DANISH MINISTRY OF THE ENVIRONMENT

Environmental Protection Agency

State of LCA in Denmark 2003

Introduction to the Danish LCA methodology and consensus project

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Environmental Project No. 1205 2007
Miljøprojekt

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Please note that publication does not signify that the contents of the reports necessarily reflect the views of the Danish EPA.

The reports are, however, published because the Danish EPA finds that the studies represent a valuable contribution to the debate on environmental policy in Denmark.

Content

Preface

This guideline has been prepared within the Danish LCA methodology and consensus-creation project during the period from autumn 1997 to 2003.

The guideline is a part of a series of guidelines dealing with key issues in LCA. These guidelines are planned to be published by the Danish Environmental Protection Agency during 2004 and 2005.

A primary objective of the guidelines has been to provide advice and recommendations on key issues in LCA at a more detailed level than offered by general literature like the ISO standards, the EDIP-reports, the Nordic LCA-project and SETAC-publications. The guidelines must be regarded as an elaboration of and a supplement to this general literature and not a substitute of this literature. The guidelines, however, build on the line of LCA-methodology known as the EDIP methodology.

It is important to note that the guidelines have been developed by a consensus process involving in reality all major research institutions and consulting firms active in the field of LCA in Denmark. The advice given in the guidelines may thus be said to represent what is generally accepted as best practice today in the field of LCA in Denmark.

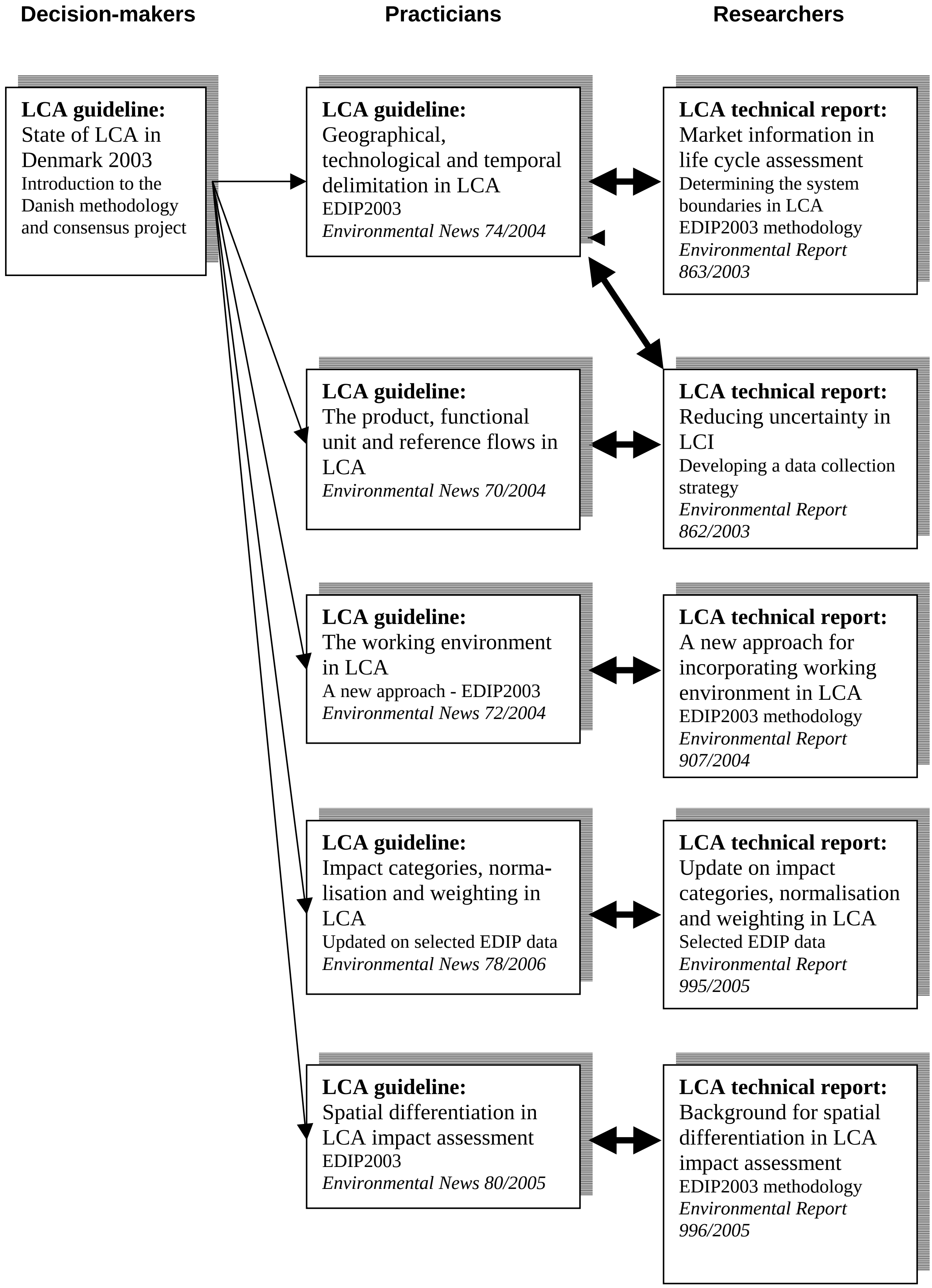
The guidelines are supported by a number of technical reports, which present the scientific discussions and documentation for recommendations offered by the guidelines. These reports are similarly planned to be published during 2004 and 2005. The guidelines and the technical reports are presented in the overview figure below.

The development of the guidelines and the technical reports have been initiated and supervised by the Danish EPA's Ad Hoc Committee on LCA Methodology Issues in the period 1997 - 2001.

The research institutions and consulting firms active in the development and consensus process comprised:

COWI A/S (Project Management)
Institute for Product Development, the Technical University of Denmark
FORCE Technology
The Danish Technological Institute
Carl Bro
The Danish Building Research Institute
DHI - Water and Environment
Danish Toxicology Institute
Rambøll
ECONET
Danish Environmental Research Institute

Guidelines and technical reports prepared within the Danish LCA methodology and consensus project



1 Introduction

This guideline is a cross-cutting and unifying guideline on LCA developed within the Danish LCA methodology and consensus project.

The guideline addresses decision-makers and users of LCA in private companies as well as public and governmental institutions.

The objectives of the guideline are:

1. To describe the choices that have to be made in the process of developing an LCA, thereby allowing the reader to identify requirements to an LCA considering the anticipated utilization of the LCA.

2. To be an introduction to the other technical guidelines, prepared within the methodology and consensus project (reference is made to the preface), as well as other relevant LCA literature, as ISO standards, EDIP-publications etc.

More directly the purpose of the guideline can be said to explain the appropriate way to use and utilize LCA.

LCA is not science. LCA is , however, a tool based on science. It is a tool, that e.g. is used to assess environmental impacts related to products.

In reality the results of an LCA is used together with financial and technical considerations for decision making. LCA, therefore, must be classified as a decision support tool.

This guideline describes the state of LCA today and advantages and drawbacks related to different choices of methodology. Hereby the guideline hopefully assists in securing that LCA is used and respected for what it really is:

A good and appropriate tool in many cases, a tool which may give the right perspective to many choices and decisions, but in no way a miracle tool that will present an answer to all questions.

The guideline summarises many of the discussions that have taken place within the Danish LCA methodology and consensus project and has also gained inspiration in those publications referred to in the different sections. Furthermore, the guideline has drawn heavily on the publications [Jensen et al. 1997], [Wenzel 1998] and [Weidema 1998].

