SimaPro 5

User manual

product ecology consultants

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Introduction into LCA methodology and practice with SimaPro 5.1

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Contents

1 Introduction into LCA with SimaPro 5

1.1 Introduction

This manual provides general information about the backgrounds of the life cycle assessment methodology, and provides practical advice on how to perform LCA studies. It can be read without having SimaPro in front of you.

Chapter 2, 3 and 4 describe the LCA methodology in general. Apart from some text boxes, these chapters make no direct reference to SimaPro. Chapter 5 describes organisational aspects of LCA, while only chapter 6 deals with the way you model life cycles in SimaPro.

Once we have introduced you to the most important concepts and terminology, we suggest you start up SimaPro and perform your first experiments. We have devoted much effort in developing clear help texts. If you want to know more, press F1 to get help on the issue you are currently dealing with. The help files are also available as Reference Manual in PDF format.

Other SimaPro manuals, such as the database manuals, can be found as PDF files on the installation CD-ROM.

1.2 Defining applications of LCA in your organisation

Life cycle assessment is a technique for assessing the environmental aspects associated with a product over its life cycle. The most important applications are:

- Analysis of the contribution of the life cycle stages to the overall environmental load, usually with the aim to prioritise improvements on products or processes.
- Comparison between products for internal or internal communications.

LCA is a relatively young technique; it became popular in the early nineties. Initially many thought that LCA would be a very good tool to support environmental claims that could directly be used in marketing. Over the years, it has become clear that this is not the best application for LCA, although it is clearly important to communicate LCA results in a careful and well-balanced way.
A recent survey on how LCA is used [Rubik and Frankl] shows that the most common reasons for the application of LCA are for internal purposes:

- Product improvement
- Support for strategic choices
- Benchmarking
- External communication

The same study also shows two different adoption patterns of LCA in companies:

- Bottom up: someone in the organisation decides to investigate the usefulness of LCA for his organisation.
- Top down: Top management decides to systematically apply LCA.

Both strategies turn out to be successful, although in both approaches some major pitfalls can lead to failure in the adoption process. The most important pitfall is the lack of a clear definition of the purpose and application of LCA.

In many companies, the marketing department is the initiator, as it would like to show environmental benefits of products, but usually the marketing department finds out that LCA results are difficult to communicate. Often others, usually the R&D or the environmental department takes over the role of initiator.

The most frequently encountered pattern in the early stages of LCA implementation is the start-up of an experimental project. The most important goal is to learn what LCA is, what one can learn from it and how reliable the results seem.
This learning attitude is very important. Learning is more important than the result of the first LCA. According to the study of Frankl and Rubik and, an interesting situation occurs if the first LCA gives strange or unexpected results. In some organisations, the result is seen as a reason to disqualify the usefulness of LCA as a tool. Other organisations use the unexpected result as a positive learning experience.

After this first study is done companies decide whether they want to continue, and adopt a more structured approach. Success factors of LCA implementation are:

- A clear description of the reason for using LCA.
- A clear definition of the way LCAs are to be communicated internally and externally.
- A reasonable budget.

In the early stages of LCA development, much focus was given to the very long, detailed and expensive studies. From our own contact with SimaPro users, we see a clear trend towards screening and simplified studies. Such shorter studies are possible after collecting data for the most commonly used materials and processes that are relevant for the company. Most commonly used materials are already included in the SimaPro LCA databases. However, if the products in your company require very special products or materials, it is possible that you will have to invest in collecting data for these processes and materials.

Building a database

The data in SimaPro are structured in such a way that you can distinguish between data that is relevant for your current LCA project only, and data that can be useful in any other (future) project. The latter type of data is not stored in projects but in libraries.

When you purchase SimaPro, you will get a number of libraries filled with all kinds of data on commonly used materials, production processes, transport, energy and disposal processes. While performing your LCA, you enter all the new data in the project and not in the library. If you need data from the library, you can make a link to that data; if you want to edit the library data, you copy it into your project and edit the copy only. If you have collected data that could be useful for other projects, you can move it to a library. In this way, you can gradually build up high quality data in your libraries, while you have all the flexibility you need in the projects.
(In the Light version, you cannot edit data in the libraries, and you cannot create a new project)

1.3 Some remarks on ISO standards for LCA

There are four ISO standards specifically designed for LCA application:
ISO 14040: Principles and framework
ISO 14041: Goal and Scope definition and inventory analysis
ISO 14042: Life Cycle Impact assessment
ISO 14043: Interpretation

It is completely up to you if you want to conform to these standards or if you want to deliberately deviate. Of course, if you deviate, you may not claim that your LCA has been made according to the international standards, and it will be more difficult to convince others of the reliability of your results.

The ISO standards are in fact defined in a quite vague language, which makes it difficult to see if an LCA has been made according to the standard. Unlike the 14000 standard, it is also not possible to get an official accreditation that states that an LCA, an LCA methodology or LCA software such as SimaPro has been made according to the standard.

During the development of SimaPro 5 we have carefully analysed the standards and made all efforts to conform to the terminology and concepts defined in the standards.

However, no software developer can claim that LCAs made with a certain software tool automatically conform to the standards. For example, ISO 14042 does not allow weighting across impact categories for public comparisons between products. However weighting is explicitly allowed for other applications, and thus SimaPro does support weighting. This means it is your responsibility to use weighting in a proper way. Similar examples can be made for issues like allocation rules, system boundaries etc.

The most important consequence of aiming to adhere to an ISO standard is the need for careful documentation of goal and scope and interpretation issues. In fact as an LCA practitioner, you have a rather wide choice of alternative ways to perform your LCA, as long as you carefully document what you do.

New in SimaPro5.1: Matrix inversion as calculation routine

In SimaPro 5.1 a major revision has been made in the way the software calculates the inventory. In previous versions, the sequential calculation routine was used. SimaPro started at the top of the tree, and determined how much of the underlying processes was needed. From each underlying process, it went to the next level etcetera.

In the new routine, the process structure is interpreted as a matrix, that is solved (very fast) with inversion techniques. This has the advantage that we can now also calculated "looped" data structures such as input output datasets and databases as the ETH-ESU energy database.

The use of "looped" datasets also required us to change the traditional tree representation. We have now added a new way to visualise process structures in the form of a network, which is a very powerful tool, also for the traditional datasets. Much attention was paid to getting an optimal layout of the network structure.

One problem with looped datasets could not be solved. If a process is in a loop, we cannot specify the relative contributions of the inputs in an impact assessment graph. This is a fundamental limitation, however the old representation is still available, as soon as the process is not in a loop.

2 Defining goal and scope

An LCA study consists of four steps:

1. Defining the goal and scope of the study.
2. Making a model of the product life cycle with all the environmental inflows and outflows. This is usually referred to as the life cycle inventory (LCI) stage.
3. Understanding the environmental relevance of all the inflows and outflows, this is referred to as the life cycle impact assessment (LCIA) phase.
4. The interpretation of the study.

The main technique used in LCA is that of modelling. In the inventory phase, a model is made of the complex technical system that is used to produce, transport use and dispose of a product. This results in a flow sheet or process tree with all the relevant processes. For each process, all the relevant inflows and the outflows are collected. The result is usually a very long list of inflows and outflows that is often difficult to interpret.
In the life cycle impact assessment phase, a completely different model is used to describe the relevance of inflows and outflows. For this, a model of an environmental mechanism is used. For example, an emission of SO2, could result in an increased acidity, increased acidity can cause changes in soils that result in dying trees, etc. By using several environmental mechanisms, the LCI result can be translated into a number of impact categories such as acidification, climate change etc.
A usually highly controversial issue is the weighting of impact categories, as this is to a large part a subjective issue.

Understanding the multidisciplinary nature of LCA

One of the complexities of LCA lies in its very multidisciplinary character. Following [Hofstetter 1998] we can distinguish three spheres that are all required in an LCA. Each sphere has very different characteristics:

- **Technosphere:** The modelling of technical systems, such as production processes, transport processes etc. Usually, uncertainties in technosphere are not greater than a factor 2, while almost all measurements are verifiable and repeatable.
- **Ecosphere:** The modelling of environmental mechanisms ("what happens with an emission?"). Uncertainties are often one to three orders of magnitude, and often verification is difficult or impossible, for example one cannot test-run climate change and repeat this several times to get good measurements.
- **Valuesphere:** Dealing with subjective choices. This includes weighting of impact categories, but as we will see, values also play an essential role when an allocation procedure or a time horizon is selected. For example, in impact assessment it is important to choose if the potential damage from heavy metals is integrated over just 100 years or eternity. Value sphere is typically in the area of social sciences. In value sphere one cannot really speak of uncertainties, as one can say a "single" truth does not exist.

As LCA practitioner, you will need to understand these different ways of thinking, in order to communicate effectively with experts in each sphere, and to manage debates about uncertainty and reliability.

2.1 The need to define goal and scope

As with all models of reality, one must understand that a model is a simplification of reality, and as with all simplifications, this means that the reality will be distorted in some way. The challenge for the LCA practitioner is thus to develop the models in such a way that the simplifications and thus distortions do not influence the result too much.

The best way to deal with this problem is to carefully define a goal and scope of the LCA study before you start. In the goal and scope, the most important (often subjective) choices are described, such as:

- The reason for executing the LCA, and the questions that need to be answered.
- A precise definition of the product, its life cycle and the function it fulfils.
- In case products are to be compared, a comparison basis is defined (functional unit).
- A description of the system boundaries.
- A description of the way allocation problems will be dealt with.
- Data and data quality requirements.
- Assumptions and limitations.
- The requirements regarding the life cycle impact assessment (LCIA) procedure, and the subsequent interpretation to be used.
- The intended audiences and the way the results will be communicated.
- If applicable, the way a peer review will be made.
- The type and format of the report required for the study.

The goal and scope definition is a guide that helps you to ensure the consistency of the LCA you perform.

The goal and scope is not to be used as a static document. During the LCA, one can make adjustments, if it appears that the initial choices are not optimal or practicable. However, such adaptations should be made consciously and carefully.

Goal and scope definition in SimaPro

In SimaPro 5, a special section is available to describe the goal and scope for each project. There are three sections:

1. Text fields, in which you can describe the different aspects required for a goal and scope definition. The texts entered here can later be copied and pasted into your report.
2. A libraries section. Here you can predefine which libraries with standard data you consider appropriate for the project you want to run. For example, if your LCA is to be relevant for Europe, you can switch of the US Franklin database that is supplied with some versions of SimaPro. By switching this library off, you will not see the data while you are running the project. This avoids accidental inclusion of data you do not want.
3. A data quality section. Here you can define the data characteristics you want. After defining your profile, you will see that the DQI field in the process indexes will have different colours: Green means that a process matches exactly with your requirements, yellow means there is a small mismatch, orange means there is a considerable mismatch, while red indicates there are big deviations.

With these three sections, you have a guide in making a consistent LCA study.

2.2 Defining the goal

It is obvious an LCA should have goal. However, in ISO there are some particular requirements as to the goal definition:

- The application and intended audiences shall be described unambiguously. This is important, as a study that aims to provide data that is applied internally can be quite differently structured than a study that aims at making public comparisons between two products. For example, in the latter case, ISO states weighting may not be used in impact assessment and a peer review procedure is necessary. It is also important to communicate with interested parties during the execution of the study.
- The reasons for carrying out the study should be clearly described. Is the commissioner or practitioner trying to prove something, is the commissioner intending to provide information only, etc.

Some LCA studies serve more than one purpose. The results may both be used internally and externally. In that case, the consequences of such double use should be clearly described. For example, it could be that different impact assessment methods are used for the internal or external versions of the study.

2.3 Defining the Scope

The scope of the study describes the most important methodological choices, assumptions and limitations, as described below. As LCA is an iterative procedure, the term initial is added to most of the paragraphs below. This means one starts with initial system boundaries and initial data quality requirements that can be adapted later if more information becomes available.

2.3.1 Function, functional unit and reference flow

A particularly important issue in product comparisons is the functional unit or comparison basis. In many cases, one cannot simply compare product A and B, as they may have different performance characteristics. For example, a milk carton can be used only once, while a returnable milk bottle can be used ten or more times. If the purpose of the LCA is to compare milk-packaging systems, one cannot compare one milk carton with one bottle. A much better approach is to compare two ways of packaging and delivering 1000 litres of milk. In that case one would compare 1000 milk cartons with about 100 bottles and 900 washings (assuming 9 return trips for each bottle).

Defining a functional unit can be quite difficult, as the performance of products is not always easy to describe. For example, what is the function of an ice cream, a car sharing system, or a holiday?

2.3.2 Initial system boundaries

Product systems tend to be interrelated in a very complex way. For example, in an LCA on milk cartons, trucks are used. However, trucks are also products with a life cycle. To produce a truck steel is needed, to produce steel, coal is needed, to produce coal, trucks are needed etc. It is clear that one cannot trace all inputs and outputs to a product systems, and that one has to define boundaries around the system. It is also clear that by excluding certain parts as they are outside the system boundaries, the results can be distorted.

It is helpful to draw a diagram of the system and to identify the boundaries in this diagram. Important choices in this area are:

- Will the production and disposal of capital goods (trucks, injection moulding machines etc) be included? As in energy analysis, one can distinguish three orders:
  1. First order: only the production of materials and transport are included (this is rarely used in LCA).
  2. Second order: All processes during the life cycle are included, but the capital goods are left out.
  3. Third order: Now the capital goods are included. Usually the capital goods are only modelled in a first order mode, so only the production of the materials needed to produce the capital goods are included.
- What is the boundary with nature? For example, in an LCA on paper it is important to decide if the growing of a tree is included. If it is, one can include the CO2 uptake and the land use effect. In agricultural systems, it is important to decide if agricultural areas are seen as a part of nature or as a production system (technosphere). If this is seen as nature, all pesticides that are applied is to be seen as an emission. If agricultural areas are seen as an economic system, one can exclude the pesticides that remain in the area, and only include the pesticides that leach out, evaporate or that are accidentally sprayed outside the field.

Some suggestions for default system boundaries

In most LCA's capital goods are not included, and for most LCAs this can give satisfactory results. In some cases however this will give important distortions. For example in an LCA including a significant amount of hydro power, leaving out capital goods would mean that all the infrastructure, like dams, pipes etc. are omitted, and in fact there would be nothing left to model. An important example is the ETH database on energy systems. According to this report, the contribution of capital goods in the average generation of electricity is about 30%; thus leaving out capital goods gives a relatively important distortion.
In addition, for agricultural systems, capital goods turn out to be quite significant. For most LCAs of agricultural systems the boundary with nature is set to include the agricultural area within the economic system.

