emissions to water, emissions to land, other environmental aspects

data quality *
a data characteristic relevant for the capacity of the data to satisfy stated requirements

data quality requirements *
specification, in general terms, of the quality criteria to be satisfied by the data used in an LCA

depletion
a decrease in the stock of a biotic or abiotic resource due to extraction thereof

descriptive LCA
a type of LCA focusing on the contribution of a particular way of fulfilling a certain function to the entire spectrum of environmental problems as they currently exist or are being created

detailed LCA
the baseline LCA elaborated in this Guide, complying with the ISO 1404X standards and representative of studies typically requiring between 20 and 200 person-days of work

difference analysis
a type of LCA focusing on the differences between two alternative product systems, thus ignoring those unit processes that are qualitatively and quantitatively identical

economic flow
a flow of goods, materials, services, energy or waste from one unit process to another; with either a positive (e.g. steel, transportation) or zero/negative (e.g. waste) economic value

economic process
→ unit process

economy-environment boundary
see also: system boundary

elementary flow *
matter or energy entering or leaving the product system under study that has been extracted from the environment without previous human transformation (e.g. timber, water, iron ore, coal) or is emitted or discarded into the environment without subsequent human transformation (e.g. CO_2 or noise emissions, wastes discarded in nature)
see also: environmental intervention

emission
a chemical or physical discharge (of a substance, heat, noise, etc.) into the environment, considered as an environmental intervention

endpoint
→ category endpoint

endpoint approach
→ damage approach

environment system
the natural environment and its constituent processes

environmental effect
→ environmental impact

environmental impact
a consequence of an environmental intervention in the environment system

environmental intervention
a human intervention in the environment, either physical, chemical or biological; in particular resource extraction, emissions (incl. noise and heat) and land use; the term is thus broader than (‘elementary flow’

environmental life cycle assessment *
→ life cycle assessment
environmental mechanism *
for a given impact category, the chain of environmental processes linking interventions to impacts; modeled in LCA (usually only partially) to one or more category endpoints by means of a characterisation model
environmental process
a physical, chemical or biological process in the environment system that is identified as part of the causal chain linking a particular environmental intervention to a particular impact, e.g. pollution leaching or bioaccumulation; for a given impact category, the environmental processes together form the environmental mechanism
environmental profile
the overall result of the characterisation step: a table showing the indicator results for all the predefined impact categories, supplemented by any other relevant information
environmental relevance *
the degree of linkage between a category indicator and category endpoint
expert review *
→ critical review
extraction
withdrawal of a biotic or abiotic resource from the environment in a unit process, considered as an environmental intervention
final product
a product requiring no additional transformation prior to use
flow diagram
a graphic representation of the interlinked unit processes comprising the product system
foreground system/process
a system or process for which primary, site-specific data are used in an LCA, for whatever reason
format
a structured framework for representing and possibly processing unit process data as well as any relevant remarks
function
a service provided by a product system or unit process
functional flow
any of the flows of a unit process that constitute its goal, viz. the product outflows of a production process and the waste inflows of a waste treatment process
functional unit *
the quantified function provided by the product system(s) under study, for use as a reference basis in an LCA, e.g. 1000 hours of light (adapted from ISO)
goal and scope definition *
the first phase of an LCA, establishing the aim of the intended study, the functional unit, the reference flow, the product system(s) under study and the breadth and depth of the study in relation to this aim
grouping *
a step of Impact assessment in which impact categories are aggregated in one or more sets defined in the Goal and scope definition phase; it may take the form of sorting and/or ranking
impact assessment *
the third phase of an LCA, concerned with understanding and evaluating the magnitude and significance of the potential environmental impacts of the product system(s) under study

impact category *

a class representing environmental issues of concern to which environmental interventions are assigned, e.g. climate change, loss of biodiversity

impact score

→ indicator result

indicator result *

the numerical result of the characterisation step for a particular impact category, e.g. 12 kg CO_2-equivalents for climate change

inflow

→ input

input

a product (goods, materials, energy and services), waste for treatment or environmental intervention (including resource extraction, land use, etc.) modeled as 'entering' a unit process (adapted from ISO)

interested party

→ stakeholder

intermediate product *

an input or output from a unit process which undergoes further transformation before consumptive use

interpretation *

the fourth phase of an LCA, in which the results of the Inventory analysis and/or Impact assessment are interpreted in the light of the Goal and scope definition (e.g. by means of contribution, perturbation and uncertainty analysis, comparison with other studies) in order to draw up conclusions and recommendations

intervention

→ environmental intervention

inventory analysis *

the second phase of an LCA, in which the relevant inputs and outputs of the product system(s) under study throughout the life cycle are, as far as possible, compiled and quantified

inventory table

the result of the Inventory analysis phase: a table showing all the environmental interventions associated with a product system, supplemented by any other relevant information (adapted from ISO)

land occupation

the unavailability of a given plot of land for alternative uses for a certain period of time

land transformation

the change in the quality of a given plot of land due to a particular mode of human use, measured in terms of changes in biodiversity and life support functions