2 What is LCA

2.1 What is LCA - the brief version

LCA stands for Life Cycle Assessment and is a tool aimed at giving an answer to the question:

What is best *(or worst)* seen from an environmental point of view.

LCA may be used for comparing products and systems and services based on the use of industrial products. A product in this context should be taken to include chemical substances, materials as well as real industrial products.

LCA may also be used to analyze environmental impacts for products throughout the entire life cycle of the product, aiming at identifying the most important environmental impacts and thereby determine, where to invest efforts in improving the environmental characteristics of the product.

LCA is not a specific methodology, but rather a name for a group of methodologies, which is as a common characteristic based on a systematic inventory and assessment of environmental impacts throughout the entire life cycle for a product. The purpose of undertaking this inventory and assessment is basically to make it possible to integrate environmental concerns into decision processes. LCA is therefore normally classified as a decision support tool that provides information on the potential environmental impacts related to products.

International definition
The international definition of LCA, as stated in ISO Standard No. 14040, is as follows [Jerlang et al. 2001]:

LCA is a technique for assessing the environmental aspects and potential impacts associated with a product, by

- *compiling an inventory of relevant inputs and outputs of a product system;*
- *evaluating the potential environmental impacts associated with those inputs and outputs;*
- *interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study.*

LCA studies the environmental aspects and potential impacts throughout a product's life (i.e. cradle-to-grave) from raw materials acquisition through production, use and disposal. The general categories of environmental impacts needing consideration include resource use, human healt,h and ecological issues.

The life cycle
It is characteristic of LCA that the assessment covers the entire life cycle of a product not restricted by national boarders, and therefore includes the following:

- Extraction (of raw materials), inclusive of mining
- Production (of materials and products)

- Use
- Disposal, inclusive of recycling, waste incineration, biological waste treatment and landfilling as well as existing and future emissions from such facilities

The relevance of including the entire life cycle comes from the fact that impact on the environment may take place at any step throughout the life cycle. For different products the main impacts may, however, differ between the life-cycle phases. For some products the most important impacts may take place during the extraction phase. For other products the main impacts may be linked primarily to the production, the use or the disposal phases of the life cycle.

Environmental impacts (and related health effects)
In principle LCA is covering all important types of environmental impacts. In table 1 are listed the environmental impacts that may be considered in LCA. In reality LCA will often be limited to the environmental impacts which can be quantified using existing methodologies. However, the correct approach is to include all types of environmental impacts in the assessments, although some types of impacts can only be assessed qualitatively.

LCA is developed as a tool for assessment of environmental impacts. Nothing prevents assessments of social or ethical conditions etc., as e.g. child labour or human rights, by the same principles as those used in connection with environmental impacts. However, no generally accepted methodologies to undertake such assessments have so far been developed, and LCA is by most people regarded as a tool that only deals with environmental impacts.

The working environment (occupational health and safety) is partly an exemption. So far the working environment has typically not been included in LCA. In Denmark the general understanding is that the working environment should be included in the assessments at least to ensure that benefits regarding the exterior environment do not lead to deteriorations of the working environment. Reference is made to section 3.5.

The LCA process
The work to be carried out in an LCA will typically cover the following:

1. Definition of goal and scope inclusive of system boundaries

2. Collection of data on inputs and outputs related to the product during the entire life cycle (input/output covers raw materials, emissions and waste)

3. The potential environmental impacts that follow from these inputs and outputs are calculated (this calculation may include normalisation and weighting)

4. Interpretation of results (assessment of methodology choices, data shortages, system boundaries and uncertainties etc. compared to the scope of the LCA)

These activities represents the typical basic steps in every LCA. Depending on the goal, scope and consequences etc., the efforts invested may however vary. An LCA may be simple and cheap, or an LCA may be complicated and expensive. This question is discussed further in sections 2.3 and 4.

Table 2.1
Environmental impacts (impact categories) that are or may be considered in LCA.[1)]

Impact	**Explanation**
Global warming	Heating of the atmosphere due to emission of CO_2 and other gasses retaining heat radiation otherwise been emitted to the outer space. This heating may cause climatic changes. Integrated in the EDIP methodology.
Stratospheric ozone depletion	The ozone layer in the stratosphere protects against ultraviolet (UV) radiation from the sun. Emission of persistent hydrocarbons containing chlorine or bromine destroys the ozone layer. Thereby the UV radiation is increasingly giving risk of skin cancer, eye diseases and reduced immune defence for humans and animals together with damage to plants. Integrated in the EDIP methodology.
Acidification	Emission of acidifying compounds, e.g. SO_2 , NO_x and ammonia attacks leafs and needles on trees and acidifies topsoil and lakes. Integrated in the EDIP methodology.
Eutrophication	Emission of nutrients, in particular phosphorus and nitrogen, to lakes and the sea, causes increased growth of algae. When the algae die, they sink to the bottom and are decomposed. By the decomposition process oxygen is consumed, and heavy growth of algae may therefore lead to oxygen depletion in the sea and lakes, resulting in death of fish. Emission of nitrogen compounds to the atmosphere may also contribute to this process and may furthermore result in displacement of nutrient-poor ecosystems on land, like heath and raised bog. Integrated in the EDIP methodology.
Photochemical ozone formation	Emission of organic solvents and non-combusted organic compounds to the air close to the ground may react with NO_x to form ozone and other reactive oxygen compounds that are toxic to humans, animals and plants. Integrated in the EDIP methodology.
Toxicity to humans	Many chemicals and heavy metals are toxic to humans and affect humans via the environment, e.g. via the air, food, drinking water etc. Integrated in the EDIP methodology.
Toxicity to the environment	Many chemicals and heavy metals are toxic to animals and plants. Integrated in the EDIP methodology.
Consumption of non-renewable resources	Many of the materials, e.g. metals being used in daily life, are extracted from concentrated occurrences in nature. These occurrences are not recreated or at a rate so slow that it has no practical significance. Our use of the materials means that they either disappear, e.g. mineral oil, or are dispersed into nature, e.g. metals. Our use means that these resources at a time will be used up and thus they will not be available to future generations. Integrated in the EDIP methodology.
Landfilling of waste	Waste being landfilled, occupies land that could have been used for other purposes. The waste will, furthermore, slowly be decomposed into chemical substances, which may leach or evaporate and thereby have an impact on the environment. This environmental impact may in the future be replaced by a calculation of the real impacts, e.g. land use. Integrated in the EDIP methodology.
Working environment	The impact that humans are exposed to through their work. Covers accidents, poisoning and wear of the human body. Integrated in the EDIP methodology.
Land use	All activities occupy land, which could have been used for other purposes - e.g. as nature for re-creational purposes. This environmental impact is not integrated in the EDIP methodology today, but is quantified in other LCA methodologies and may be integrated in EDIP in the future.
Noise, odour and radioactivity	Noise, odour and radioactivity affect humans, animals and to some extent also plants. These types of environmental impacts may only be partly quantified and are typically not included in LCA today, but can be included in the future.
Energy	In many cases the consumption of energy can be the dominating cause of environmental impacts like global warming, acidification and eutrophication. In *simplified LCA* one may often choose to focus on energy consumption as an impact category in itself.

Note to table 1
1) Impact on biodiversity, i.e. the natural biological variation and biological resources, is not included as an independent impact category, as this type of impact is a consequence of most other impacts.

It is emphasized that in an LCA many choices and assessments are made that have an impact on the final result. Furthermore, uncertainties are connected with data and calculations. The interpretation of calculation results is therefore a very important step in LCA.