2.3.3 Criteria for inclusion of inputs and outputs

Apart from the criteria for system boundaries, one can also use a certain threshold below which you consider it useless to collect data for an inflow or an outflow.
ISO recommends using one or more of the following bases for such a threshold:

- If the mass of the inflow is lower than a certain percentage. The problem is of course that this only works for materials and not for transport distances and energy.
- If the economic value of an inflow is lower than a certain percentage of the total value of the product system. The problem with this and the previous approach is that flows with a low value or low mass could have significant environmental impacts.
- If the contribution from an inflow to the environmental load is below a certain percentage. This seems the most relevant choice, but the problem is that one cannot really know the environmental contribution before the flow is investigated. Once it is investigated, one may wonder why it should not be used. Another problem is the use of the term the environmental load. In many LCAs single scores are not used. In that case, one must determine the contribution of a flow against all relevant data and impact categories which can be quite complex procedure.

Recently the use on input output tables has been suggested as a viable way to estimate the "missing" environmental load. The principle behind such tables is explained in section 2.5. Such tables provide environmental load per unit of costs, so if one knows the costs associated flow (option 2), an estimate the environmental load can be made, as in option 3.

Using thresholds in SimaPro

The effect of using cut-of criteria can be analysed in the improved process tree screen in SimaPro 5. In many LCAs process trees become very large. LCAs with over 10000 processes are no exception. These process trees contain many processes that are not contributing very much. This can be illustrated by setting the cut-off threshold for displaying processes in the process tree at 0.1 % of the environmental load (for a single score or an impact category). In most cases, only 10 to 30 processes turn out to have a contribution that is above this threshold. Now it becomes much easier to see the relevant issues in the process tree.

A similar function can be found in the contribution analysis. This function gives you the relative contribution per process in a list of processes. A process that is used more than once may have a small contribution in each instance, but the total contribution of all instances can still be significant. Contribution analysis shows this total contribution.

The SimaPro 5.1 database now also contains input output data, that can be used to estimate "missing" impacts

2.3.4 Data Quality Requirements

It is important to determine in advance what type of data you are looking for. In some studies you would like to get an average of all steel producers in the whole world. In other studies you would like to have only data from a single steel producer or from a group of Electro steel producers in Germany. Likewise, you should determine if you want data on average, modern, or worst case technology.
Other Data Quality issues are completeness, consistency and reproducibility.

Data Quality in SimaPro

In SimaPro you can define a profile of the data you would like to get. In that profile, you can define your preference for:

- Time of data collection
- Region
- Representatively and type of technology
- Allocation
- System boundaries

In the libraries with data supplied with SimaPro, these characteristics are also set for each process. SimaPro automatically compares the profile in each process with the profile you have set. A colour-coded Data Quality Indicator (DQI) indicates to which extend a process fulfils your requirements.
Allocation and system boundaries are not mentioned as data quality aspects in ISO, still we believe it is very important you use data that adheres to your preferences.

2.3.5 Allocation

Many processes usually perform more than one function or output. The environmental load of that process needs to be allocated over the different functions and outputs. There are different ways to make such an allocation. ISO recommends the following procedure in order to deal with allocation issues:

- Avoid allocation, by splitting the process in such a way that it can be described as two separate processes that each has a single output. Often this is not possible, for example wooden planks and saw dust are both an economic outputs of a sawmill, but one cannot split the sawing process into a part that is responsible for the saw dust and the planks.
- Another way to avoid allocation is to extend the system boundaries, and by including processes that would be needed to make a similar output. For example, if a usable quantity of steam, produced as a by-product, is used in such a way that it avoids the production of steam by more conventional means, one may subtract the environmental load of the avoided steam production. A practical problem is often that it is not always easy to say how the steam would be produced alternatively.
- If it is not possible to avoid allocation in either way, the ISO standard suggests allocating the environmental load based on a physical causality, such as mass or energy content of the outputs. For example if the sawdust represents 40% of the mass, one can allocate 40% of the environmental load to sawdust. In the case of allocating steam, we believe the mass of the steam is not a very relevant basis.

If this procedure cannot be applied, ISO suggests using an socio-economic allocation basis, such as the economic value. For example if the saw dust represents 20% of the value generated by the sawmill one can allocate 20% of the environmental load to this output.

Although ISO mentions the socio-economic basis as a last resort, it is used very often. The advantage is that economic value is a good way to distinguish waste (no or negative value) from an output, and it expresses the relative importance of an output.

Allocation in SimaPro

In SimaPro each process can have multiple outputs and avoided outputs at the same time. This means you can combine system boundary expansion and direct allocation in any way you like. Behind each multiple output, you can add a percentage that indicates the allocation share. It is up to you to decide on which principle you base this allocation percentage.

2.4 Inventory

The real hard work in any LCA is the data collection and data treatment itself. There are a number of data sources (see also chapter 5):

- The data supplied in commercial databases.
- Data supplied by industry sectors, such as the European Plastic Manufacturers, the Aluminium and Steel industries etc.
- Data supplied by universities and other researches, such as the ESU database on energy systems in Switzerland.
- National database project as they develop in several countries.
- Literature data in general; especially data that describe processes, such as the Ullmans Encyclopaedia of Industrial Chemistry.
- Specialised Internet sites, such as **www.spold.org** and **www.globalspine.com**. These sites are a market place for LCA data.

In many cases however, you will have to find specific data from your own or other companies. Most frequently one or more questionnaires are to be made to collect such data. It is very important to establish good contacts with the persons that are supposed to fill in the questionnaire. It is important to understand what this person knows, in what way data is available and what terminology is used by this person.

Data collection through the SimaPro Internet User Group

SimaPro users can participate in the SimaPro Internet User Group. With this group, you reach hundreds of SimaPro users all over the world. Many users have already satisfied their data needs by posting a question in that group. The benefit of this group is that you can share LCA data in the SimaPro format, which means you do not loose data due to conversion problems to other formats.

2.5 Input output databases

From version 5.1 and onwards SimaPro contains input output databases. These databases are different form the normal "process databases" as they contain data per economic sector. For instance there is data on the agricultural sector, or on the banking sector, the transport and the consultancy sector. The benefit of this approach is that you can have a complete dataset for an entire economy. The disadvantage is that the information is not very specific. For instance, you cannot compare two building materials if they both come from the same building materials sector.

2.5.1 The concept of an Input output table

Each national or regional economy can be described as a table in which the supplies between sectors, as well as the supply to consumers and supplies to export are registered in financial terms. In the figure below such a table is made as if there are just three different sectors: agriculture, industry and services. The role of governments has also been omitted. In practice the number of sector ranges from about 100 to 500. The supplies are noted in the rows.

A supply from one sector to the others is of course the same as the purchasing, so if you read the table in rows, you will get the purchases of the sector. Of course the sectors also import, and usually the assumption is that the imported goods and services come from a same division of sectors, so also here we assumed that the countries we import from have the same three sectors.

If we add up the supplies, we get the total value generated by the sector in the right/hand column. We can also add the total value of all purchases, and put them at the bottom row. The difference between total value and total purchases is the added value of the sector. This is not the same as profit, as the sector will have to pay its wages, costs of loans etc.. The added value is however an important measure for our purpose

	Agriculture	Industry	Services	Exports	Consumers	Total
Agriculture	Trade within the sector	Agriculture supplies to industry	Agriculture supplies to services	Agriculture supplies to exports	Argiculture supplies to consumers	Total value
Industry	Industry supplies to agriculture	Trade within the sector	industry supplies to services	Industry supplies to exports	Industry supplies to consumers	Total value
Services	Service supplies to agriculture	Service supplies to industry	Trade within the sector	Services supplies to exports	Services supplies to consumers	Total value
Agricultural imports	Imports of agricultural goods	Imports of agricultural goods	Imports of agricultural goods			
Industrial imports	Imports of industrial goods	Imports of industrial goods	Imports of industrial goods			
Imports of services	Imports of services	Imports of services	Imports of services			
total	Total costs	Total costs	Total costs			

Figure 1
Schematic representation of the core of an input output table for just three economical sectors.
The first three rows represents the supplies to different other sectors, to consumers and exports.
The second three rows specify the imports.

2.5.2 Adding environmental load

It is possible to collect environmental data per economic sector from statistical sources. Many researchers have done this for the most important industrial countries although this data are not always very complete. Form the explanation above, it may become clear that having data from the sector alone is not enough; one needs to trace the environmental load that comes with the delivered between the sectors. In order to do so, all environmental data is divided by the added value of the sector, and the input output table is used to trace the supplies. In principle this allows us to trace all environmental load throughout the whole economy. There are no system boundary problems everything is 'in' and all allocations are done based on economic value. A big problem is however, what to do with the imports. There are two solutions:

1. Assume the environmental load per value from foreign products is equal to the domestic products. This may hold well for imports from industrialised countries, but is a bad assumption for imports from non-OECD countries. However, this is done most often
2. Develop IO tables for the international regions, and model the links between these regions.

In general we can say that the first solution works quite well in large economies, such as the USA that have a high domestic production compared to the trade. For small economies with large trade volumes like the Dutch this approach does not work well.

2.5.3 Using Input output tables in your LCA

One of the consequences of using IO tables, is that you no longer use mass or energy as inputs, but value. You will need to trace the price excl. tax for components, material or services. The IO tables are especially suited for the following purposes:

- As estimated data for decisions on cut/off
- To make screening LCA´s
- To include difficult to get data on for instance services. For instance, you may want to add the average impact of retailing, or promotion to the life cycle of the product. If you know how much is spend on these services, it is easy to include these.

Input output databases in SimaPro

SimaPro 5.1 now contains a set of four interlinked input output tables. The Dutch IO table (105 sectors) has been linked to three international tables: OECD countries in Europe, other OECD countries and non/OECD countries (each 30 sectors). Although this dataset is valid for the Netherlands, it can be used for quick assessments and for estimating "missing data".

3 Interpretation

3.1 Uncertainty

All data in life cycle models have some uncertainty. One can distinguish three main types:
1. Data uncertainties
2. Uncertainties on the correctness (representatively) of the model
3. Uncertainties caused by incompleteness of the model

In theory, data uncertainties are relatively easy to handle, as such uncertainties can be expressed as a range or standard deviation. Statistical methods, such as Monte Carlo techniques can be used to handle these types of uncertainties. A practical problem is however, that very few LCA databases give information about uncertainty ranges or standard deviations. A good reason may be the presence of two other uncertainty types that cannot be expressed adequately with an uncertainty range.

Uncertainty on the correctness of the model refers to the fact that there is not one way to make a model of reality. In each LCA, one will have to make more or less subjective choices in order to make a model. Some examples are:

- Representatively. Very often, we have to use data on processes that are coming from other sources. For example, we find data of growing cotton in Pakistan, but we need data for growing cotton from India. With this, we cause an error, but it is difficult to assess how big it is.
- Allocation basis; there is no single way to choose an allocation basis.
- Future events. Many LCAs deal with products that have a long lifetime. This means these products will be disposed of in a few decades. No one really knows how waste treatment is organised by that time.
- Choice of functional unit. It is often not clear on which basis we compare products.

All these factors have can have very significant impacts on the results. The only way to deal with them is in the sensitivity analysis, see below.

Uncertainty caused by incompleteness refers to the unavoidable data gaps. Important issues are:

- System boundaries, as we have discussed above it is not easy to apply consistent boundaries and cut of criteria.
- Incomplete data sheets and insufficiently specified data. In many cases, data is gathered from interviews and through questionnaires, and often data will be partially available. A particular problem is that often data is gathered in sum parameters, like BOD and PAH. In the next stage, the Impact assessment it is very difficult to interpret such sum parameters if one does not know which substances are involved.
- Mismatch between inventory and impact assessment. In many cases, inventory data that is collected does not have a characterisation factor, and therefore this finding is ignored in the rest of the LCA.

Especially because of the last two types of uncertainties, it is very difficult to apply a uniform system to deal with uncertainties in LCA. The best solution is to combine Monte Carlo analysis for data uncertainties with sensitivity analysis for model uncertainties.

3.2 Sensitivity analysis

In order to see the influence of the most important assumptions, it is strongly recommended to perform a sensitivity analysis during and at the end of the LCA. The principle is simple. Change the assumption and recalculate the LCA. With this type of analysis you will get a better understanding of the magnitude of the effect of the assumptions you make. You will find that the outcome of the LCA can be quite heavily depended on some of the assumptions. This does not need to be a problem as long as the conclusions of your LCA are stable. However, if you find that under one assumption product A has a higher load than B, and under a different assumption product B has a higher load, you carefully need to explain under which assumptions your conclusions are valid. You may also conclude that there is no single answer, as everything depends on the assumptions.

Sensitivity analysis in SimaPro

Finding the most important assumptions is typically something that can only be done by experts; computers cannot have the intuition humans have. However, computers can play an important role by allowing humans to recalculate results under different assumptions. The best way is to make copies of some of the data and to make the different assumptions in the copies.

3.3 Contribution analysis

An important tool in understanding the uncertainty of your result is the use of the contribution analysis. With such analysis, you determine which processes are playing a significant role in your results. We have often found that in an LCA containing hundreds of different processes 95 or even 99% of the results is determined by just ten processes. With the information you can focus your attention on these processes, and analyse if these processes are sufficiently representative, complete and if their are important assumptions within these processes.

Contribution analysis in SimaPro

SimaPro has two ways of finding the contribution from a process:
1. In the graphical representation of the process tree
2. the contribution analysis section of the result screen

In the process tree, a small thermometer indicates the relative contribution of the process. The advantage of this approach is that you can exactly see what the role of the process in the life cycle is. A disadvantage is that some processes can occur many times in an LCA. For example, the process record Electricity Europe will occur many times in a European LCA. It could well be that in each of these occurrences the contribution of this process is just a few percent, but that the total contribution from this process is very significant if the process occurs 10 or more times. For that reason, we have developed the Contribution analysis result. Here all contributions from a single process are added. Therefore, in contribution analysis you can see the total contribution of European electricity.

3.4 Gravity analysis

Contribution analysis shows which processes create high environmental load. However this does not reveal the cause of the load. For instance if process A uses a large amount of coal based electricity, contribution analysis will show that coal electricity is important, but in fact, it is process A that causes coal to be used. In Gravity analysis we can look at the interrelations between the processes and show which processes are in fact responsible for the load, while these processes in themselves may have low emissions.