LCA process

the integral series of exchanges among the individuals and organisations participating in an LCA project, from project initiation and guidance through to interpretation and discussion of the results

LCA project

a project that seeks to obtain particular results by means of an LCA study and LCA process; besides commissioning parties and practitioners, it may also involve other organizations and individuals, in the capacity of data supplier, peer reviewer or interest group, for example

LCA study

an environmental study in which LCA methodology is employed, performed by practitioners who may or may not be affiliated to the party or parties commissioning the study

life cycle *
the consecutive, interlinked stages of a product system, from raw materials acquisition or natural resource extraction through to final waste disposal

life cycle assessment (LCA)
compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle; the term may refer to either a procedural method or a specific study

life cycle impact assessment *
→ impact assessment

life cycle impact category indicator *
→ category indicator

life cycle interpretation *
→ interpretation

life cycle inventory analysis *
→ inventory analysis

life cycle inventory analysis result *
→ inventory table

life support functions
the ecological structures and processes that sustain the productivity, adaptability and capacity for renewal of lands, water and/or the biosphere as a whole

marginal modeling
a type of modeling whereby changes in inputs and outputs are modeled on a marginal basis (e.g. full attribution to one additional train passenger of the extra power consumption required for transporting that passenger). Note: use of the word marginal is sometimes ambiguous; see section 1.2.3.4 of Part 3 for more details

midpoint approach
→ problem-oriented approach

multifunctional process
a unit process yielding more than one functional flow, e.g. co-production, combined waste processing, recycling

multifunctionality and allocation *
a step of the Inventory analysis in which the inventory model is refined and the input and output flows of multifunctional processes are partitioned to the functional flows of those processes

natural resource
a biotic or abiotic resource that can be extracted from the environment in a unit process

non-functional flow
any of the flows of a unit process that are not the goal of that process, viz. product inflows, waste outflows and environmental interventions

normalisation *
a step of Impact assessment in which the indicator results are expressed relative to well-defined reference information, e.g. relative to the indicator results for global interventions in 1995

normalisation factor
the reciprocal of the indicator result for a particular impact category and reference system; used in the normalisation step

normalisation result
→ normalised environmental profile

normalised environmental profile
the result of the normalisation step: a table showing the normalised indicator results for all the selected impact categories, supplemented by any other relevant information

normalised indicator result
: the numerical result of normalisation for a particular impact category, e.g. 0.02 yr for climate change

open loop recycling *
: recycling of material generated in one product system in a different product system

optional extension
: an option for enhancing the quality of a detailed LCA to address any obvious shortcomings

outflow
: → output

output
: an economic flow (e.g. energy, waste for treatment) or environmental intervention (e.g. pollutant or noise emission) modeled as 'leaving' a unit process (adapted from ISO)

perturbation analysis
: a step of the Interpretation phase to identify any process data in which minor changes may significantly alter the inventory table, the (normalised) environmental profile or the weighting result, to identify efficient options for product improvement or to focus attention on sensitive items

phase
: any of the four basic elements of an LCA, viz. Goal and scope definition, Inventory analysis, Impact assessment and Interpretation

pollution
: a change in the state of the environment due to emissions

practitioner *
: an individual group or organisation conducting an LCA

primary function
: the main function delivered by the product system under study

problem-oriented approach
: definition of category indicators close to environmental interventions

procedure
: the rules and arrangements adopted to manage an LCA study

process
: → unit process
: see also: environmental process

product
: a positively valued economic flow of goods, materials, energy or services produced in a unit process and possibly serving as an input to another unit process

product system *
: a set of unit processes interlinked by material, energy, product, waste or service flows and performing one or more defined functions

proportional modeling
: a type of modeling whereby changes in inputs and outputs are modeled proportionally (e.g. equal attribution to all passengers of the increase in power consumption needed for transporting one additional passenger). Note: use of the word proportional (and average) is sometimes ambiguous; see section 1.2.3.4 of Part 3 for more details

prospective LCA
: → change-oriented LCA

ranking *
: a grouping method whereby impact categories are hierarchically ranked (e.g. high, medium, and low priority), applying value choices

recycling

a unit process, or set of processes, for collecting and/or treating waste from a unit process for useful application in the same or in a different product system (closed and open loop recycling, respectively)

reference flow

quantified flow generally connected to the use phase of a product system and representing one way (i.e. by a specific product alternative) of obtaining the functional unit