As the relevant choices and assessments as well as the interpretation are typically subjective, i.e. depend on the person undertaking the choice, the assessment or the interpretation, there will often be issues that can be discussed. Therefore it is generally important to undertake quality control of LCA. Quality control is in LCA terminology named *critical review*.

Irrespective of quality control the scientific field of environment is very comprehensive, and it is continuously being developed. Some of those methods and principles of assessment assumed correct today could be outdated and regarded as wrong in 10 years from now. 10 years from now we may also recognize that important environment impacts are not covered by the methodologies applied today. In reality LCA is a tool, which continuously is being developed. This development should be expected to continue for at least the next 10-20 years.

This means that the outcome of an LCA seldom should be regarded as the ultimate truth. The outcome of an LCA should as the general rule be regarded as a qualified estimate of the truth and optimally as the best possible estimate based on the knowledge available at the time of the assessment.

Irrespective of this, LCA is an important tool already today. Not least because LCA is the only tool that can give a reasonably reliable answer to the following question: Which product or system is the best from the environmental point of view?

2.2 Applications of LCA

LCA is the natural tool for all decision-makers, who need to make a choice between different materials, technologies or products and want to consider environmental issues in this process.

The development of LCA reflects an increasing demand on all levels in society to integrate environmental concerns in decision processes and choose the alternatives which from an environmental perspective are the best. Many times in decision processes environmental issues are considered parallel to technical and financial issues. It is basically the responsibility of the decision-makers to determine the importance of the individual parameters in the process.

Authorities
The authorities are using LCA for action planning at society level, which again may be reflected in legislation. LCA may also form the foundation for product standards, duties and incentive arrangements. To this may be added

the use of LCA as foundation for guidelines in public green procurement and criteria for environmental labelling.

Companies
Companies are using LCA in particular for development of new products and processes inclusive of investments in new facilities and routines of operation. Typically LCA will initially be used as an analytical tool to determine the focus for further efforts (hot spots). Later in the process LCA may be used as a decision support tool to determine the alternatives that are the best from the environmental perspective. The use of LCA will vary from "here and now" decisions to tactical and strategic planning in the long-term perspective, and LCA may be an integrated element of the corporate environmental management system.

Also marketing should be emphasized. The environmental performance of products is increasing in importance as a parameter of competition. Today this is most obvious regarding products as packaging. However, the trend can also be observed for products, e.g. electronics, generally marketed on their technical performance.

Marketing inter alia covers offensive marketing, in which the company is sending the message that their products in the environmental perspective are better than the products from their competitors. This may be compared to the more defensive style of marketing that companies want to make sure that their products cannot be "attacked", e.g. due to a content of hazardous substances, and that the companies anyway want to be able to respond, if competitors claim to be environmentally better. Finally environmental declarations and other sorts of environmental information to customers and other interested persons should be mentioned.

Other users
Public service and construction companies are using LCA in relation to investments and system choices. This applies to transport as well as solid waste and wastewater treatment. Guidelines in environmental design and construction are based on LCA thinking.

To this may be added e.g. consumer organisations and other grass-roots organisations, who inter alia may use LCA, when it comes to debate on public matters.

Environmental costs assessments
LCA should be an integrated element in environmental costs assessments, as LCA is used to clarify the environmental consequences of different options, whereas the economic calculations may be regarded as a special form of weighting.

To the extent Cost-Benefit Analyses (CBA) addressing environmental issues are not based on LCA, it must be anticipated that the result of a CBA will not necessarily correspond to the result of an LCA, since the preconditions and assumptions on which the results are based may be different.

What can LCA not be used for?
LCA is in itself not sensitive enough to be the only tool applied, when the risks related to introducing new chemicals in products are assessed. In such cases should be supplemented by *Risk Assessment* to assess the fate of the actual products and chemicals in society. In some cases it may be advisable,

before a risk assessment is initiated, to assess the turnover and flow of the chemicals in society using *Substance Flow Analyses.*

It is furthermore important to be aware of the fact that LCA gives an estimate of the *potential* environmental impacts, which is not necessarily the same as the *actual* impacts, as the actual impacts may depend on the local conditions, e.g. of the extent to which the emission is diluted and the total load on the recipients in question. LCA therefore cannot replace environmental impact assessment for production facilities according to the law of environmental protection. LCA may, however, be used as documentation towards the authorities justifying selection of specific technologies.

LCA cannot replace workplace assessments and other types of working environment assessments carried out according to the law on working environment (reference is made to section 3.5).

2.3 LCA levels

LCA may be carried out at several levels, which differ heavily with respect to effort and thoroughness required and frequently also the uncertainty related to the result.

According to tradition one should distinguish between at least the following 3 levels, for which the effort and the thoroughness required are increasing considerably from level 1 to 3 (cf. e.g. [Jerlang et al. 2001]):

Level 1
Life-cycle thinking

Level 2
Simplified LCA

Level 3
Detailed LCA

Level 1 - life-cycle thinking is also known as conceptual LCA and covers the type of LCA that primarily is a qualitative assessment based by and large on knowledge at hand of significant environmental impacts during the life cycle of the products. Life-cycle thinking will typically be presented in rules of thumb like [Remmen & Münster, 2002]:

- Reduce consumption of energy and materials throughout the life cycle of the product
- Replace hazardous substances by more environmentally acceptable alternatives
- Use materials that can be recycled
- Design to allow the product in whole or partly to be recycled
- Make the product easy to repair

SWOT-LCA is also included as life-cycle thinking. SWOT is a systematic qualitative assessment of Strengths, Weaknesses, Opportunities and Threats.

Level 2 -simplified LCA is often known as screening LCA. This type of LCA will try to reduce data collection and thereby the total effort. One will start with an introductory screening aimed at identifying the most important environmental impacts throughout the life cycle of the product. This screening will frequently be semi-quantitative. Based on the result of the screening the further work is focused on the issues deemed to be the most important. Then EDIP MECO-methodology (see section 2.4) is an example of a methodology for simplified LCA.

Level 3 - detailed LCA covers the type of LCA, in which a computer programme is use to establish a model containing all the relevant data. A quantitative calculation is carried out for all environmental impacts that can be quantified. A significant advantage of this level is that when the computer model has been established, it is a small task to evaluate many different alternatives.

Common to all levels are that the assessment aims at including all parts of the life cycle and all important environmental impacts. The difference between the levels is related to the effort invested for data collection and calculations and thereby the detailing, the thoroughness and the precision obtained. The necessary manpower input required can as a rule of thumb be summarised as follows:

Level	Known as	Manpower required (yardstick)
1	Life-cycle thinking	Hours
2	Simplified LCA	Days
3	Detailed LCA	Weeks - months

In section 4. is discussed for which activities the individual levels are appropriate.

2.4 Guidelines and tools

Today a very long list of guidelines and tools related to LCA exists. In the following the guidelines and tools that from a Danish perspective should be regarded as the most important are briefly presented.

ISO standards
The general framework for LCA is determined by the ISO standards ISO 14040-43 [DS/EN ISO 14040, 1997 - 14043, 2000]. These standards provide guidance regarding the single steps in LCA, but do not define any specific methodology and will typically not give concrete examples on how to perform the single steps in LCA. The Danish Agency of Standardisation has, however, also published a commented translation of the standards (see

[Jerlang et al. 2001]). This translation includes a number of examples for illustration of the text.

That an LCA fulfils the ISO standards should be regarded as a form of quality mark. For this reason it is relevant to be familiar with the ISO standards.