Gravity analysis in SimaPro

Gravity analysis is used in the Network representation of the processes (see chapter 6). In this presentation each process is only shown once, and we can see how the environmental load is propagated through the network.
In small networks the gravity analysis is carried out directly; in larger network you must activate this function with a button. After the analysis is complete, you can analyse the network structure

The gravity analysis takes some time, as the procedure requires the following steps:

- Initially the flows between the processes is calculated, using matrix inversion
- Then each process is changed a little bit (the output is changed), and the calculation is repeated
- This results in slightly different outcomes for all processes; the relative influences are stored
- When all processes have been treated this way, it is clear how each process contributes to the total environmental load

3.5 The LCI results

The result of the inventory phase is referred to as the LCI results. It is a list of emissions and raw materials with an amount. In many cases, the list covers a few hundreds of substances, which make the LCI result very difficult to interpret. However, the benefit is that the result is very detailed, and it is not affected by the uncertainties introduced in impact assessment.
We believe, and ISO underlines this, that it is always useful to apply impact assessment procedures in order to better understand the significance of each LCI result.

LCI result in SimaPro

In the LCI, result tables there are several functions that let you help to understand the significance of each LCI result. For example you can generate a sorted table where you see the substances that contribute to the impact category "Climate change" you can also see how much each LCI result contributes.

4 Impact assessment

4.1 Introduction

Most LCA experts do not develop impact assessment methodologies, they prefer to select one that has been published. In this manual we will not explain how to develop an impact assessment method, but how to select one, and if the method allows, how to refine one.

Like in the inventory stage, also in impact assessment the Goal and Scope definition is the most important source of guidance for the selection of the method and the impact categories.

The most important choice you make is the desired aggregation level of the results. This usually depends on the way you would like to address your audience, and the ability of your audience to understand detailed results. Figure 2 presents a schematic overview of some of the possibilities.

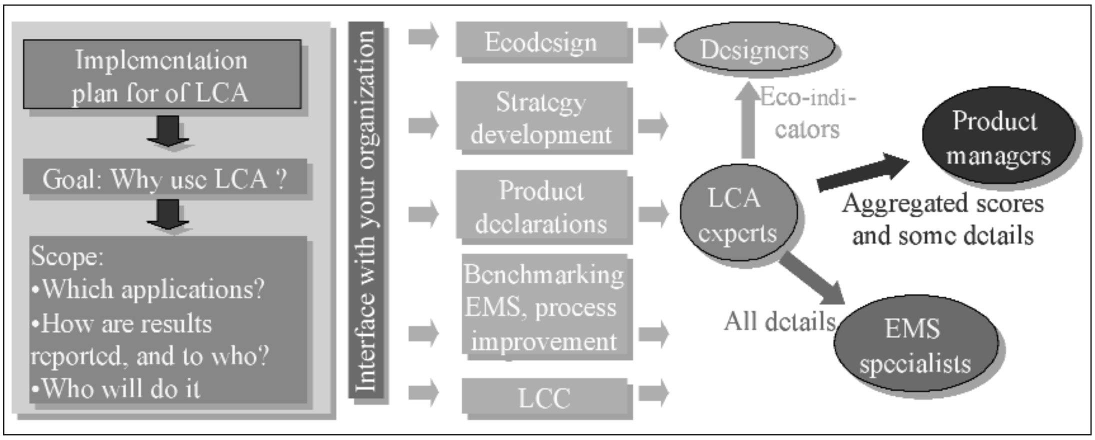


Figure 2
The choice of the impact assessment method depends largely on the addressed audience.

4.2 ISO on impact assessment methods

In the ISO 14040 standard defines an LCA as a compilation and evaluation of the inputs and outputs and the potential environmental impacts of a product system through its life cycle. In this definition, it is clear that impact assessment is an integral part of LCA.
Life cycle impact assessment is defined as the phase in the LCA aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a product system.

The impact assessment methods themselves are described in ISO 14042. In this standard a distinction is made between:
- Obligatory elements, such as classification and characterisation
- Optional elements, such as normalisation, ranking, grouping and weighting

This means that according to ISO, every LCA must at least include classification and characterisation. If such procedures are not applied, one may only refer to the study as a life cycle inventory (LCI)
An important distinction is made between internal and external applications. If results are intended to compare (competing) products and they are to be presented to the public, weighting may not be used.

In the ISO 14042 document a large range of issues are mentioned that need to be decided and described. The figures in this paragraph illustrate the procedure that is designed in this standard. The illustrations are taken from a draft ISO14047 document that is intended to illustrate the interpretation of ISO 14042.

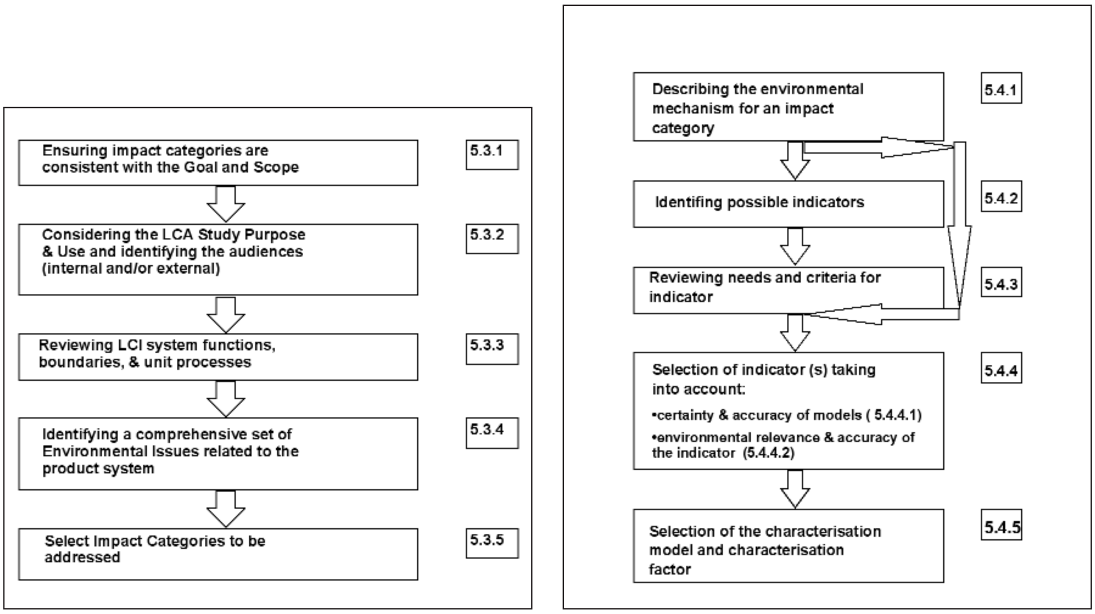


Figure 3
Schematic diagram illustrating the most important steps in the
ISO 14042 standard for the obligatory elements Classification and Characterization.
The numbers refer to the paragraphs in the standard.

4.3 Selection of methods and impact categories

An important step is the selection of the appropriate impact categories.
The choice is guided by the goal of the study. This can be illustrated by some examples:
In an LCA comparing transport by truck and by rail, the following environmental issues are relevant:

- Land use needed for the road and rail surfaces.
- Small particulates (below PM10) from diesel engines and tyres.
- Noise.
- Impact categories that reflect the impacts of the use of fossil fuel for electricity generation, industrial furnaces and diesel engines. These should at least include:
  - Climate change.
  - Acidification, eutrophication.
  - Other toxic effects on humans and ecosystems, including ozone formation, which are included in existing impact categories.
  - Depletion of fossil fuels and minerals (e.g. zinc, aluminium, copper (power supply of trains.)

Other impacts or impact categories can be included, but seem less essential. It requires some expert judgement to make such a list, and to understand which impact categories should be defined to cover all these issues.

Dealing with incomplete impact assessment methods

ISO is very clear on the requirement that it is not allowed to leave out possibly important issues. For example, issues like land- use, fine particle matter and noise may not be omitted in this case. This important requirement can be used to eliminate a number of standard impact assessment methods that do not include such issues:

CML 92	does not include noise, land use and has weak models for fine particle matter
Eco-indicator 95	does not include land use, noise and fossil fuel depletion
Eco-indicator 99	does not include noise
EPS 2000	Includes all, but sometimes in a course manner

This example shows us that so far only EPS 2000 includes noise as an impact category, although the way it is implemented is rather course. A recent publication of [Müller-Wenk 1999] makes a proposal on how to include this impact category in the Eco-indicator 99 [1].

From this example (not taken from ISO) it is clear that a description of the environmental relevance of the impact categories selected is essential for each LCA you make. One should not simply take a published method without supporting this choice carefully.

[1] In some cases it is possible to combine impact categories from different sources. For example, the CML 1992 method could be extended by adding a published method on noise and land used. However in such case great care must be taken to avoid overlaps in the impact categories. Usually it is also difficult to Normalize and weight such results.

An important help in the process of selecting impact categories is the definition of so-called endpoints[2]. Endpoints are to be understood as issues of environmental concern, like human health, extinction of species, availability of resources for future generation etc. ISO does not recommend using certain endpoints, but requires a careful selection and definition of endpoints first. After that impact categories can be selected, as long as the environmental model that links the impact category to the endpoint is clearly described. It is not necessary to describe this link quantitatively.

[2] It is not easy to distinguish between impact categories and endpoints. For example, some would say seawater rise is an impact category, while others would call it an endpoint.

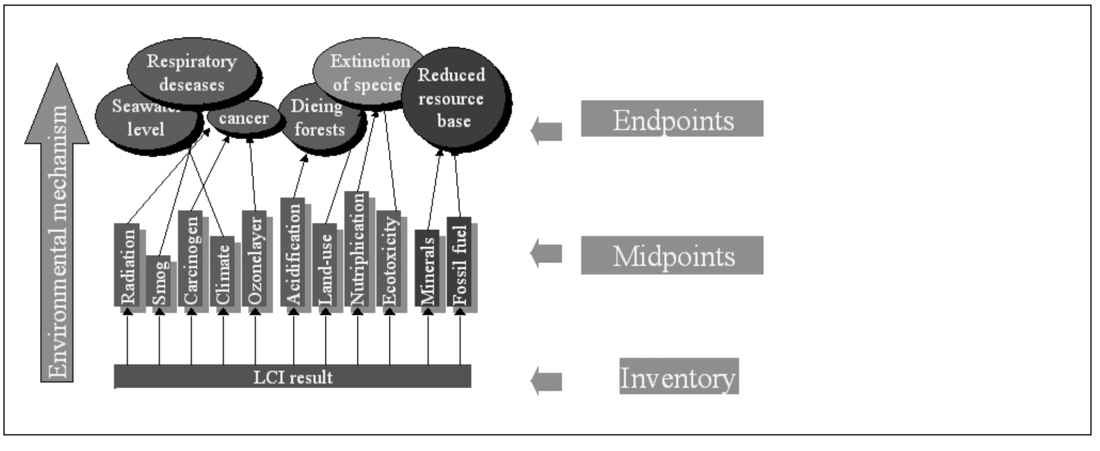


Figure 4:
general overview of the structure of an impact assessment method.
The LCI results are characterised to produce a number of impact category indicators. According to ISO, one must document the environmental relevance of each indicator by describing the link to the endpoints. Endpoints can be selected by the practitioner, as long as the reasons for including or excluding endpoints are clearly documented.

Selecting impact categories in SimaPro

SimaPro is shipped with a large number of standard impact assessment methods. We have tried to select the most authoritative methods. Each method contains a number (usually 10 to 20) of impact categories. Most users will simply select one complete method, instead of selecting impact categories. However, SimaPro does allow you to add or delete impact categories from or to a method. We advise you not to change the method as supplied in the impact assessment library, but to copy the method to your project and make the changes there. In this way, you can always revert to the original method. SimaPro also allows you to develop completely new methods.

4.4 Classification

The inventory result of an LCA usually contains hundreds of different emissions and resource extraction parameters. Once the relevant impact categories are determined, these LCI results must be assigned to these impact categories. For example CO_2 and CH_4 are both assigned to the impact category "Global warming", while SO_2 and NH_3 are both assigned to an impact category acidification. It is possible to assign emissions to more than one impact category at the same time; for example SO_2, may also be assigned to an impact category like Human health, or Respiratory diseases.

Assignment in ISO 14042

ISO describes a procedure that can be used if a substance cannot do two things at the same time. An SO_2 molecule that is inhaled, cannot cause acidification. Usually this can be ignored, as it leads to very strange results. This can be understood when one realises that emissions cause no harm in the environment, but concentrations do. Emissions contribute to a certain concentration.

An example where such an assignment procedure is relevant can be found in the Eco-indicator 99 method, and other methods that include land use.
In the Eco-indicator method, the damage caused by agricultural practices is determined by empirical data from botanists, who have studied the bio diversity of the land. It is impossible to say if a decrease in biodiversity is caused by the use of pesticides, fertilisation or otherwise. If the impact category Land use is combined with the impact category Ecotoxicity and Eutrophication a double count can be introduced, that should preferably be avoided. (See also [Goedkoop and Spriensma 1999])

4.5 Characterisation

Once the impact categories are defined and the LCI results are assigned to these impact categories, it is necessary to define characterisation factors. These factors should reflect the relative contribution of an LCI result to the impact category indicator result.

For example, on a time scale of 100 years the contribution of 1 kg CH_4 to global warming is 42 times as high as the emission of 1 kg CO_2. This means that if the characterisation factor of CO_2 is 1, the characterisation factor of CH_4 is 42. Thus, the impact category indicator result for global warming can be calculated by multiplying the LCI result with the characterisation factor.

Endpoints and midpoints

The ISO standard allows the use of impact category indicators that are somewhere between the inventory result (i.e. emission) and the "endpoint". Indicators that are chosen between the inventory results and the "endpoints" are sometimes referred to as indicators at "midpoint level".

In general, indicators that are chosen close to the inventory result have a lower uncertainty, as only a small part of the environmental mechanism needs to be modelled, while indicators near endpoint level can have significant uncertainties. However, indicators at endpoint level are much easier to understand and interpret by decision makers than indicators at midpoint.

Examples:

The CML 92 methodology is a typical example of a midpoint method. The impact category indicators are chosen relatively close to the inventory result. For example, the impact categories for global warming and ozone layer depletion are based on the IPCC equivalency factors. The impact category on acidification is based on the number of protons H^+ that could be released per kg of emitted substance. Such impact category indicators have usually rather abstract units. For example, the unit of global warming is kg CO_2 equivalence, and the unit for acidification is kg SO_2 equivalence.

In methods like the Eco-indicator 99, the indicator for climate change is expressed in Disability Adjusted Life Years (DALY). This is a unit used by the WHO and Worldbank to evaluate health statistics. The impact category indicator for Acidification is expressed in the percentage of decreased biodiversity over an area during a certain period. These indicators are of course much more difficult to calculate, as the complete environmental model has to be taken into account, and in that model many assumptions have to be made. They are thus more uncertain. On the other hand, their meaning is easier to understand and evaluate.

There is a typical trade-off between uncertainty in the model of the environmental mechanism and the uncertainty in the interpretation. It depends on the goal and scope and the ability of the targeted audiences to understand aggregated or dis-aggregated results, which choice is made.