release

→ emission

retrospective LCA

→ descriptive LCA

sensitivity and uncertainty analysis

a step of the Interpretation phase to assess the robustness of the overall LCA results with respect to variations and uncertainties in the methods and data used

sensitivity check *

an ISO step included in this Guide as part of sensitivity and uncertainty analysis

simplified LCA

a simplified variety of detailed LCA conducted according to guidelines not in full compliance with the ISO 1404X standards and representative of studies typically requiring from 1 to 20 person-days of work

sorting *

a grouping method whereby impact categories are sorted on a nominal basis, e.g. by characteristics such as emissions and resource use, or global, regional and local spatial scales

stakeholder *

an individual group or organisation concerned about or affected by the environmental performance of a product system or the outcome of an LCA. Note: the LCA commissioner is also a stakeholder

step

a discrete element of any of the four phases of an LCA; some steps (e.g. data format, calculation method) are areas of concern rather than actions

subcategory

a subdivision of an impact category, e.g. freshwater aquatic ecotoxicity as a subcategory of ecotoxicity

system boundary *

the interface between a product system and the environment system or other product systems

third party *

a critical reviewer or a stakeholder other than the LCA commissioner or practitioner

transparency *

open, comprehensive and understandable presentation of information

unit process *

the smallest portion of a product system for which data are collected in an LCA

use process

a unit process in which the final product is consumed, thereby delivering the function under study

waste (for treatment)

an economic flow with a zero or negative value produced in a unit process and serving as an input to another unit process (note: materials such as waste paper and scrap metals with a positive economic, i.e. market value are thus not wastes but products) (adapted from ISO)

weighting *
a step of Impact assessment in which the (normalised) indicator results for each impact category assessed are assigned numerical factors according to their relative importance, multiplied by these factors and possibly aggregated; weighting is based on value-choices (e.g. monetary values, standards, expert panel)

weighting factor
a factor obtained with a weighting method and used to express a particular (normalised) indicator result in terms of the common unit of the weighting result

weighting profile *
the result of the weighting step: a table showing all the weighting results, supplemented by any other relevant information

weighting result
the numerical part of the result of weighting and aggregation of all (normalised) indicator results, e.g. 0.08 yr (note: the result may be expressed as more than one numerical value)

Explanatory figures

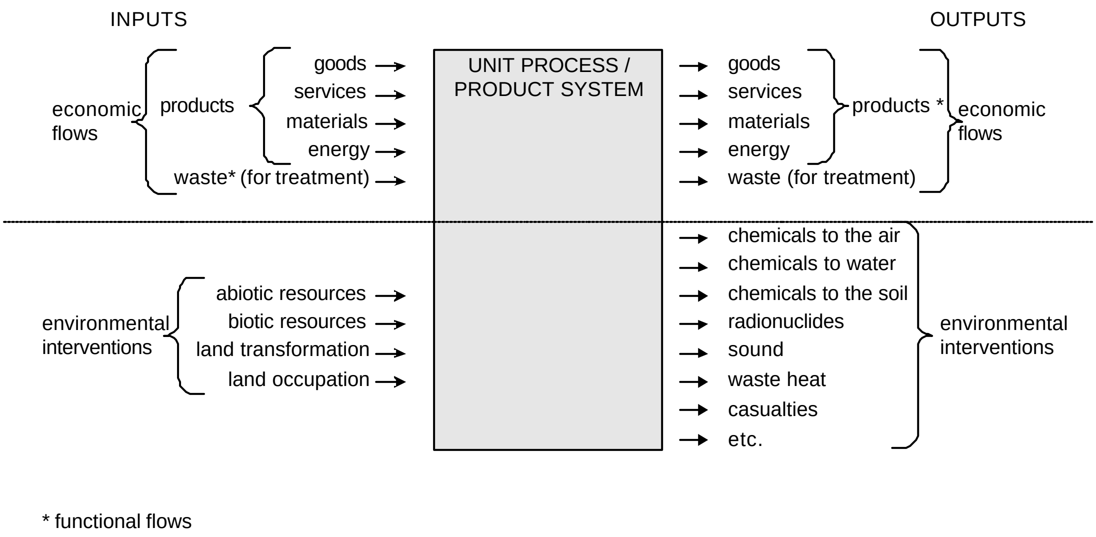


Figure 2: Basic structure of a unit process (or product system) in terms of its inputs and outputs.