The EDIP methodology

The EDIP methodology is the closest one may get to an official Danish LCA methodology. The methodology is developed at the Technical University of Denmark supported by the Danish EPA and the Association of Danish Industries. EDIP stands for *Environmental Development of Industrial Products*. The EDIP methodology comprises a screening methodology , known as the MECO-methodology, and a detailed methodology that assumes the use of computer programmes. Both of these methods are described in the EDIP-handbooks, which are published in Danish in 1996 [Wenzel et al. 1996; Hauschild 1996] and in English in 1997-98 [Wenzel et al. 1997; Hauschild & Wenzel 1998]. Simultaneously with the publishing of the English version an expansion and updating of the data foundation took place. The two versions are for practical purposes known as EDIP96 and EDIP97. The detailed version of EDIP fulfils the ISO standards.

MECO stands for "Materials, Energy, Chemicals and Other issues" and states the headlines used for the assessment criteria in this methodology. For materials (synonymous with resources) and energy are typically used quantitative calculations, whereas chemicals and other issues are assessed qualitatively or semi-quantitatively depending on how carefully the assessment is carried out.

Other Danish LCA handbooks

Of other Danish LCA handbooks must be mentioned:

- **Kom godt i gang med livscyklustankegangen (Get a good start with life-cycle thinking)**
  This booklet [Remmen & Münster 2002] describes the environmental work at the company level based on life-cycle thinking and is in many ways a good introduction to the kind of LCA known as life-cycle thinking.

- **Håndbog i miljøvurdering af produkter - en enkel metode (Handbook in environmental assessment of products - a simple methodology)**
  This handbook [Pommer et al. 2001] is issued by the Danish EPA and should be regarded as a easily accessible presentation of the EDIP methodology. The handbook is focused on the MECO methodology, but contains much good advice related to the entire process of undertaking an LCA. The handbook is addressing all types of users, private companies and others and is furthermore suitable for teaching activities.

- **Green Network's handbook in life-cycle assessment**
  The handbook [Green Network, 1999] is developed by Green Network in the County of Vejle, Denmark. The handbook is based on the EDIP methodology (primarily the detailed level). The handbook is addressed directly to private companies and should be used together with Green Networks handbook on environmental reviews. The handbooks may be regarded as an example of how local authorities may aim at guiding private companies.

SETAC reports
SETAC stands for Society of Environmental Toxicology and Chemistry and is a international scientific society. SETAC is the most important international platform for scientific discussion and development of consensus in the LCA field. SETAC has throughout the years published a number of reports and guidelines on LCA, which are commonly referred to. SETAC and SETAC reports are primarily relevant to persons aiming at keeping up with the new scientific development within LCA.

Dutch LCA guidelines
Also in the Netherlands significant developments within LCA are continuously taking place. The basic handbook *Environmental life cycle assessment* from 1992 [Heijungs et al. 1992] has recently been updated. The updated version *Life cycle assessment - an operational guide to the ISO standards* [Guinée et al. 2001] could be relevant to persons, who are dealing with LCA in a international context.

Computer tools
Many types of software designed for LCA have been developed during the last decade. In the report [Jensen et al. 1997] a thorough overview is given. The dominating computer tool in Denmark has been the EDIP tool, which was marketed by the Danish EPA. When the Danish LCA Center was established in 2003, it was furthermore decided that EDIP tool no longer would be supported and updated.

Development and updating of computer tools able to use the EDIP methodology will in the future take place via the Danish LCA Center. It is assumed that the following computer tools would be approved to dissemination of the EDIP methodology:

GaBi
GaBi is the official partner to the Danish LCA Center, and GaBi vil continuously be updated in order to support any significant improvement of the EDIP methodology. GaBi is in particular utilised by large industrial companies in Europe, e.g. the automobile industry in Germany.

SimaPro
SimaPro is probably the most widely distributed computer programme for LCA in a global context.

3 What is new in EDIP2003

3.1 EDIP2003 versus EDIP1997

The Danish LCA methodology and consensus project has introduced a number of important changes and improvements to the methodology known as EDIP1997. As the project was finalised in 2003, it was decided to name the EDIP methodology as it is now EDIP2003.

In table 3.1 is summarised what is new in EDIP2003 compared to EDIP1997, and it is indicated in which guidelines the topics are dealt with in more detail. In the following a brief introduction is given to these topics.

Table 3.1 What is new in EDIP2003

LCA step	**Topic**	**Reference**
1. Goal and scope	Definition of the functional unit	Guideline on *Product, functional unit and reference flows in LCA*
2. Inventory	Market-based system delimitation	Guideline on *Geographical, technological and temporal de- limitation in LCA*
3. Impact assessment	Spatial differentiation	Guideline on *Spatial differentiation in life cycle impact assessment*
	New normalisation and weighting factors for different geographical areas based on EDIP1997 1)	Guideline on *Impact categories, normalisation and weighting in LCA*
Crosscutting	New assessment methodology on the working environment	Guideline on *The working environment in LCA*

1) These new normalisation and weighting factors are regarded as an update of EDIP1997 and *not* as a part of EDIP2003, since spatial differentiation has now been introduced.

Besides these guidelines a new report dealing with calculation of emissions and environmental impacts from landfilling of waste is also being finalised. This report has been developed outside the methodology and consensus project and will not be described further here. Reference is made to [Hansen et al. 2004].

3.2 Definition of the functional unit

The functional unit is a key concept in LCA. The functional unit is the reference unit, which is being assessed and compared in an LCA. This unit can briefly be characterised as a quantified description of the output or service delivered by the product system/systems assessed in an LCA. The service delivered by a coffee machine may e.g. be described as 5 cups of coffee 2 times a day 300 days a year during 5 years.

Experience shows, that the definition of the functional unit may often determine the result of an LCA.

With the guideline on *Product, functional unit and reference flows in LCA* [Weidema et al. 2004] a procedure has been developed that can assist in assuring that the functional unit is correctly defined.

Some of the considerations presented in this guideline have previously been presented in a simplified version in the publication: *Håndbog i miljøvurdering af produkter - en enkel metode (Handbook in environmental assessment of products - a simple methodology)* [Pommer et al. 2001].

3.3 Market-based system delimitation

Market-based system delimitation is an important new element that can be compared to introducing a economic way of thinking in LCA.

Traditionally in LCA one has used data, which describe the present production processes taking place. Occasionally is used an average of several different processes. E.g. electricity is often calculated as a weighted average of hydropower, nuclear power and coal-based power.

It has now been recognized that the most correct approach is to use data for production processes that reflect the real technological consequences and thereby also the real environmental consequences of the decisions made based on an LCA.

The fundamental issue is that when an LCA identifies e.g. a certain material as being advantageous, a demand for this material is created. In a free market the response to this demand will typically be an increased production by the manufacturer, who is the most competitive and is not constrained with respect to the size of the production. Therefore the data to be used in the LCA should be data from this manufacturer and not necessarily data from the present suppliers of the material.

The consequences of this line of thinking is best illustrated by an example:

A company situated in Europe is mainly using electricity based on hydropower. In an LCA the company must, however, take into account that hydropower is a technology that is constrained in Europe. By and large there are no opportunities left for increasing the production capacity for hydropower in Europe. If the company in an LCA is assuming that it needs more electricity, the company also has to accept that this extra electricity will be produced by other technologies than hydropower. As e.g. nuclear power is also constrained in Europe - in this case the constrain is political - the company will in most cases have to assume that the extra electricity the company needs will be based on fossil fuels like coal or natural gas. In the

LCA the company therefore has to rely on coal or natural gas technology and not hydropower.

In order to carry out a reliable LCA, it is thus necessary to know the market conditions for the central products and production processes.