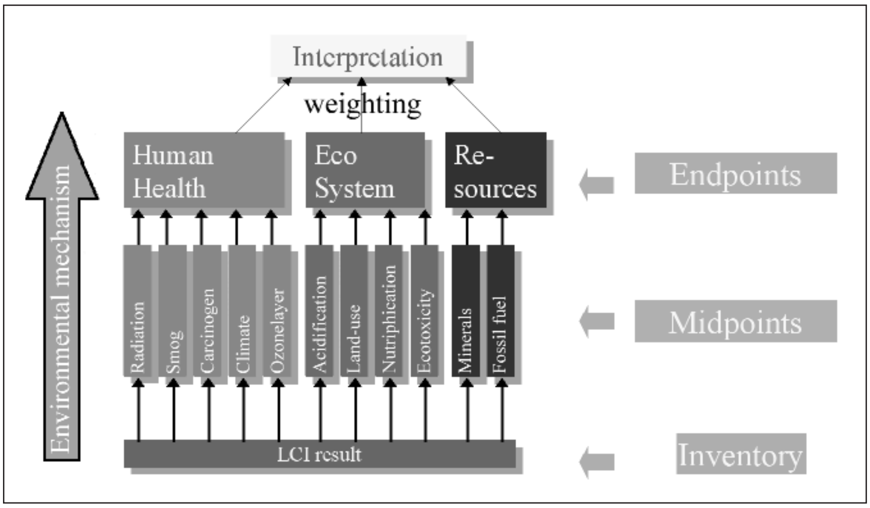


Figure 5
Schematic overview of the methodology proposed by Goedkoop & Spriensma.
The environmental models for each impact category are extended up to endpoint level, as the impact category indicators that relate to the same endpoint have a common unit, these indicators can be added. In the case of ecotoxicity, the endpoint is Ecosystem Quality, expressed as Potential Disappeared Fraction of plants

Environmental mechanisms

As an example, we will discuss an environmental mechanism of emissions that have an effect on human health, according to the Eco-indicator 99 methodology, a typical example of an endpoint method.

Fate analysis
When a chemical substance is released, it finds its way through the environmental compartments air, water and soil. Where the substance will go, and how long it will stay depends on the properties of the substance and the compartments. A well soluble substance will be collected in the water compartment, while a substance that easily binds to organic particles may end op in specific types of soil. Another aspect is the degradability, as most organic substances have a limited lifetime. In so called "fate analysis" models the transfer between compartments and the degradation of substances is modelled. Consequently, the concentrations in air, water, soil and food can be calculated.

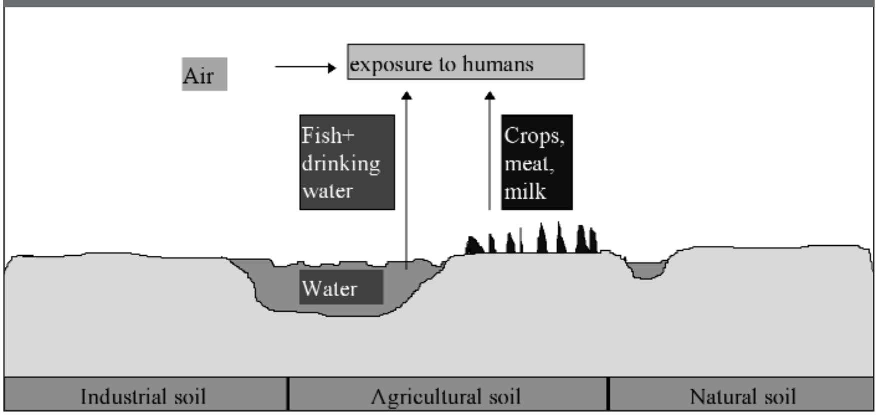


Figure 6
Schematic representation of a fate model used for toxicity.
For other substance types other fate models are used.

Exposure
Based on the calculated concentrations we can determine how much of a substance is really taken in by people and by plants or other life forms.

Effect analysis
Once the exposure of a substance is known it is possible to predict the types and frequencies of diseases and other effects.

Damage analysis
The predicted diseases can now be expressed into our damage unit. For example, if we know that a certain level of exposure causes ten extra cases of a certain type of cancer, we can find data on the average age people get this type of cancer and the average chance that people will die. Based on this data, we can calculate how many years of life are lost, and how many years are lived disabled, as people are ill and have to be treated in hospital. For the toxic effects on ecosystems we calculate what percentage of plants and lower species are exposed to toxic stress, while for acidification and eutrophication we model what percentage of plants are likely to disappear (Potentially Disappeared Fraction). Damages to higher species like birds and mammals could not be calculated, but there are good reasons to assume that the damage to plants and lower organisms is also representative for the damage to populations of higher animals.
For most substances, the damages are calculated on a European scale. For some substances, like greenhouse gasses, ozone-depleting gasses, radioactive substances with a long lifetime, the damage is calculated on a worldwide level, as these substances are dispersed worldwide.

Characterisation in SimaPro

Like in all LCA software to date, you cannot distinguish between fate, exposure and damage factors; there is simply one characterisation factor. In SimaPro, you can simply generate a list of LCI results and add a characterisation factor to it. There are several ways to check the completeness of the list.

- A Check method button will generate a table of all substances that occur in the database and an indication which substance is used in which impact category. If you do so, you will notice that there is quite a big mismatch between the list of substances in the inventory data and the availability of characterisation factors.
- During the calculations with SimaPro you can ask the software to check which substances in the current LCI result are not accounted for in the currently selected impact category. You can switch this check on or off in the Options screen.

4.6 Optional steps

As indicated normalisation, grouping and ranking are used to simplify interpretation of the result. These steps are regarded as optional steps in ISO 14042.

4.6.1 Normalisation

Normalisation is a procedure needed to show to what extent an impact category has a significant contribution to he overall environmental problem. This is done by dividing the impact category indicators by a "Normal" value. There are different ways to determine the "Normal" value. The most common procedure is to determine the impact category indicators for a region during a year, and if desired, divide this result by the number of inhabitants in that area.

Normalisation serves two purposes:

1. Impact categories that contribute only a very small amount compared to other impact categories can be left out of consideration, thus reducing the number of issues that need to be evaluated.
2. The normalised results show the order of magnitude of the environmental problems generated by the products life cycle, compared to the total environmental loads in Europe.

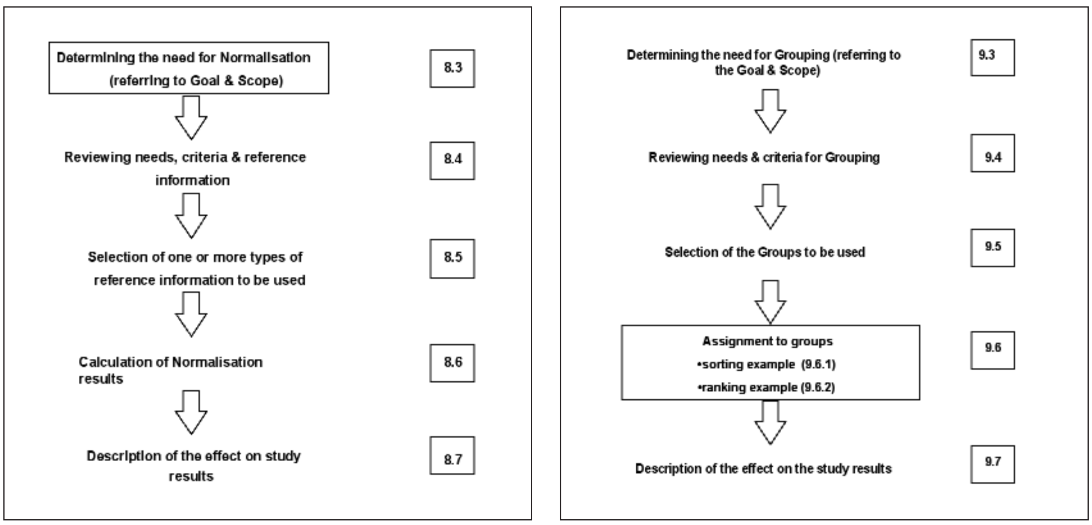


Figure 7
Schematic diagram illustrating the most important steps in the ISO 14042 standard.
The numbers refer to the paragraphs in the standard.
Here the procedure for normalisation and grouping are illustrated.

Normalisation in SimaPro

For each impact assessment methods, you can define and store a number of different normalisation (and weighting) values. This allows you to have different versions of each method, without having to maintain different sets of characterisation factors. For example, we supply a Dutch, European and a worldwide normalisation set for the CML 1992 method. You can also edit or add normalisation sets.
This allows you to check the influence of selecting normalisation set. Once a Normalisation set has been defined in the impact assessment method, you choose in each graph to use the characterised results or the Normalised results. Some impact assessment methods, such as those based on monetary evaluation do not need Normalisation. In SimaPro, you can indicate this while defining a method. The result is that it is not possible to show Normalised impact categories for such methods. As you can see also in SimaPro Normalisation is an optional step.

4.6.2 Grouping and ranking

In order to avoid weighting, while making results easier to interpret, impact category indicators may be grouped and ranked:

- Impact category indicators that have some common features may be presented as a group. For example, one can for a group of impact category indicators with Global, regional and local significance.
- Ranking refers to a procedure, where impact categories are sorted by a panel in a descending order of significance.
- Both procedures can be used to present the results.

Grouping and ranking in SimaPro

You can change the order in which the impact categories appear in graphs from within the impact assessment methods. This is an easy way to rank the results.

4.6.3 Damage assessment

The methods presented here will all still be difficult to interpret, as there is a wide range of impact category indicators. To simplify interpretation further, a grouping procedure can be used in the Eco-indicator 99 and the EPS2000-methodology. In these methods, the category indicators are defined close to one of the three endpoints to achieve an optimum environmental relevance. The impact category indicators that refer to the same endpoint are all defined in such a way that the unit of the indicator result is the same. This allows addition of the indicator results per group. This means that the indicator results can be presented as three indicators at endpoint level without any subjective weighting. Interpreting three instead of a multiple set of indicators is much easier. The figure below illustrates this procedure.

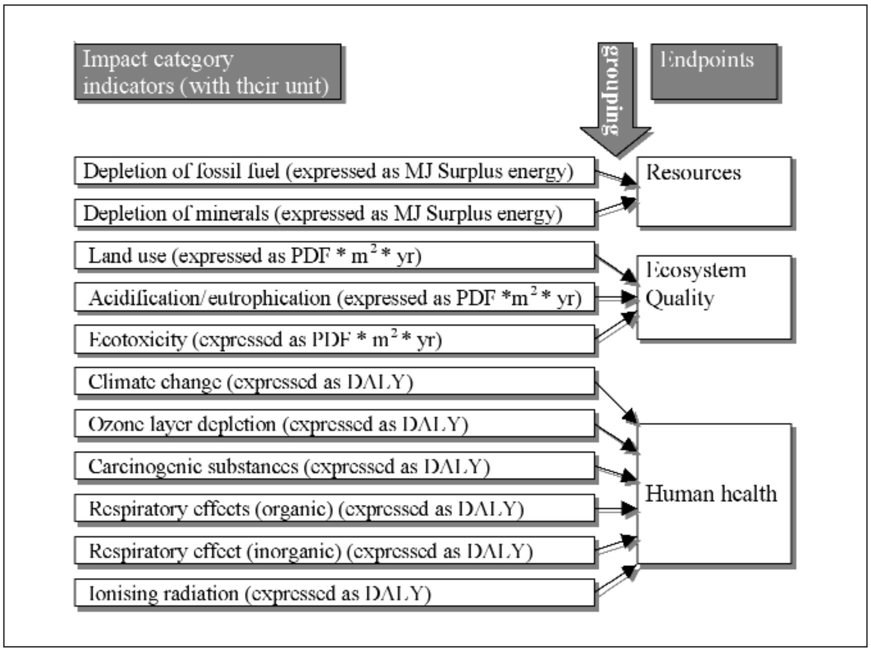


Figure 8
Illustration of the grouping option on the Eco-indicator99 method.
This procedure allows to reduce the number of impact categories to just three instead of 11 without subjective weighting

Damage assessment in SimaPro

In SimaPro 5, you can indicate if a method contains damage assessment. If you do so, you get the opportunity to define damage categories and damage factors. These are used to convert the impact categories before they are added. If a method has a damage assessment step, you can also display this step as a graph.

4.6.4 Weighting

Weighting is the most controversial and most difficult step in life cycle impact assessment, especially for midpoint methods. Two solutions have been proposed to solve or simplify the weighting problem:

1. Use a panel that assesses the impact category and proposes default weights. There are several problems in this approach:
   - It is very difficult to explain to a panel the meaning of the impact category indicators. They are too abstract ("CO2 equivalency" or "proton release"), and even if they are more concrete, like Human Health, expressed as DALY or biodiversity, different people will have a different interpretation.
   - In a Midpoint approach, the number of indicators to be assessed is usually rather large (10 to 15).
   - Panels tend to give a very small range of weights (usually between 1 to 3). This is called Framing in social sciences. This is a problem in both endpoint and midpoint methods.

2. Distance to target. If it is possible to set a target for each impact category and its target can be used to derive at a weighting factor. If the difference is high, the weight is high. The Ecopoint method uses targets set by the Swiss government, the Eco-indicator 95 method uses targets that reflect to necessary reduction to lower the damage to a certain level that is the same for all impact categories (this can also be interpreted as a damage approach). Also this approach has some difficulties:

- In the case policy targets are used, it is not clear if all targets are equally important.
- policy targets are usually formed as a compromise between interest groups, and need not to reflect the "real" need to reduce environmental impacts.
- In case scientific targets are used, different types of damages need to be weighted.

3. Monetarisation: In EPS all damages are expressed in the same monetary unit: Environmental Load Units comparable to Euros. In the methodology, the assumption is made that these different types of costs (present cost and willingness to pay and future extracting costs) can be added. This can be interpreted as a weighting step in which the weighting factors for these different types of costs equals one.

In the Eco-indicator 99 methodology, the weighting problem was the starting point of the development. Some of the problems associated with the weighting have been reduced or solved, but the weighting step will always remain difficult. An interesting approach has been developed by [Hofstetter et all 1999] using a weighting triangle. This triangle can be used to present the weighting problem on a case-by-case basis to stakeholders. It can be used to take a decision without actually knowing the weights.

Weighting in SimaPro

You can define any number of weighting sets for each impact assessment methods. If a method contains a damage assessment step, the weighting factors apply to the damage categories, if not, they apply to the impact categories. You can also exclude the weighting option from a method.