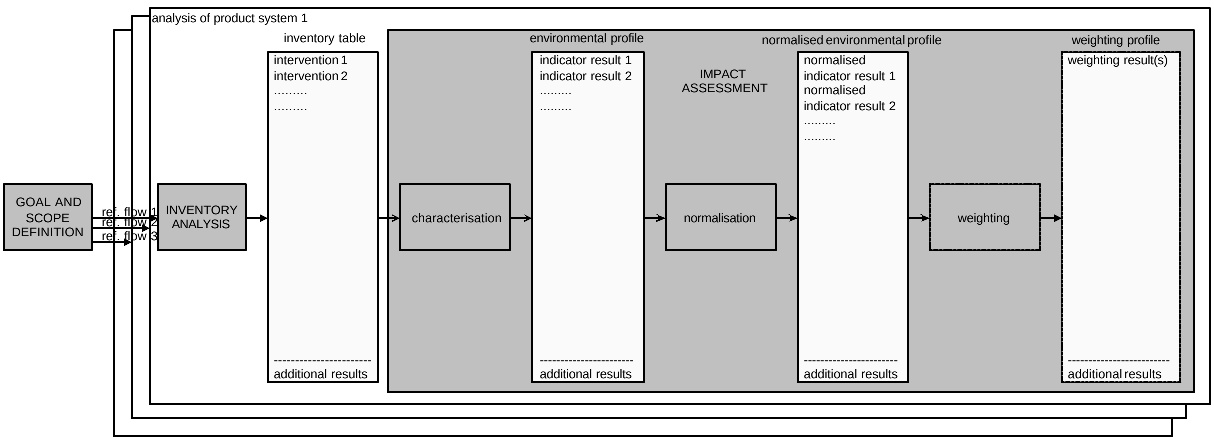


Figure 3: Main sequence of phases and steps of an LCA, as set out in this Guide, showing respective results. Phases (in capitals) and steps (lower case) are shown as grey boxes, results as white 'forms'. The dashed line around 'weighting' indicates that this is an optional

step which according to ISO 14042 “shall not be used for comparative assertions disclosed to the public”.

Abbreviations

ADI	acceptable daily intake
ADP	abiotic depletion potential
ALI	annual limit of intake
AP	acidification potential
BDP	biotic depletion potential
BUWAL	Bundesamt für Umwelt, Wald und Landschaft (→ SAEFL)
CBA	cost-benefit analysis
CFC	chlorofluorocarbon
CML	Centre of Environmental Science - Leiden University
CMLCA	chain management by life cycle assessment
DALY	disability adjusted life years
DCB	dichlorobenzene
DGM	Netherlands Directorate-General of Environmental Management (part of VROM)
EBIR	equal benefit incremental reactivity
EDIP	environmental design of industrial products
EI 99	Eco-indicator 99
EIA	environmental impact assessment
EIOLCA	economic input-output life cycle assessment
EP	eutrophication potential
EPS	environmental priority strategy
ETH	Eidgenössische Technische Hochschule (Zürich)
FAETP	freshwater aquatic ecotoxicity potential
FNPP	free net primary production
FSETP	freshwater sediment ecotoxicity potential
GWP	global warming potential
HTP	human toxicity potential
IOA	input-output analysis
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LCA	life cycle assessment
LCI	life cycle inventory analysis (note: this abbreviation sometimes also includes the Goal and scope definition)
LCIA	life cycle impact assessment
LSS	life support system
MAETP	marine aquatic ecotoxicity potential
MCA	multi-criteria analysis
MIET	missing inventory estimation tool
MIR	maximum incremental reactivity
MOIR	maximum ozone incremental reactivity
MRPI	milieurelevante product informatie (environmentally relevant product information)
MSETP	marine sediment ecotoxicity potential
MTC	maximum tolerable concentration
MTR	maximum tolerable risk
MVOC	non-methane volatile organic compound
NOEC	no observed effect concentration
NPP	net primary production
ODP	ozone depletion potential
OP	odour potential

OTV	odour threshold value
P.M.	*pro memoria* (as a reminder)
PAF	potentially affected fraction
PBT	persistence, bioaccumulation, toxicity
PEC	predicted environmental concentration
PNEC	predicted no-effect concentration
POCP	photochemical ozone creation potential
RA	risk assessment
RAINS	regional acidification information and simulation
SAEFL	Swiss Agency for the Environment, Forests and Landscape (→ BUWAL)
SETAC	Society for Environmental Toxicology and Chemistry
SFA	substance flow analysis
SI	*Système International des Unités*
SPEP	species-pool effect potential
SPINE	Sustainable Product Information Network for the Environment
SPOLD	Society for the Promotion of Life-cycle assessment Development
TETP	terrestrial ecotoxicity potential
UNEP	United Nations Environment Programme
USES-LCA	Uniform System for the Evaluation of Substances, adapted for LCA
VOC	volatile organic compound
VROM	Netherlands Ministry of Housing, Spatial Planning and the Environment
WIA	SETAC-Europe Working Group on Impact Assessment
WMO	World Meteorological Organisation
WRI	World Resources Institute