With the guideline on *Geografical, technological and temporal delimitation in LCA* [Weidema 2004] a tool has been developed to evaluate these market conditions and identify the production processes, relevant in the LCA in question. These production processes is here known as *the affected production processes*. It is emphasized that the time perspective can be very important in these assessments (reference is made to section 4.2 - subsection on trend analysis/projection).

It must also be recognised that this development of methodology is new, and that the experience available so far is limited. In the following is briefly discussed some of the most important issues, which may cause hesitation.

The affected production processes cannot be determined with certainty
In several cases one may likely be in doubt of which production processes are the right ones to consider. In these cases it will be correct to identify several scenarios which include the possible processes. If e.g. it is assumed realistic that the affected production processes for electricity will be either coal technology or solar battery technology, it will be correct to establish 2 scenarios - one scenario based on coal technology and another based on solar battery technology.

Is it still relevant to use data from the present production processes?
Yes - as stated in the guideline on *Geografical, technological and temporal delimitation in LCA* it should be considered relevant to use data from the present production processes in the following situations:

- As educational introduction to LCA, because the approach in some cases may seem more simple. Only data from companies belonging to their own chain of products are needed.

- In the initial analysis of environmental impacts in the life cycle of a product aimed at determining the most significant impacts and thereby to decide on which issues it is relevant to focus in order to improve the environmental performance of the product. However, actual changes in design and selection of materials should be determined based on market-based system boundaries.

Environmental product declarations
Internationally as well as in Denmark efforts are in these years invested in defining common guidelines for environmental product declarations. Among other issues efforts are invested in developing a new ISO standard on environmental product declarations. The current trend of this work seems to be that the guidelines will not require market-based system delimitation. A discussion of advantages and drawbacks of using market-based system delimitation compared to the approach of basing the LCA on the present production processes is integrated in the report *Market information in life cycle assessment* [Weidema 2003].

Does the market-based system delimitation allow that the LCA will endorse initiatives not necessarily recognised by the market?
The market-based system delimitation normally requires that actions without

a real positive environmental impact cannot be endorsed in an LCA. If a company is choosing "green" electricity, this can only be endorsed, if the action of the company implies that the production capacity of "green" electricity is also expanded in reality. If such an expansion does not take place, the use of "green" electricity by the company will only have as a result that other users of "green" electricity will convert from "green" electricity to e.g. coal-based technology.

Correspondingly a company using secondary raw materials for its production will only be able to endorse this, if a real extra collection of second-hand materials is taking place as a consequence of the company's choice. Otherwise the result of the company's choice will be that the use of secondary raw materials by others will be displaced by the use of virgin raw materials.

According to the guideline on *Geografical, technological and temporal delimitation in LCA* it is, however, allowed to count on the signal value of the action under the precondition that it is clearly stated that the signal value is taken into account.

This means that it is acceptable in the LCA to count on the fact that the company by the action of buying "green" electricity is sending a signal of that a market for such products exists. The signal may actually contribute to ensure that an expansion of the production capacity of "green" electricity or the collection of second-hand materials will be realized. Either because some market actors see the opportunity of a good business, or because the issue is becoming subject to political initiatives as e.g. legislation.

In case signal values are taken into account, it will be most correct to include 2 scenarios - with and without signal value - as it cannot be known for sure, whether the development called for by the signal will actually be realized.

3.4 Normalisation, weighting and spatial characterisation

Also within these fields some news are introduced:

- Based on the same calculation principles as in EDIP1997 new normalisation and weighting factors for different geographical areas have been developed.

- The option of using spatial characterisation has been made available.

Normalisation and weighting factors
In EDIP1997 only one set of normalisation and weighting factors was given, which was based on Danish data apart from the global effect categories, i.e. global warming and stratospheric ozone depletion.

With the guideline on *Impact categories, normalisation and weighting in LCA* [Stranddorf et al. 2006] it is now possible to choose between 3 sets of factors covering the following geographical areas:

1. Denmark

2. EU-15

3. The world

The new normalisation factors correspond to the reference year of 1994, whereas the new weighting factors correspond to the reference year of 2004.

Companies hereby have the opportunity of making calculations considering conditions on export markets as well as in Denmark for the non-global impact categories (i.e. all categories apart from global warming and stratospheric ozone depletion). With respect to global warming and stratospheric ozone depletion the normalisation is continuously based on the global emissions.

The updated normalisation and weighting factors cover all impact categories in EDIP1997 apart from the categories addressing waste for landfilling. These last categories are not updated, as it is foreseen that they at least partly will be superfluous when a coming report (reference is made to [Hansen et al. 2004]) on assessment of emissions and environmental impacts from landfilling is ready.

That an environmental impact is normalised means that the size of the impact - i.e. typical the size of the emission - has been related to the total load per year within a specific geographical area and thereby also a specific number of humans. The environmental impact thereby for all impact categories can be expressed in person-equivalents. This step in principle makes it possible to compare the size of the impact between impact categories and see whether e.g. global warming or acidification in a relative perspective is the most important impact in the actual case.

The weighting is following the normalisation and means that the normalised environmental impacts are multiplied by a factor that reflects the decision-maker's position on the importance of the different environmental impacts.

The weighting factors established in EDIP have all been based on politically accepted targets of reduction to the extent such targets have been established at all.

It is emphasized that the fact that the weighting reflects the decision-makers position on the importance of the different environmental impacts means that the decision-maker is allowed to define his own weighting factors.

If a company e.g. in its own environmental policy is stressing that hazardous substances are not to be used in the product or in the manufacturing process it would be logical for the company to assign extra high weighting factors for impact categories dealing with human or environmental toxicity.

Spatial characterisation

The possibility of using spatial characterisation is also an important new element in EDIP and one of the central differences between EDIP1997 and EDIP2003. Spatial characterisation means that the LCA will take the geographical location of the emissions into account. Furthermore, changes have been introduced to the models behind some of the impact categories. This has reduced the uncertainty related to estimates of the environmental impact for a number of regional and local impact categories, like acidification, photochemical ozone formation and eutrophication. It is noted that eutrophication in EDIP2003 is divided in the water environment and the terrestrial environment.

The characterisation factors given in EDIP1996 and EDIP1997 are mainly estimated from the basic properties of the chemical substances. Thus no attention has been paid as to where the emission is taken place in geographic perspective, and one is therefore talking about a so-called site-independent characterisation of environmental impacts.

In reality the geographical location of the emission may significantly influence the seriousness of the impact to the environment. This is related not only to where the pollution is transported, but also to the sensitivity of the local environment receiving the pollution to an extra load.

The acidification effect of an SO_2 emission in countries like Norway and Sweden is thus about 1000 times worse than for a similar emission in Greece. It may therefore be of high importance in LCA whether the emission takes place in Scandinavia or in Greece.

Similar differences may be observed for the impact categories photochemical ozone formation and eutrophication in the terrestrial environment.

In the guideline on *Spatial differentiation in life cycle impact assessment* [Hauschild & Potting 2005] is described when it is relevant to undertake spatial characterisation, and how this is actually done.

As stated in the guideline, spatial characterisation is so far not included in an LCA computer programme and it will until then be complicated to undertake the calculations. It can be assumed that spatial characterisation will be integrated in the LCA computer programmes that is being approved by the Danish LCA Center in the coming years (reference is made to section 2.4). Until then it is recommended that spatial characterisation is used as a manual procedure in those cases, in which it is assumed to have a considerable influence on the outcome of an LCA, i.e. in which the impact categories acidification, photochemical ozone formation and eutrophication are assumed to be of considerable importance and the most important processes during the life cycle dominantly are located in Europe.