The triangle concept as alternative to fixed weights

For those users that do not want to use the default weighting factors, we recommend using the mixing triangle developed by [HOFSTETTER 1999]. This triangle (see figure 9) can be used to graphically depict the outcome of product comparisons for all possible weighting sets. Each point within the triangle represents a combination of weights that add up to a 100%.

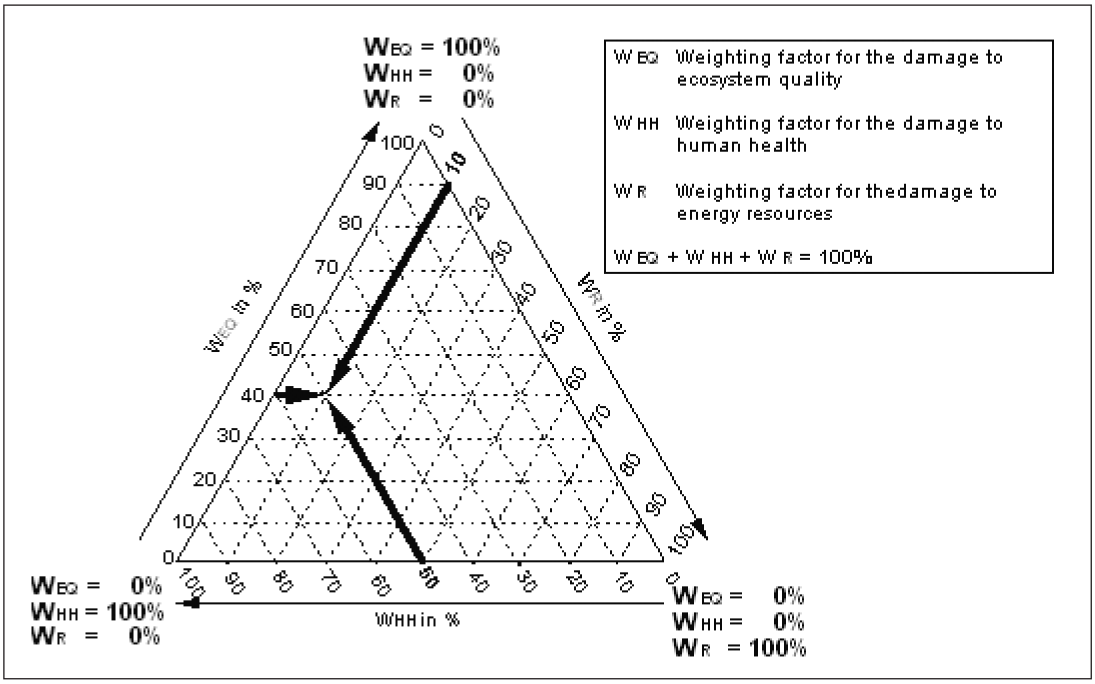


Figure 9
The mixing triangle: The marked weighting point is positioned where Human Health is weighted 50%, Ecosystem Quality 40% and energy Resources 10%.
The point is defined by following each side until the dotted flashes leave towards the point in the triangle (based on Hofstetter 1998).

An important feature is the possibility to draw lines of indifference (figure 10). These are lines representing weighting factors for which product A and B have the same environmental loads. The lines of indifference divides the triangle into areas of weighting sets for which product A is favourable to product B and vice versa. The weighting triangle can display the result of an LCA without knowing the weighting factors. According to Hofstetter, such a representation is a very useful tool to enhance the transparency of the weighting process, as it shows under which conditions (which weighting factors) product A is better than B. The stakeholders do not have to set discrete weights, but they have to agree whether it is plausible that the weights would fulfil the conditions under which A is better than B or not. Such a discussion process turns LCA into a consensus building process, instead of a tool that produces simple single truths.
Our mission is not the development of a consensus-building tool, but there is no reason not to use this methodology as such, if the conditions facilitate an open discussion with the stakeholders. More information on this subject can be found in [HOFSTETTER 1999]

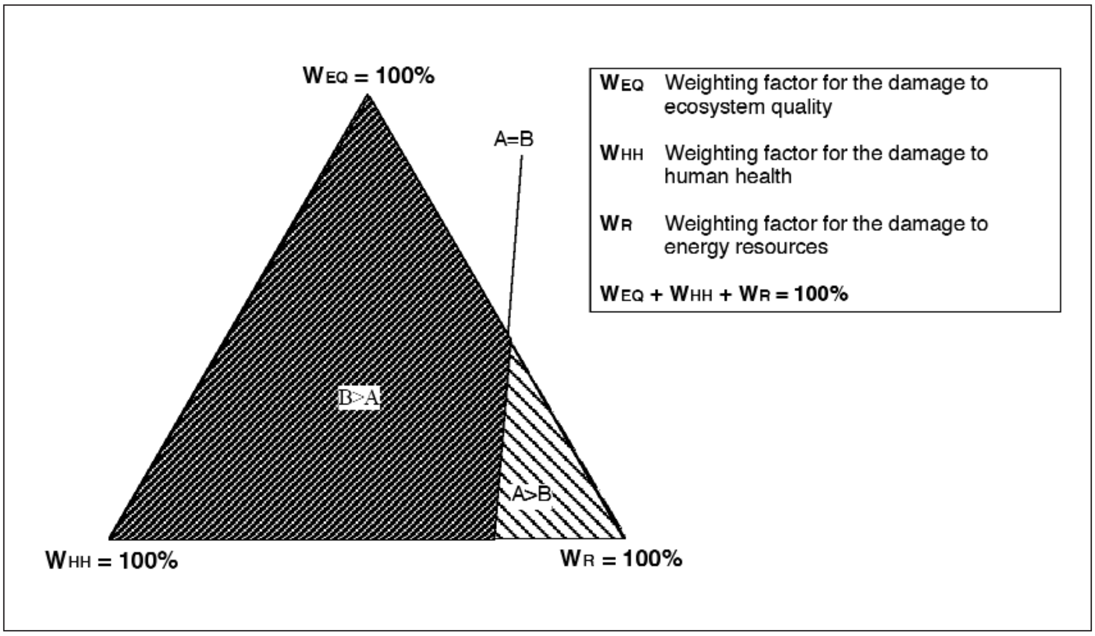


Figure 10
The line of indifference in the weighting triangle and the sub-areas with their specific ranking orders (B>A means that alternative B is environmentally superior to A and the eco-index A is higher than B).

The triangle in SimaPro

SimaPro has an option to automatically generate a triangle. This option can only be used for impact assessment methods that use exactly three damage categories, such as the Eco-indicator 99. The triangle option can be used during the normalisation step. Please observe that if all damage categories of product A are higher than product b, the line of indifference will lay outside the triangle, which means it will have only one colour.

5 Organising your LCA activities

The previous chapters have described LCA methodology from a more theo retical and methodological point of view. In this chapter, we will discuss some important practical issues, like planning, budgeting, data collection and presentation issues.

5.1 Estimating the workload

It is of course very important to consider how much time and money you will have available for your LCA activities. A general estimate for a typical LCA is difficult to give. In our consultancy work, the workload can vary between 2 days for a quick screening using already available information and 200 days for an extensive LCA.
Although we can make no sharp borderlines, we can distinguish four types of LCA studies:
1. Screenings
2. Short studies
3. Extensive studies
4. Continuous LCA operations

The characteristics, including a budget indication, are discussed below.

5.1.1 Screening

If you need to get a quick answer, and if speed or budget is more important than precision, you can make a screening using already available or estimated data, already in your database. For missing data, you take provisional alternatives. If you for example need data on nickel production, and you only have data on some other non-ferro-metals, you use these alternatives to get an impression of the importance of this process.

In order to work efficiently you should try to limit your goal to get only a limited set of clear conclusions, like:

- Is it likely (but perhaps not certain) that a product will have a lower environmental load if I use steel instead of plastic?
- Is the use phase dominant, and is it justified to put all efforts in the development on optimising the use phase?
- Does recycling seem to have a significant impact on the total environmental load, or is the effect negligible?

After defining your LCA and drawing your conclusions in this way, you should always include a sensitivity analysis to see if your estimates and less representative data can really influence your key conclusions.

Be very careful with communicating such short screenings in external communication. Never base public statements or comparisons between your products and competing products on such screenings.

How SimaPro supports screenings

Perhaps the most important issue in screenings is to have a large database with commonly used materials and processes. Another important feature is the ability to separate between the data in libraries and projects. Before you start to work on an LCA, you should open a specific project in which you store your data (A Light version of SimaPro does not allow you to create a new project, all your work is stored in the same project). We strongly advise you never to change the data in the libraries, especially not if you make "quick and dirty" changes for your screening. If you need to edit an existing record, first copy it into your project and make the change in that copy. This advice is also relevant in case you want to edit impact assessment methods for the screening.

In a screening, it is essential to be able to quickly identify the relative contribution of processes, in order to check them. SimaPro supports this in several ways:

- The ease of tracing the origins of the results. If you generate a process tree in SimaPro, you will see small bar charts in each element of the process tree. These indicate the relative contribution of processes or parts of the process tree to an indicator, to the mass flow or to an LCI result.
- Contribution analysis allows you to identify which processes really contribute most to the overall results. Often only 10 out of several hundred processes contribute more than 95% to the overall result. This allows you to critically analyse these most important processes.

5.1.2 Short internal LCA's

If you need to take a decision that has significant influence on the product development process or communication strategy, but do not want to use the LCA report itself for external communication, you should set up a short LCA study. For such a study, the goals could be more ambitious, like:

- What are the dominating causes for the environmental load in the production phase, the use and the disposal phase?
- How much benefit would a product take back system bring us?
- How is our product performing in relation to competitors, is it likely that our competitors could make an environmental claim that is justifiable. To what extend can we use environmental claims in our external communication?
- Would we qualify for an ecolabel?
- Which of our businesses could be considered as sustainable; that is, we earn relatively much money, at a relatively low environmental load.

A pragmatic approach is to start with a very short screening to identify the relative importance of data gaps in your database. From this you can set-up a data collection strategy, and identify which data could be collected from literature, and for which could be collected by approaching suppliers or other players in the product chain.

As this is a short study, your data will not be perfect it is very important to critically analyse to what extend you can really justify your conclusions. A sensitivity analysis, in which you change important assumptions and in which you test different impact assessment methods, is needed.

If you want to conform to the ISO standards, you should not directly publish this LCA report if it is not peer reviewed.

How SimaPro supports short LCA's

Apart from the issues mentioned in the textbox on screenings, an important tool is the Data Quality Indicator. In SimaPro, each time you define a new project, you can define the standards you desire for the data that is to be collected. These standards relate to issues as age, representatively, regional aspects, system boundaries and allocation. If the data you use from the standard database or if the data you collect does not match these requirements a colour code will warn you. Other important tools are:

- The documentation of processes. Each record can have an extensive attachment. In the standard database, these attachments have been completed for the most relevant datasheets. This allows you to clearly understand the models underlying the data in this record.
- The guidance on interpretation. A separate section allows you to type in the observations you need to make according to ISO.
- Data exchange facilities using the SimaPro format, the SPOLD format or the Excel CSV format

5.1.3 Extensive LCA for publication

If you would like to make detailed environmental claims, and use your LCA report in the public debate, you should make a more extensive LCA. Distinguishing factors are:

- According to ISO 14040, you should include an independent peer review in the process. Experience has shown that it is best to invite a peer reviewer already at the first stage when the goal and scope is defined. This will allow the peer reviewer to give suggestions for improvement at a time improvement is still possible. The peer review statement should be published in the report.
- The requirements for the reporting are much higher. You should carefully describe all procedures, choices, data gaps etc, and you should perform an extensive sensitivity analysis. ISO 14043 provides a guideline for this.
- If your aim is to compare products, and if you want to conform to ISO14042, you should not publish weighted results.

Even after all these precautions, we advise you to be very careful with public statements that are directly based on an LCA report. Experience shows that debates about LCA reports can be quite difficult to manage.

How SimaPro supports Extensive LCAs

For extensive LCA's you will need the same tools as described in the previous boxes. Documentation, data quality and interpretation issues even become more important. SimaPro can be used to define very complex products, using a system of assemblies and subassemblies, and it can handle very complex use and end of life models. For example if auxiliary products like batteries or packaging materials are used, they can be defined as a separate additional life cycle, each with its own specific production and waste disposal model. It is also possible to model complex take-back, disassembly, reuse and recycling scenarios.
SimaPro can also handle very large process trees. We have performed studies with 50.000 processes in a single process tree. Calculating such an LCA just takes one to a few minutes depending of the speed of your computer.

Perhaps the most important feature to support large LCAs is the availability of a multi-user version. This version will allow you to work on the same LCA project in the same database with several different LCA experts. The system is set up in such a way that one person can be made responsible for the data quality. This person can also assign user rights and passwords to others controlling the access to certain parts of the data, depending on the skill and responsibility of these persons.

5.1.4 Environmental life cycle information system (ELMIS)

The ISO standards and many LCA specialists consider LCA studies implicitly as an ad-hoc activity. A study is done to support a decision and after this, the activity stops until a new decision needs to be supported. We now see a clear trend away from this ad-hoc approach, as more and more organisations tend to see LCA as a continuously maintained Environmental life cycle information system (ELMIS).

In such a system, the aim is to gradually develop and improve an LCA database that can be used to answer the most important issues a company or organisation could be confronted with. The benefits of developing such a system are for example:

- Your questions can be answered much more quickly once you have a database that contains the most relevant materials and processes for your organisation.
- The experience with earlier studies is not lost, but adds to the overall competence of the LCA department.
- The ELMIS information can be used in environmental reporting.
- There is more continuity in the workload for the LCA department.

Nice examples of such ELMIS type systems are for example:

- Industry associations that develop a database for their type of industries and maintain this database for further development. An example is the European Cardboard industry (FEFCO) the world Steel industry (IISI) and the European plastics industry (APME)
- Companies like Philips, Unilever and many other large companies, who have build up a large LCA database on for example electronic components and oils needed for margarine. Philips for example translates the LCA information into Eco-indicators that are used by the design departments.
- Building industries in Canada, England and the Netherlands have set up, or are setting up systems for the communication of LCA results between companies, and disseminating this information to contractors and architects.

Of course, also ELMIS systems need a clear goal and scope. It is essential to carefully consider the data requirements for your systems, and think how you maintain and document the system.

How SimaPro supports ELMIS type projects

Apart from the features mentioned earlier, we would like to focus your attention on the Script features. Scripts are designed to be a programmable user interface for non-LCA experts. A Script contains a set of questions about a product and its life cycle. By answering these questions, the user defines a functional unit, without having to understand all the complexities of LCA methodology. After completing all questions, SimaPro will start to perform the LCA for this functional unit and SimaPro will present graphs and tables with the results of the calculation. These results are simple to obtain, but not simplistic. The user can still trace the origins of the results. Full transparency is thus guaranteed.
In SimaPro Analyst and Multi-user version, you can define your own Scripts, with the build in Script language. Writing Script requires a good understanding of LCA and a reasonable good feeling for programming.
Scripts have been successfully used to present and disseminate data between and within companies, even for SMEs. Usually scripts are run in the Light version of SimaPro. This version is relatively cheap. Examples of Script projects can be found on **www.pre.nl**.

If transparency of data is not a requirement, and if you believe it is sufficient to provide data as Eco-indicator scores, you can also use our very simple ECO-it tool. This tool is intended to be used by designers. SimaPro Analyst and SimaPro Multi-user are shipped with a free license of ECO-edit, a tool with which you can develop or edit Eco-indicator databases.

With these two tools, you can develop two "frond ends" for the users of the LCA information you have gathered. These tools require relatively little background knowledge and virtually no training.

5.1.5 Some guidelines for budget estimates

Although many factors can influence the time needed to perform an LCA, the table below may give you some guidance. These estimates assume that the work is performed by experienced persons. If you start in this field, you should add a few days or weeks to get to grips with the methodology and all practical issues.

(time in working days)	**Screening**	**internal LCA**	**external LCA**	**ELMIS**
Discussions needed to formulate goal and scope.	1	2-4	10	10 + updates
Data collection	2-5	5-15	25-100	continuously
Data processing into software and performing calculations	1	2-4	10	continuously
Interpretation and sensitivity analysis	1	2-4	10-20	continuously
Reporting	1-2	2-5	10-30	continuously
Peer review	N/A.	optional	10-30	optional
total estimate	5-10	15-40	75-200	and up

5.2 Operational procedures

The way you organise the LCA work clearly depends on your goals and the organisational environment you are working in. In this paragraph, we give you just some suggestions.

5.2.1 Working on your own

If you are working as the only LCA expert in your organisation, it is relatively simple to organise your work. Important issues to consider are:

- Do not edit the resources stored in libraries, unless you are completely sure.
- Be sure to make back-ups. You can run SimaPro Single user versions over a network; this means you can locate the database files on a server.

5.2.2 Working in a team

If you are working in a team of LCA experts things become a little more complex. By far the best way to work is to use a multi-user version of SimaPro, as this allows you to work on the same database. In the Multi-user version, you can use the following facilities and features:

- All users log in using a username and password.
- The database manager can define certain user types (like expert, novice, guest etc.) and assign certain access rights to these types. Furthermore, he or she can assign a user type to each user, and he or she can determine which user has access to which project.
- The database manager is the only one who can edit the libraries, and the manager can determine which data can get the library status.

5.2.3 Working from different locations

The Multi-user version uses a so-called client server principle; this means that the calculation work is performed on the server, but the data is managed by the client computers. This reduces the data traffic over the network considerably, which makes it possible to work from different parts of the world via relatively slow connections with a band-with of a few 100 kb/second.

Working in a team with a number of single user licenses will create a system that is impossible to manage, as sooner or later all databases will be completely different. You should avoid this at all times. If you started with a single user, you can upgrade to a Multi-user without any conversion of the databases.

5.2.4 Gathering and assessing data

The most demanding task in performing LCAs is data collection. However much data is available in your database you will usually find that at least a few processes or materials are not available, or the available data is not representative. Depending on the time and budget you have available, there are a number of strategies to collect such data:

- Try to understand first if the data you miss could have significant influence on the total result. If for example, if it appears that this data will not contribute more than 0.1 to 1% on any of the impact categories, you may well give up the data source and use an estimate instead. Estimates can be made by using data from similar processes, by estimating the energy use in that process, or by using statistical data from so called input output databases.
- Try literature data. There are many books that describe industrial processes, and very often, they provide clear enough descriptions to estimate the energy use, the waste and in some cases some emissions. This can also be a good start for the development of questionnaires.
- Ask your suppliers and other players in the product chain such as recyclers and in some cases even your competitors. (see below)

- Use the internet resources that are being developed:
  - **www.spold.org** is intended to become a data market place where demand and supply are matched. All this data will be offered in the SPOLD format. SimaPro can import this format.
  - **www.globalspine.com** is a market place where you can purchase data in the Spine format. This format is not yet supported by SimaPro.
  - Mid 2003 the launch is expected of a very large dataset on **www.eco-invent.ch**
  - The SimaPro Internet User Group. All SimaPro users can become a member of this group. Many have asked for specific data in this group and many very useful replies have been given.
  - The PRé website links section has many useful internet addresses too.

Collecting data from other parties is not always easy. It is useful to carefully consider the following points:

- The willingness to supply data is of course determined by the relation you have with these parties. Some parties will be interested as they may have common goals; some will see your LCA activities as a thread. In some cases most of the data collection effort is in the establishing a good relation, in which parties have trust in each other. At least you have to be very open to state why you need the data, what will be done with it, and how it will be presented.
- Confidentiality issues can be very important. Sometimes emission data can reveal certain technical or commercial secrets. One way of dealing with this is to involve an independent consultant that averages the data from different suppliers. Sometimes a branch or industry association can have this role, as they can average the data from their members.
- Terminology issues. Per industry sector, there are different ways of measuring and expressing things. If you develop a questionnaire for a party, you should try to use the terms, the units and the customs that are applicable within this sector. In order to do so you should first discuss the issues you are interested in and then produce a questionnaire.

After you have collected the questionnaires, you should carefully assess if the data is reasonable and consistent and sufficient complete. In general, a second or even third round is needed to get clarifications.

5.2.5 Communicating your results

The traditional way to disseminate results is by printing a report or book. The ISO standard more or less assumes you will do this. However, writing reports is a costly matter and very few people read it completely. It is also a very inflexible way of presenting data. You write what you have done and you describe your assumptions. However, the reader has a very limited idea of what would happen if other assumptions are made, or if the same data is used on a different project or life cycle. In the paragraphs below, we describe two alternatives to writing paper reports:

1. Scripts
2. Eco-indicator tools

In our experience, disclosing the full LCA report is not the best way to communicate them. We suggest you define a clear communication strategy before you start your LCA work. All to often projects have started without a clear goal as to what type of information is to be communicated and in what form.

5.2.6 Ownership of data and methods

By publishing LCA data, you usually include data you have not generated yourself. There are no objections to publish the data supplied with SimaPro

in printed form, as long as you refer to the origin. However, it is not allowed to use this data in electronic form in other tools than SimaPro without our permission. This is due to the way we have sub licensed some of the data from other sources.
This issue has become particularly important since the emergence of the SPOLD data exchange format. This format is intended to exchange your own original data, and not to redistribute data from for example the BUWAL library supplied with SimaPro.

There are no objections to using calculated results in other electronic products. For example, if you calculate Eco-indicators and you want to include these in your internal software or a marketable product there is no problem, as long as you take responsibility for the quality of this work.

For impact assessment methods a similar situation occurs. All methods have been published, however not all method developers would appreciate it if you would copy the method into other electronic tools. Please ask permission from the authors of the methods if you intend to do so.

5.2.7 Archiving old projects

Upon finishing a project, it is advisable to archive it with some care, as the data in your project usually depends on data in libraries and other projects. If you do not archive the project, you may find that after some time the results of this project are changed by changes in the libraries. The best way to archive the project is to export it in SimaPro format, while enabling all related data in libraries to be included in the export file. It is also a good practice to include the relevant impact assessment methods in this export file. Users of a Light version cannot export data.

5.3 Script writing

Since 1998, we have developed an alternative way of presenting the LCA results using scripts. Scripts present themselves as a series of questions to the user. The questions focus on the functional unit and some basic assumptions. By answering the questions, the user can perform its own LCA, without actually having to understand all the details of LCA methodology, or how SimaPro works.

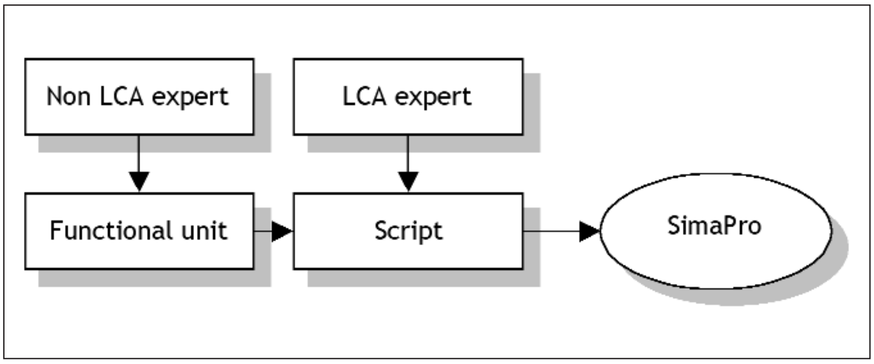


Figure 11
The LCA expert can develop an interface between the non-expert user and the tool. The expert is responsible for developing the interface and the database in such a way that the results are methodologically correct. The user is responsible for submitting correct data on the product composition and the life cycle.

Scripts can be developed by any LCA expert who has some basic understanding of how a macro can be programmed. The LCA expert can assume the responsibility that the Script results in a methodologically correct LCA, while the user can take the responsibility that the product and life cycle are properly defined.

Scripts are run as an extra layer on SimaPro. Although the user only sees the questions and the results of the LCA, underneath the script the full SimaPro database and all the intermediate results are available for further inspection the results are thus completely transparent.

Writing scripts is often not more costly than writing a report, and we believe scripts are a very good alternative to a report. The scripts can be presented in the low cost SimaPro light version. On **www.pre.nl** some examples of projects using scripts can be found.

5.3.1 Develop scripts for non experts

The script language allows you to develop a user interface, targeted to the interest of a specific user group. Before you start programming scripts, you should address the following questions:

- Who is the target audience?
- What skill level do they have, how much do they know about the product and LCA?
- Which type of product systems should they be able to model, and which characteristics of the product or the life cycle should be open for modification?

Script are usually combined with a specific datasheet, so often you can only start programming the scripts if you have at least a rough version of the data and impact assessment methods ready.

5.3.2 Structure of the scripting language

When you run a script, you see a number of screens with questions and usually some predefined answers. Each screen is defined in a Node. Apart from the visible nodes, there are some invisible nodes. Nodes are placed in a logical order to from a script.

A useful feature in the script language is the possibility to jump from one node into another. This allows for efficient programming, as you can define a number of sub scripts that perform some tasks that can be repeated. This jumping also allows you to design alternative routes or branches through the script. For example, you can ask the user in a certain node if he wants to compare two products, or to define another product. Depending on the answer, another subscript is activated as the next node.

The main task in script programming is defining nodes. Most nodes are quite easy to define, although there are also some more complex nodes:

General node

- Message node: displays a message to the user.

Data entry node

- Enter text node, allows user to give enter a name; for example the name of an assembly.
- Enter value node, allows user to enter a value; for example the amount of steel in an assembly.
- Select process node, allows user to select a process into an assembly; for example, he can choose between the different types of steel in the database.
- Choose script route node, allows a user to decide which is the next task.

Processing nodes (usually invisible nodes)

- Call script node, jumps to and activates another script.
- Operations node, This is one of the most complex and advanced nodes. It allows you to include arithmetic operations within the script. For example, you ask the user for the height and width, and you let the operation node calculate the surface.
- Processing node, needed to let the script start working.

Result nodes

- Calculate node, lets SimaPro perform calculations.
- Show Graph node, lets SimaPro show the results of impact assessment in a predefined way.
- Show Substance node, lets SimaPro show the LCI results.
- Show process tree node, lets SimaPro display a graphical process tree representation.

In the help file, you will find more information on the specifics of these nodes.

While the user goes through the scripts, he enters data. This data is stored in variables. In addition, the script nodes themselves can create new information that need to be stored in variables. A debugging window is available to see how the contents of the variables change during test runs of the scripts during the development. It is also possible to define conversion factors for the script variables. These are defined under the general data section.

5.3.3 Script "forms"

When the user runs through a script, a form can be created, that holds all the data that was entered. This form can be used to modify data, and immediately get the results, a very good way to answer "what if" questions.
Forms can be stored under a filename for future reference. In fact this opens the possibility to develop a specific use interface for a specific LCA problem.

5.3.4 Managing scripts

In the script projects run so far, the Scripts and the associated databases were developed by one team of developers and distributed in the so-called "Light" version of SimaPro. This version has the benefit that the libraries cannot be changed. So if you store your data in a library, the script will always be able to find the data you assumed to be available in the script.

Scripts and variables are stored in a specific project or library. The data (assemblies processes etc.) created or edited from within the script can only be stored in the same project as the script. However, you can jump to scripts from within a project to a script in another project or library, as long as that script does not produce or edit any data.

After presenting the first version of the script, there will probably be a reason to provide updates. This can be done by sending a new version of the libraries and the scripts to the users. Users who want to maintain the data generated with the previous version can import this data from their old database into their new database.

5.4 Eco-indicator tools

Transparency of the data is not always required because the audience for who you develop the data has no or just a very limited interest or knowledge on environmental themes. In this case, you may wish to consider presentation of single scores such as Eco-indicators, EPS scores or Swiss Ecopoints. Such scores can be easily generated by SimaPro.
To provide these indicators in an easy to use tool, we developed ECO-it. This tool lets any user make an LCA in a few minutes, provided al the required single scores are in th4e database. The tool comes with 200 standard indicators according to the Eco-indicator 99 method. You can extend this range, or create new databases with a simple editor called ECO-edit. A copy and a license for this editor are included with the SimaPro analyst and multi-user version.

6 Performing an LCA in SimaPro

In this section we summarise how you perform an LCA study in SimaPro. It does not exactly describe which keys or buttons to press. Instead, this chapter aims to introduce to you the most important concepts you will encounter when working with SimaPro.

6.1 Overview

Upon starting SimaPro, you are asked to open a project or library:
- A project is an area in which you store the data you are about to collect and process.
- A library is a special type of project that contains the standard data supplied with SimaPro or data from other data suppliers. Libraries are a resource for all your projects. In general you should not edit this data, but use it in your projects.

A more detailed description of the structure of libraries and projects is provided at the end of this chapter. For now, it is sufficient to know that you work in projects and that you use libraries as a resource for data and methodologies.

Once you open a project or library, the SimaPro LCA explorer will appear. This provides access to all the different data types in the software.

The upper part of the explorer screen contains project or library specific data; the lower part contains general data that is not stored in projects or libraries. The buttons in the toolbar execute frequently needed commands.