Even if it has not been possible to develop spatial characterisation for the impact categories human toxicity and eco-toxicity, the guideline includes calculations on test-substances which illustrate the potential significance of spatial characterisation in these cases.

It is, furthermore, possible to undertake a so-called site-independent characterisation of environmental impacts based on the new models. The guideline on spatial differentiation in LCA does also include calculation factors for site-independent characterisation. These factors correspond to the site-dependent characterisation factors and may be used for processes in LCA , when the geographical location is not known.

The advantages of undertaking site-independent characterisation according to EDIP2003 are that a more precise assessment of the real environmental impacts is obtained, and that the uncertainties related to the spatial differentiation are now known. These uncertainties are stated in the guideline.

Since this methodology development is new there is so far only little experience to build on. In the following some important issues are briefly addressed.

When is it recommended to use spatial characterisation?
It is recommended to use spatial characterisation when:

- The impact categories acidification, photochemical ozone formation and eutrophication are assumed to be significant regarding the outcome of an LCA

- The most important processes during the life cycle are dominantly located in Europe, and it is known in which country in Europe the processes are taking place.

For what production processes can spatial characterisation be carried out?
Spatial characterisation can be carried out for all production processes taking place in Europe, assuming that it is known in which country the processes are located. For production processes located outside Europe spatial characterisation is not possible, and one has to use the calculation factors that are designed for site-independent characterisation.

If the country of production is unknown, one also has to use site-independent characterisation.

When is it recommended to use site-independent characterisation according to EDIP2003?
Site-independent characterisation according to EDIP2003 can be used as an alternative to the traditional calculation according to EDIP1997. Generally it is recommended to use site-independent characterisation according to EDIP2003, when the following preconditions are fulfilled:

- The most important processes during the life cycle are dominantly located in Europe - this condition is due to the fact that the calculation factors for EDIP2003 correspond to an average for the whole of Europe.

- The impact categories acidification, photochemical ozone formation and eutrophication (in the soil and water environment) are assumed or assessed to be significant regarding the outcome of the LCA in question.

- The ordinary weighting factors in EDIP are not used - as these weighting factors correspond to the data foundation of EDIP1997 and therefore not relevant to EDIP2003.

When is it recommended not to use spatial characterisation?
It is recommended that spatial characterisation should not be used when the LCA is forming the foundation for:

- Environmental product declarations

- Criteria for environmental labelling

- Marketing in general

The argument for not recommending spatial characterisation in these cases is that use of spatial characterisation in principle could have as a result that companies are choosing to situate production plants at places, where the environment can withstand a high level of pollution rather than choosing a more environmentally-friendly technology. This attitude should be characterised as environmental dumping and as a misuse of spatial characterisation.

In these situations either site-independent characterisation according to EDIP2003 or the traditional calculation based on EDIP 1997 must therefore be used.

New normalisation factors under EDIP2003
As the impact categories acidification, photochemical ozone formation and eutrophication are characterised and calculated in a new way in EDIP2003, it has been necessary to develop new normalisation factors. The new factors are presented in the guideline.

3.5 Working environment

The wish of being able to integrate the working environment in LCA is based on the notion that it cannot be considered acceptable if improvements of the outer environment are obtained at the expense of the working environment.

The original version of EDIP (EDIP1996) therefore included a methodology for assessment of the working environment. This methodology, however, has never been used to any extent noteworthy - likely due to the requirements of the methodology regarding collection and preparation of data.

It is therefore a pleasure that the project has succeeded in developing a new methodology for assessment of the working environment in relation to LCA. This methodology replaces the original methodology in EDIP1996. The methodology is described in the guideline on *The Working Environment in LCA - a new approach* [Schmidt et al. 2004].

The new methodology is a trade assessment methodology, which combines statistical data on production in industrial trades with statistical data on the number of work related damage and accidents reported for each trade. Thereby a yardstick is obtained on the working environment load per unit produced in these trades. This yardstick allows that the working environment load is compared between the trades and thereby an assessment of whether the load will increase or decrease, when a material is replaced by another.

The methodology should be regarded as a screening methodology having the advantage that it is simple and objective.

It is emphasized that the methodology is developed specifically for LCA and that the methodology cannot replace workplace assessments and other types of working environment assessments carried out according to the law on working environment.

It can be assumed that the methodology will be integrated in the LCA computer programmes that will be approved by the Danish LCA Center in the coming years (reference is made to section 2.4). Until then is recommended that the methodology is used as a manual procedure in the cases, in which the decision-maker finds it important to consider the working environment in the assessments.

4 Practical advice

4.1 Choices in LCA - basic considerations

Fundamentally the choices to be made during the preparation of an LCA will deal with what this LCA is to be used for. However, it is not enough to determine the goal and the application. One also has to consider the complexity of the situation and the consequences of the decisions to be made. In reality also the experience available and the willingness to invest are relevant issues.

The goal and the application
In table 4.1 some typical applications of LCA are listed. This list does not claim to be complete, but aims primarily to present an overview and be a foundation of the advice to be given in the following sections.

It is always essential that the decision-maker has clearly defined to himself what the goal of the LCA to be undertaken is. And the goal should be defined as precisely as possible. Ideally the task is to answer the following questions:

- ***Who** are going to use the results?*

- *For **what purpose?***

- ***When?***

- ***Which consequences** would follow from the decisions that will be made?*

Integrated in these questions may be more sub-questions which are having an impact on the form of LCA that shall be undertaken and how. The following questions should be regarded as examples of such sub-questions:

- Are we talking about a single product or a group of products? - This is influencing the definition of the functional unit (see section 3.2) and identification of alternatives.

- What is the time perspective of the decisions that will be made? Are we only addressing matters within the next few years, or is it influencing or having an actual impact on the reality in 20-30 years from now? - This is determining whether a trend analysis should be made.

- Is the study meant only for internal use, or will it also be used externally? - This is affecting the methodology to be applied and furthermore the requirements for documentation.

It is outside the framework of a guideline like this to list all the questions, which could be relevant to different applications. Therefore, this issue will here be summarized as follows: After definition of the study goal made by the decision-maker, the LCA-practician - i.e. the person actually undertaking the study - is to return with proposals for functional unit, system boundaries, allocation principles and other basic choices of methodology. These proposal then have to be compared with the goal to assess, whether the goal will be accomplished.

Experience shows that in this process it is very important to clarify whether LCA actually is the right tool for the problem that is addressed. One may e.g. face problems which should be solved with a chemical assessment rather than an LCA.

The complexity of the situation
The situation that is being assessed in an LCA can be more or less complex. The matters making the situation complex will normally be related to:

- Multi-product systems, i.e. that the manufacturing process is delivering 2 or more different products (e.g. a slaughterhouse may deliver both skins for leather, meat for consumption and waste to be used as feedstuff).

- Recycling of materials for other purposes.

- "Trade-offs", i.e. that due to changes in product design some environmental impacts increases while other decreases.

Complex situations may be difficult to assess, if a quantification is not carried out. In such cases it is in reality given that a reliable LCA must be carried out as a *detailed LCA*. Is the situation more simple, a *simplified LCA* and partly qualitative assessments may be completely adequate. The LCA levels *detailed* and *simplified* are defined in section 2.3 and further discussed in section 4.2.

It is noted that for multi-product systems and in situations with recycling it will be necessary with special considerations on system expansion and allocation (i.e. how are the common loads allocated to the different products - e.g. how is electricity consumption allocated in the slaughterhouse on skin, meat and waste). Such questions are discussed in section 4.2 in the subsection on system boundaries and allocation.