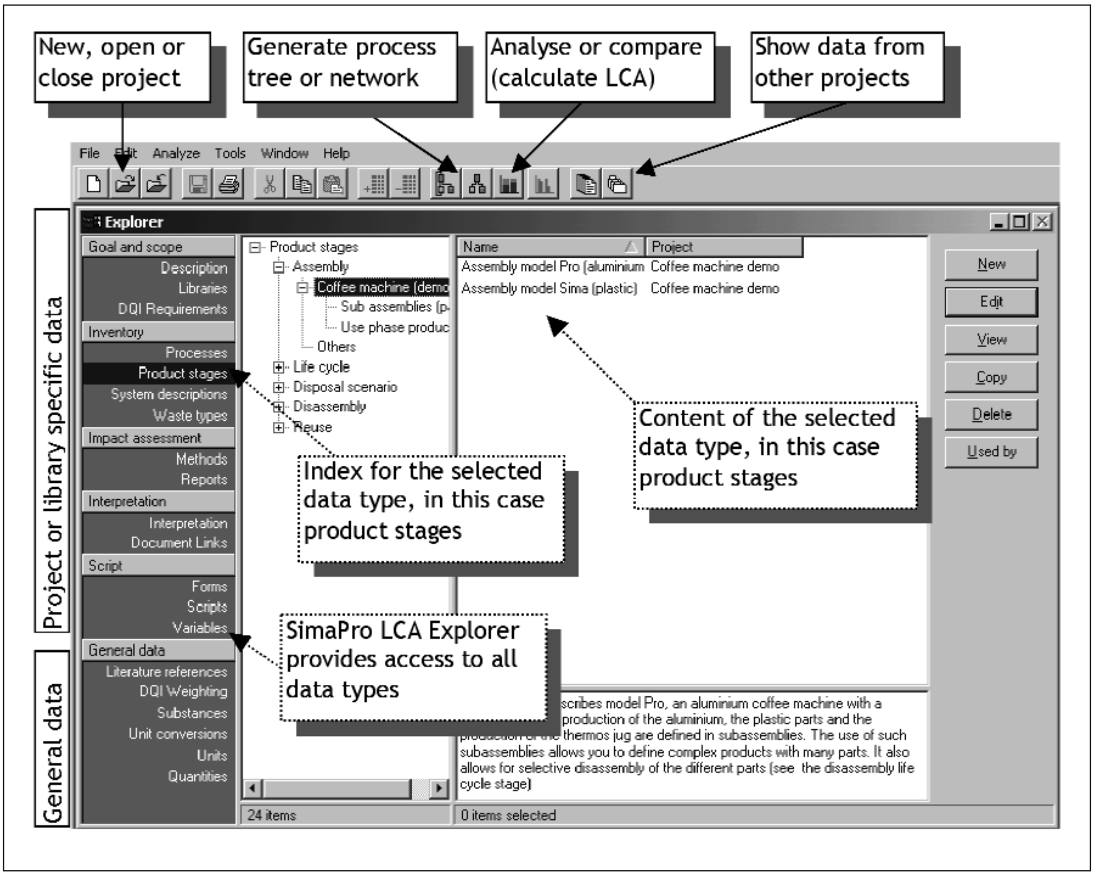


Figure 12
Overview of the SimaPro explorer on the left-hand side of the screen.
This screen provides access to all data types.
On top you find buttons for frequently used commands.

6.2 Basic steps to perform an LCA

The SimaPro LCA explorer is structured as a checklist for your LCA, as you enter or edit data in the order defined in this list. However, LCA is an iterative process, which means you need to step back and re-evaluate your earlier actions. Below we give an overview of the most important steps.

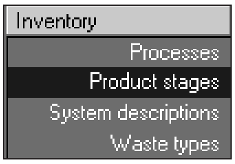
6.2.1 Describe Goal and Scope

As discussed in the second chapter it is essential that you do describe goal and scope, either in the software (under "description") or in a separate document. You can cut and paste text typed into SimaPro text fields into your word processor documents. The text fields headings in SimaPro provide you with a useful checklist of items you really need to address.
During the performance of the LCA, you may find that you need to deviate from the goal and scope. In that case, it is very useful to add such changes to the texts. It allows you and others to trace how your insight has been developing and which compromises you have made.

Another important issue is to select which libraries you would like to use. Your study will gain consistency by limiting the number of libraries, as each library tends to have different methodological and data characteristics. Of course, limiting the number of libraries will also reduce the availability of data for your project. There is a trade-off between quality and quantity here.

The data requirements section is also intend to allow you to reach a maximum of data homogeneity and quality. By setting a certain data requirements profile, you will see the colour codes in the process data index get different colours. This helps you to select the most appropriate data for your purpose.

6.2.2 Inventory



In the processes sections you create new processes. In many cases, you make links to already existing processes in libraries or other projects. If you want to edit existing processes, you should copy those to your project first and edit this copy.

If you have created and edited the most important processes, you can start building the life cycle by using product stages. Usually you start by defining assemblies and subassemblies to describe the composition of your product. Subassemblies are needed if you are defining very complex products, and if you want to model disassembly scenarios. The next step is to build a life cycle, in which you like to the assembly and if applicable to use and disposal stages or waste scenarios. This will be discussed in the next paragraphs.

Once you defined a life cycle you can make some test runs to see which aspects are having a significant impact on the overall results. Based on this, you can try to see if these need improvement. It is also useful to make such calculations with different impact assessment methods and by using the graphical representation of the process tree and by using the contribution analysis.

6.2.3 Impact assessment

The methods section lists all the available methods. You can select one of the methods as the current methodology. This will be used inn all your calculations, until you change it for another method. If you want to edit a method, we recommend copying the method into your project first

Under the reports section you can define which life cycles, processes and assemblies need to be repeatedly analysed and compared. The benefit of using a report set-up is that all life cycles or assemblies always appear in the same order, with the same colours and the same scale

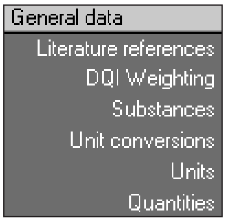
6.2.4 Interpretation

When you are nearing the end of your project, it is time to draw your conclusions and make a number of checks. The text fields under interpretation are a guide to which issues you need to address.

6.2.5 Scripts

As explained in Chapter 5.3, the Scripts section can be used to develop very useful "macro like procedures". A new feature in SimaPro 5.1 is the ability to create a form that presents all user data in one overview.

6.2.6 Other data types



The other data types like the scripts and the general data are not frequently edited during the LCA study, but contain useful supporting tables, like:

- Literature references, that you can link in your process records
- Substance names: SimaPro holds one central table in which all substance names are stored
- Units conversions as they are used in Scripts and Units and Quanitites

6.2.7 The iterative nature of LCA projects

You will experience that during the development of your project you will often make some preliminary calculations, for a number of reasons:

- Initial calculations on a model filled with rough data can show which parts of the life cycle or which processes seem to be the most relevant, and thus need further attention.
- After a few hours of editing the database, you can check if all results are reasonable and explainable. If not you may have made one or more mistakes, or the data supplied to you may contain errors.

This means that you will go through the Goal and scope, Inventory and Impact Assessment parts in an iterative way many times.

6.3 Building process trees

The core of the LCI phase is building a process tree that describes all relevant processes in a life cycle. The term process tree refers to the way processes are connected to each other. In chapter 2, we have discussed the complexities of modelling the life cycles and we have described issues as system boundaries and allocation. Now we will show how you make this model in SimaPro.

The process tree in SimaPro uses two different building blocks:

1. **Processes** are the building blocks of the process tree that do contain environmental data, as well as data on economical inputs and outputs.
2. **Product stages** do not contain environmental information, but they describe the product and the life cycle.

The use of Product stages is a unique feature of SimaPro, as we will see they allow for the modelling of very complex products and life cycles.

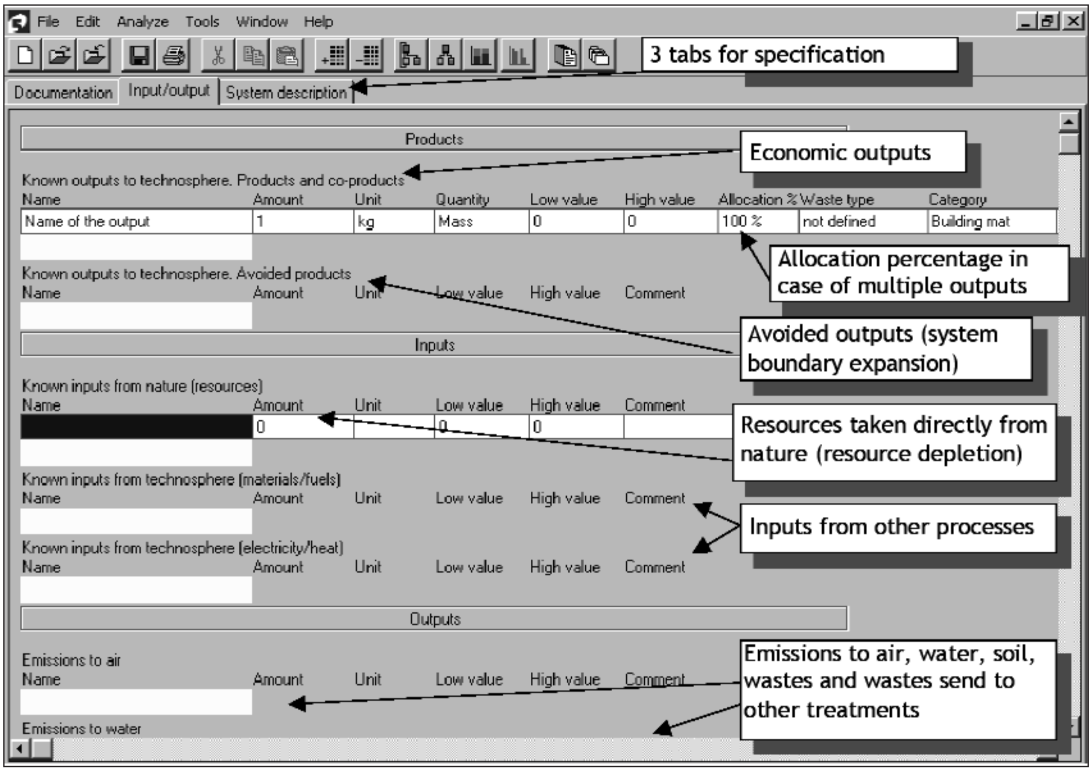


Figure 13
Empty process record (only upper part). This process record is the basic building block for the process tree's in SimaPro

6.3.1 The structure of processes

A process in SimaPro contains data on the following issues:

Environmental data, such as:

- Emissions to air, water and soil
- Solid waste (final waste)
- Non material emissions, such as radiation and noise
- Use of raw materials (in order to model depletion)

Economic data, such as:

- Inputs from other processes (processes that are described elsewhere in the database).
- Outputs; Each process must have one, and can have multiple economic outputs (In SimaPro referred to as Products).
- Outputs of waste for further treatment, such as sewage plants, incinerators etc.
- Avoided processes. As discussed in Chapter 2 this is one of the solutions of allocation problems, by enlarging system boundaries).

Documentation

- A number of text fields that are used to identify the record, such as name, Author, date and general comments.
- A number of Data Quality indicator fields, that allow you to quickly identify how some of the methodological choices have been made, and how they compare with the profile you have set in the Data Quality section.
- A system description. This separate attachment is available to describe the underlying model that is used when this data was defined.

This is the general structure of a process record. Processes are identified in the database indexes according to their output. However, waste scenario and waste treatments are identified by their inputs.

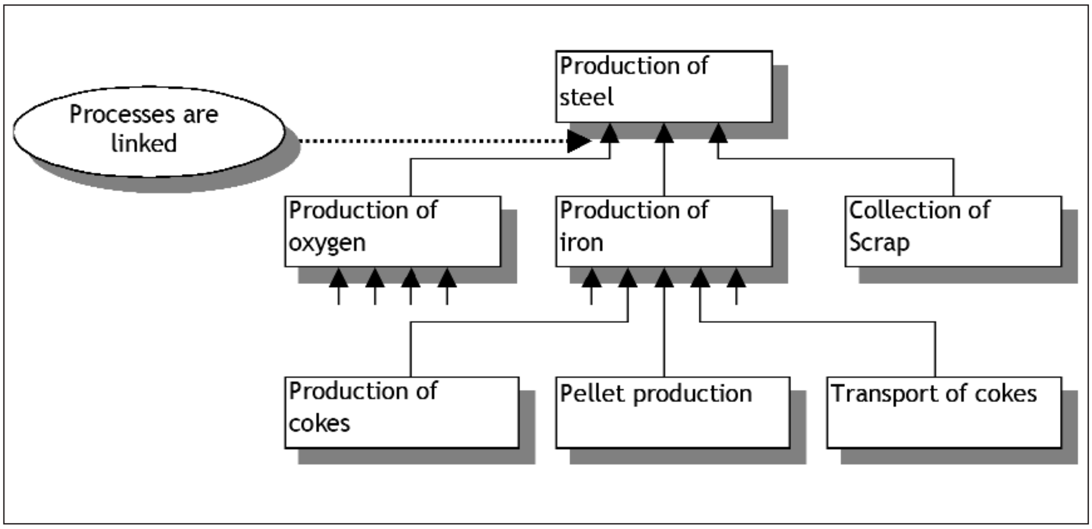


Figure 14
Schematic overview of how processes are linked to form a process tree structure.
In this case unit processes are used that describe a single process step,
which provides the highest transparency.

Process records can both describe unit processes, which describe one single process step as well as systems, which describe a combination of unit processes. For optimal transparency, it is always better to describe a system as unit processes. However, LCI data are very often published as systems instead of unit processes.

Later we will describe how processes are linked to product stages and how end of life scenarios can be described.