The consequence of the work undertaken
The consequence of the decisions made following an LCA may concern product design, selection of materials, investments etc. Completely depending on the actual situation the consequences may be deemed large or small.

It should be considered as common sense to assume that the higher the importance an LCA is ascribed, the more thorough the work must be done. This applies to LCA at society level as well as at company level and other applications.

Thoroughness in particular is a matter of being able to document and justify the choices made in the LCA and the conclusions made. The elements that must be documented concern the LCA methodology, system boundaries, the data utilised, sensitivity analysis, uncertainty assessments and similar matters.

Marketing is an application requiring careful consideration. A technology cannot in itself be *clean* or *environmentally friendly*. On the other hand a technology can be *cleaner* or *more environmentally friendly* or *less polluting* than other technologies.

It is obvious to use LCA for comparative marketing. Also here one must be careful. Normally it is only possible to state that assessed by a specific methodology and specific criteria a product may be environmentally better than another.

Reference is made to *the Consumer Ombudsman's guideline in environmental marketing* [Forbrugerombudsmanden, 2004].

Experience available
It is a fact that screening typically requires more experience than detailed LCA. Many LCA tasks can be carried out as *simplified LCA*, if they are carried out by experienced personnel. Contrary to that, it may be easier for persons with little or no experience to obtain a reliable result by using *detailed LCA*.

The experience that is available may therefore be a parameter that should be taken into account, when the approach is decided. In reality experience may be bought as e.g. consultancy assistance.

Willingness to invest
It is obvious that the company only able or willing to invest 1 week of manpower in an LCA has to choose another method and present other demands than the company able and willing to invest 6 months of manpower. In the first case the task may only be solved by assistance from a consultant. In the last case many options are available.

It is obvious that the ability and the will to invest in LCA may be so insignificant that the LCA that can be carried out will not be able to solve the problem in question. In this case, it has no meaning to initiate an LCA.

The ability and will to invest in LCA may be related to, whether we are dealing with a single LCA or a series for which large-scale advantages may apply. Large-scale advantages may be relevant to companies producing many products designed highly identical, like e.g. different models.

4.2 Choices in LCA - methodology elements and their use

In this section is presented a number of key elements in LCA, and it is discussed when it is relevant to use these elements and to what extent the decision-maker has a choice.

LCA level
The decision-maker has a choice between the following LCA levels:

- Life-cycle thinking
- Simplified LCA
- Detailed LCA

These levels are described in section 2.3. In table 4.1 is stated the applications for which the individual levels may be appropriate. As indicated in the table many applications may be carried out at several LCA levels.

Somewhat simplified and straightforward it may be said that:

- Life-cycle thinking is for internal LCA work, which is not assumed published.

- Simplified LCA is for simple problems with limited requirements on documentation. The result is typically very dependent on the practician's knowledge and experience. Simplified LCA should therefore not be used externally, if external quality control (*critical review*) has not been applied. Simplified LCA is also used as preparation for a detailed LCA and is here of value in the process of focusing the detailed LCA.

- Detailed LCA is for complicated problems, for which extensive documentation is necessary.

It is emphasized that the choice of LCA level typically has determining influence on other choices of methodology.

System boundaries and allocation
System boundaries in LCA deals with, how to delimit the product system in focus from all other product systems bordering to it. Traditionally in LCA one has used special rules to delimit the essential from the non-essential. Such a rule could e.g. be to only include processes contributing with more than 1% of the total environmental impact for one or more impact categories.

In the guideline on *Geographical, technological and temporal delimitation in LCA* [Weidema 2004] a procedure to delimit the relevant processes that shall be included in the assessment, from non-relevant processes has, however, been presented. Thereby the traditional rules for delimitation are in principle superfluous.

The guideline is also giving advice on allocation and recommends that allocation is avoided and replaced by system expansion, which means that the product system is expanded until all relevant processes are included. This recommendation is also given in ISO standard 14041 [DS/EN ISO 14041, 1998].

Even if system expansion in the future shall be regarded as the rule, allocation may not always be avoided. It is possible that in some cases system expansion may lead to an unreasonably large product system, which may be difficult and time-consuming to deal with.

Practical reasons may thus still justify allocation and the use of traditional rules for system delimitation. It is emphasized that the recommended methodology for allocation according to the ISO standard is the principle known as allocation by *the physical relationships* [DS/EN ISO 14041, 1998].

It is the responsibility of the decision-maker to decide whether the principles and rules presented by the LCA practician to determine system boundaries and to allocate are appropriate.

In accordance with the recommendations in section 4.1 *(the complexity of the situation)* considerations on allocation will normally only be relevant in relation to detailed LCA.

The need for and collection of data
Data collection is normally the activity that requires the biggest input of man-hours in LCA. Data may be obtained from databases (e.g. the EDIP database), literature and direct contact to companies. Collection of data from databases and by direct contact to companies will normally only be relevant to *detailed LCA.*

The need for data collection is determined on the basis of whether the data available are satisfying for the assignment to be undertaken. That data are not satisfying means, that they are not adequately representative of the process that has to be described. Thereby the uncertainty of the conclusions can be unacceptably high. One cannot claim that data collection implies any methodology choice by the decision-maker, but the decision-maker naturally has a choice as to when the data quality - and thereby the uncertainty of the result - should be regarded as acceptable. Data collection should typically be carried out as iterative processes, in the way that one based on screening determines the processes that contribute the most to the total environmental impacts. Thereafter the data collection is focussed on these processes.

Trend analysis/technological forecasting
LCA may be used for purposes - e.g. product development - for which the decisions are influenced or will influence the technological development many years ahead. In these cases it will be necessary to assess the likely development of the product fields in question. As example may be mentioned that if an LCA deals with a new product with a project development period of 5 years and an in-service life of 20 years, which is anticipated to be produced the next 10 years, this LCA have to be able to consider those waste treatment technologies which will be used in about 35 years from now. In table 4.1 is indicated those applications, for which a trend analysis is assumed to be relevant. Whether a trend analysis is relevant in each case depends on the time perspectives. Trend analysis is generally relevant, if it is necessary to look more than 5 years ahead. In the guideline on *Geographical, technological and temporal delimitation in LCA* suggestions are made as to how such a trend analysis/technology forecasting is undertaken. Trend analysis/technology forecasting is relevant for all LCA levels.

Impact categories
It is in principle the responsibility of the decision-maker to determine the impact categories, which should be used in the study. If the LCA in question is generally carried out in accordance with the EDIP methodology, it is recommended to accept the impact categories, which are used in this methodology.

The decision-maker, however, also has a responsibility to ensure that all significant environmental impacts are covered by the LCA in question. According to ISO standard 14042 [DS/EN ISO 14042, 2000] the impacts considered should together give a adequate picture of the total environmental load from the product or the system. This means that in case important impacts exists - e.g. noise or land use - which are not covered by the EDIP methodology, then these impacts should also be considered in the LCA in question, at least qualitatively. Land use may thus be relevant to consider for products which contains significant quantities of materials originating from forestry or agriculture.

It is emphasized that by the interpretation of results it may be allowed not to include a few impact categories, assuming that the results of these impact categories are deemed unreliable due to uncertain or missing data. It is, however, important that this is clearly stated.

Spatial characterisation
Spatial characterisation and its application are described in section 3.4. Spatial characterisation is a methodology element that in reality is only relevant to *detailed LCA.*

Normalisation and weighting
Normalisation and weighting are methodology elements, which normally are only used in *detailed LCA.* As stated in section 3.4 it is possible to choose between different sets of normalisation and weighting factors. The option should in practice be determined by the geographical location of those manufacturing processes, which are considered in the LCA in question.

It is emphasized that the decision-maker is free to develop and choose his own weighting factors. It is e.g. obvious that a county or region may recommend that the local companies are using special weighting factors for waste directed to landfilling or for eutrophication and other impact categories for which the county/region as environmental authority based on local conditions deems that special consideration is necessary. Lack of appropriate areas for landfills may e.g. be an argument for recommending specially high weighting factors for waste to be landfilled. Companies producing to a specific market may e.g. choose to assign high weight to the priorities among the customers in this market.

Sensitivity analysis and uncertainty assessment
Whether sensitivity analysis and uncertainty assessment shall be undertaken in the LCA is in reality the choice of the decision-maker. Sensitivity analysis should, however, be considered an integrated part of the data collection, and it should be designated as common sense always to include an uncertainty assessment as the basis of an evaluation of the reliability of the conclusions. This assessment may be based either on scenarios, in which important assumptions are changed, or on a real calculation of uncertainties. It is required by the ISO standards that these assessments are carried out (reference is made to e.g. ISO Standard 14043 [DS/EN ISO 14043, 2000]).

It can be expected that sensitivity analysis and uncertainty assessment will be integrated in the LCA computer programmes - at least in GaBi - which will be approved by the Danish LCA Center within the coming years (see section 2.4). It should therefore be possible and relatively simple to undertake sensitivity analysis and uncertainty assessment in *detailed LCA.*

Also related to life-cycle thinking and simplified LCA uncertainties should naturally be considered. However, no methodologies for doing this has so far been developed, and sensitivity analysis and uncertainty assessment in this context will to a significant extent have to be characterised as estimates.

Quality control/critical review
Quality control is in LCA known as *critical review*. This process is used to ensure that all delimitations, preconditions, assumptions, calculations and assessments are relevant and reliable.

It is the choice of the decision-maker to determine, whether a critical review should be carried out and in what way. The Danish EPA has issued a manual on critical review [Caspersen & Wenzel 2002]. As stated in this manual one may distinguish between:

- Critical review undertaken by an internal expert
- Critical review undertaken by an external expert
- Critical review undertaken by a panel of stakeholders.

The type of critical review to be used in an LCA will depend on the application and the consequences of this LCA. To use a panel of stakeholders is relevant to LCAs, which compare different products or services with each other and is published. In table 4.1 is assessed, when it otherwise will be relevant to use independent external persons for critical review.

When an LCA is being planned, it is important to allocate financial resources for critical review and decide, how this review should be undertaken. For LCAs that are published and could be of interest in the public debate, it should be assumed, that the selection of persons for the task may influence the general accept of the result.

ISO standards
It is the choice of the decision-maker, whether the LCA should fulfil the ISO standards. These standards are an offer and not a demand. However, the standards will beyond doubt have significance regarding the power of penetration of an LCA, i.e. that an LCA that fulfils the standard will be respected higher than an LCA that does not. Thus, this is a matter of the use of the LCA and the attitude of the decision-maker towards standards.

Generally can be assumed that *detailed LCA* following the EDIP methodology will fulfil the ISO standards, while *simplified LCA* and *life-cycle thinking* will not fulfil the standards.

In the cases, in which the decision-maker in his report chooses to state that the LCA fulfils the ISO standards, this statement should naturally be checked by the critical review.

Documentation and reporting
It is the responsibility of the decision-maker to determine the extent of documentation and reporting to be carried out.

Documentation and reporting is in particular relevant to LCAs that will be published and used externally. In this context it is a must that the choices made in the LCA and the conclusions made can be documented and justified. The elements that shall be documented concern the LCA methodology, system boundaries, data utilised, other preconditions, sensitivity and uncertainty assessments, interpretation and similar matters. Only LCAs that are documented can expect to be respected.

Documentation and reporting is, however, certainly also relevant to LCAs, which are only going to be used internally. In this case the need for documentation is linked to the need of being able to analyse the background for conclusions obtained and furthermore to be able to control, adjust and improve the LCA at a later stage.

A general requirement to documentation is that it must be open and transparent. This may however raise conflicts with respect to confidential information. An acceptable solution of this problem is normally that the persons responsible for *the critical review*, will also have access to the confidential information and thereby can confirm that this information is used in an acceptable and responsible way.

ISO Standard 14040 [DS/EN ISO 14040, 1997] also contains requirements on documentation and reporting.

Table 4.1
In table 4.1 some central elements in LCA are listed, and it is stated when they may relevant to use. It is emphasized that the table only lists elements where a choice exists that somehow is related to the field of application. Methodology elements not listed in the table, like

- system boundaries and allocation
- data requirements and data collection
- impact categories
- normalisation and weighting
- sensitivity analysis and uncertainty assessment
- ISO standards
- documentation/reporting.

may be relevant to all fields of application and that the choice of whether they should be applied, therefore, depends more on the actual task than on the field of application. Reference is made to section 4.2.

Related to table 4.1 please note the following comments:

General knowledge development by companies addresses the need of being prepared, e.g. for sudden demands of documented information on environmental issues from key customers. *General knowledge development* is, however, also important to companies that generally are integrating environmental issues in their planning. Even if g*eneral knowledge development* may be based on *simplified LCA*, *detailed LCA* will typically be more appropriate.

Strategic environmental assessment deals with the issue of assessing the company's choice of materials and products in the light of rather long-term trends in the market, e.g. supply reliability, productivity improvements, legislation initiatives and environmental trends in general. This is typically an internal activity in companies.

Concerning *marketing* and *environmental product declarations*, spatial characterisation has for ethical reasons (reference is made to section 3.4) not been listed as a relevant option.

As to *ecolabels*, the ecolabel criteria are often based on detailed LCA of generalized products, and these LCAs are normally subject to external hearing among professional and industrial bodies, which in this context should be assumed to correspond to external *critical review*.

Both for *social action plans* and for *environmentally-economic analyses* - especially cost-benefit analyses - it can be relevant with a detailed assessment of the environmental impacts. Reliable assessments of this type must necessarily consider the local conditions and thus imply *spatial characterisation*.

Table 4.1 Central elements in LCA and when to use them

Field of application	LCA level			Trend analysis	Spatial characteri sation	Critical review/ external
	Life-cycle thinking	Simpli fied	Detaile d			
Companies						
General development of knowledge		(X)	X	X	X	
Investments and system choices	X	X	X	X	X	(X)
Product development	X	X	X	X	X	(X)
Strategic environmental assessment	X	X	X	X	X	
Marketing - Offensive		(X)	X			X
Marketing - Defensive		X	X			(X)
Environmental product declarations		X	X			(X)
Public authorities						
Investments and system choices	(X)	X	X	X	(X)	X
Green procurement/environmental labelling	(X)	X	(X)			(X)
Societal action plans		X	X	X	(X)	X
Environmental cost assessments		X	X	X	(X)	X
Duties/incentive arrangements			X		(X)	(X)

X: Relevant; (X): Partly relevant

4.3 Start with the simple and easy

An important rule that cannot be repeated too often says:

"Start with the simple and easy"

The meaning is that it is common sense to start the LCA work as simple and easy as possible and expand it when the need for extra and more detailed information is recognised.

Start with *life-cycle thinking* and *simplified LCA* and expand it to *detailed LCA* only when it is deemed necessary.

Start with available data from literature and databases, and do not start collecting your own data until it is deemed necessary.

And - perhaps the most important message - be critical and honest with respect to what the results can be used for.

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