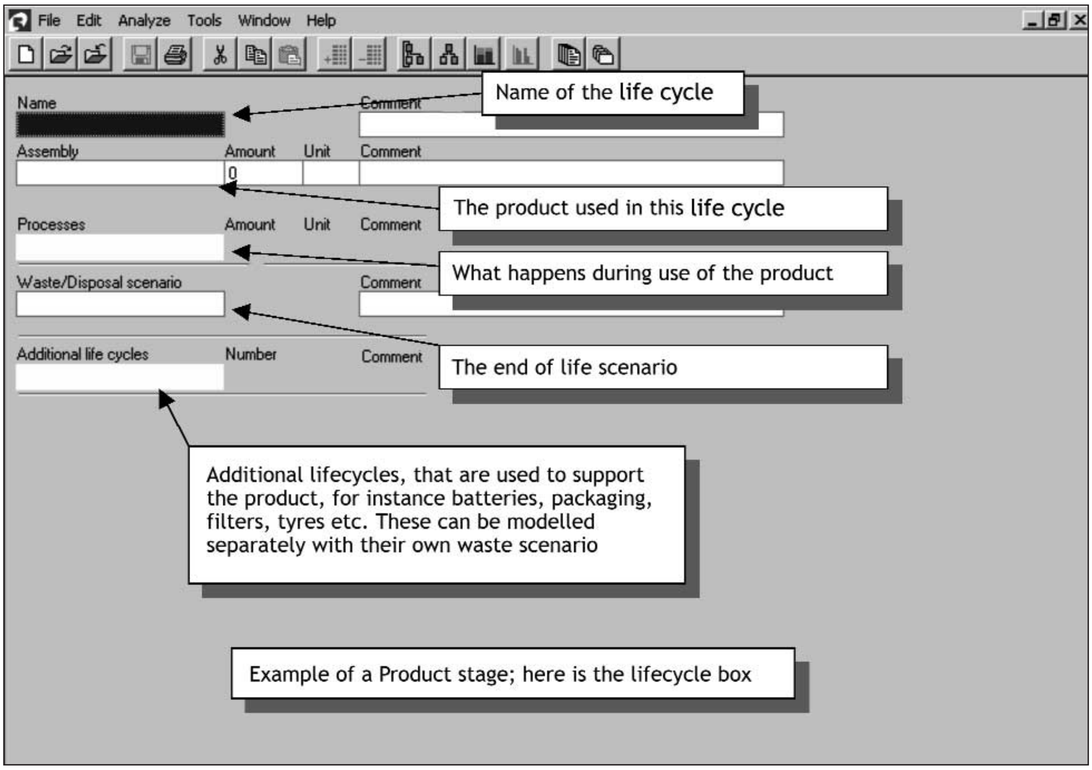


Figure 15
An example of a product stage, in this case the life cycle.
The life cycle links the product specification (the assembly)
with the use processes and the end of life scenario

6.3.2 The structure of product stages

Product stages form the top of the process tree. They do not contain environmental information; instead they refer to processes, which do contain such information.
There are five different product stages, each with its own structure.

Assemblies contain:

- a list of materials and subassemblies
- a list of production or transport or energy processes.

Together these describe the production phase of a product (Cradle to Gate). For complex products, you can create subassemblies that are linked to the top assembly.

Life cycles are the central product stage. They contain links to:

- One assembly.
- A number of use processes, such as energy use.
- A disposal or waste scenario.
- An additional life cycle. This is used in case one product uses other products like toner cartridges, batteries tires etc.

Disposal scenarios, disassemblies and reuse stages are used to describe end of life scenarios in which product disassembly or (partial) reuse of products is modelled. These will be discussed in a separate chapter.

6.4 Defining the product and the life cycle

The minimal life cycle contains at least one assembly and one life cycle stage and a number of references to processes.

6.4.1 Defining processes

Before the life cycle or assembly can be defined, all processes should be available in the database (in your project and the associated libraries).

Process trees are build up in a "bottom up" fashion. This means you usually start with processes such as resource extraction, and you end with a complete description of a product and its life cycle. Often the processes you need are already available in a library. In that case, you can make a link between a process record that is in your project and in the library. You do not have to copy the process from the library to the process, but of course, this means your project data has become dependent on your library. You can also establish such links between your current project and another project. However, it is not possible to link libraries, as it is desirable to keep them independent.

In case you would like to modify data in a library, we strongly recommend copying such a record into your project and making the changes in the copy. This is a very important guideline, as, by changing libraries you may also change LCA results in other projects. (In the Light version it is even not possible to change the data in libraries, in the multi-user version only the database manager can make such changes).

6.4.2 Defining assemblies and subassemblies

Suppose you want to model a fax machine for an LCA study. This is quite a complex product and it can have quite a complex life cycle if fax machines are collected and recycled. We will use this example throughout the following paragraphs.

In SimaPro, you can start with defining a number of subassemblies like the power supply, the electronic components, the frame, the housing etc. Such subassemblies can have subassemblies; for example, the power supply can have a subassembly to model the fan.
In each assembly or subassembly, you make links to processes, and you specify how much of a process is needed. For example in the subassembly for the housing you link to the process that has the output "sheet steel", and you specify you need 1.3 kg kilo of steel. This means that all impacts that occur in the whole process tree that is linked to the process "Steel sheet" are now included in this subassembly

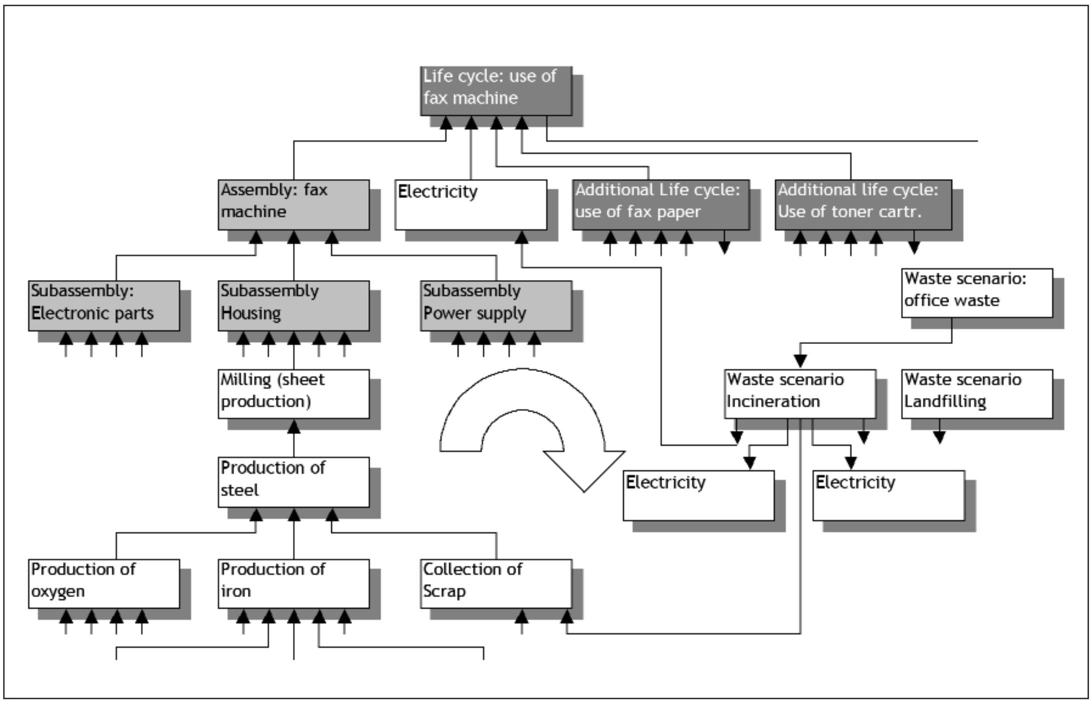


Figure 16
Schematic overview of the life cycle of a fax machine

6.4.3 Defining life cycles

The top, dark grey box is also a product stage called Life cycle. As you can see, a life cycle can link up to:

- One assembly (which may have subassemblies).
- One or more use processes, in this case electricity.
- One or more life cycles of auxiliary products, such as paper and cartridges. These auxiliary life cycles are defined just as any other life cycle; they also have an assembly and an end of life stage. This allows you to model a different end of life scenario for paper, cartridges and fax machines.
- A waste or disposal scenario (in this case a waste scenario is assumed).
- Additional life cycles.

SimaPro can generate such process tree graphs automatically. You cannot directly edit this tree graph. Editing is done in process records or life cycle stages. The figure below shows how SimaPro would generate this process tree.

6.4.4 Waste and disposal scenarios

SimaPro has a very advanced set of tools to model the end of life phase. As most LCA practitioners are not working in the end of life industries, but in the production sectors, it is important to be acquainted with the way waste processes need to be modelled. In a way, the modelling is more complex than modelling the production phase. The following paragraphs attempt to give you an overview of the terms and concepts used by SimaPro.

A distinction is made between waste and disposal scenarios:

- **Waste scenarios** are processes that refer to material flows, without observing any product characteristics. In waste scenarios, information on how the product is split up in different components (subassemblies) is lost, only information of the materials in the waste stream is maintained.
- **Disposal scenarios** are product stages that refer to product flows. Information on the way the product can be split up in components (subassemblies) is maintained, and this means you can model selective disassembly and (partial) reuse operations.

To illustrate this: glass recycling, by throwing a bottle in a glass collection container would be modelled with a waste scenario. Returnable bottles, which are washed and reused, should typically be handled in a disposal scenario. The product properties are maintained.

Waste scenarios

In waste scenarios, a waste stream is split up in different waste types, and these waste types are sent to waste treatment processes. Waste treatments actually document the emissions and other impacts you get from land filling burning, recycling, composting etc.

Waste streams can also be split up according to the waste type. This allows you to build waste treatments for a specific waste type.

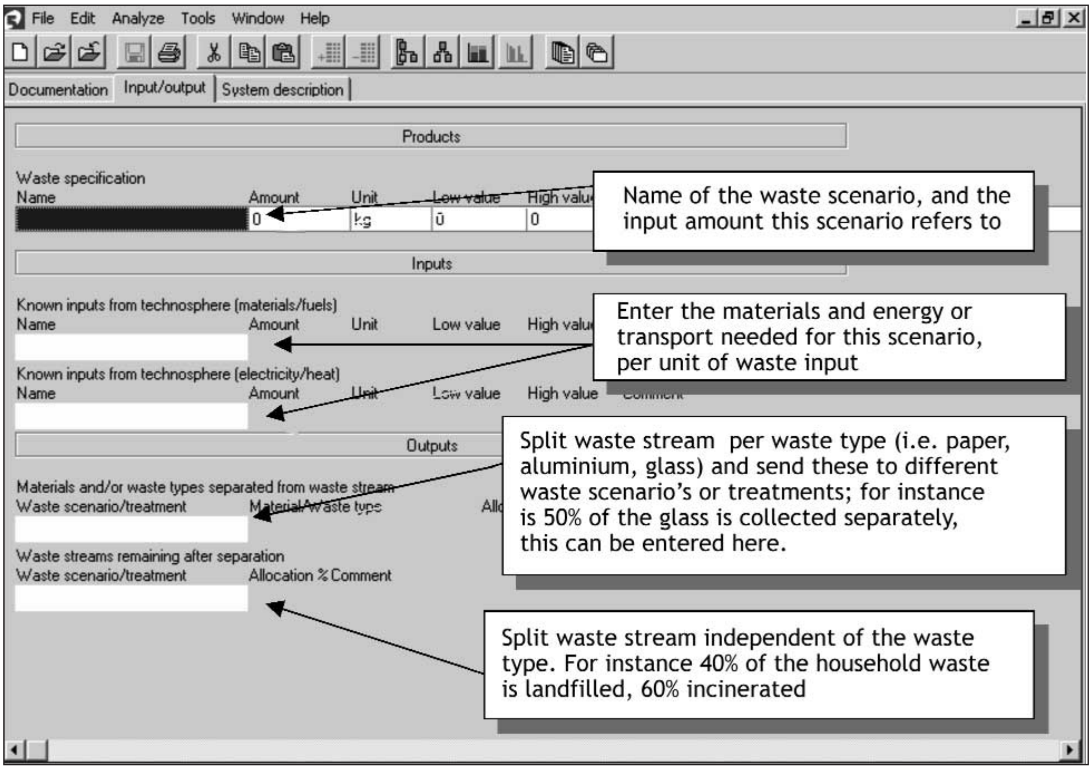


Figure 17
A waste scenario record is used to split a waste stream.
Splitting can be done per waste type or in a generic way

For example, you can define a waste scenario called Municipal waste; to describe what happens if a consumer puts a product into the waste bin. This waste scenario splits up the waste stream in a part that is land filled and a part that is incinerated. The municipality recycles probably also some of the waste, but for the clearness of the example, we disregard this now.

When waste is incinerated, many different emissions can occur. Usually an LCA practitioner would like to know which material in the product is responsible for which emissions. Furthermore, in an LCA, one would like to see the dependence between the material composition and the emissions that occur. To allow for this SimaPro can also divide the waste stream in different waste types or materials. A waste type is a general name, such as paper, plastics, PVC or ferro metals. For the waste modelling, it is usually not so important to know which paper, as the atomic composition is about equal for all kinds of paper. In SimaPro, you can define your own waste types and you can specify which materials belong to a waste type.

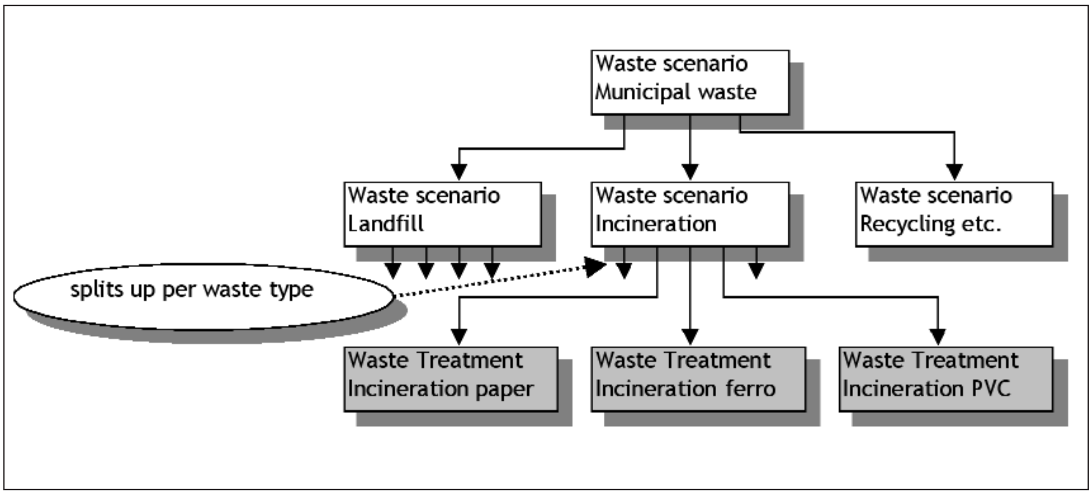


Figure 18
A waste scenario specifies how a waste stream is split up and send to other waste scenarios or waste treatments. This splitting can be specified per waste type or material. A waste treatment specifies what actually happens if a material is land filled, incinerated or recycled, etc.

With the waste types well defined, you can specify how the waste stream that is to be incinerated is split up according to the waste types. Each waste type is now "send" to a specific waste treatment. For example the waste type paper is send to the waste treatment process called "incineration of paper". This waste treatment specifies the average emissions that can be allocated to the incineration of one kg of paper.[3] Similarly, the waste type PVC can be send to a waste treatment that describes the incineration of PVC materials.

[3] Allocating emissions to a specific material is usually done by separating between process and product specific emissions. For example the amount of CO typically depends on the way the incinerator is designed and operated, and not of the chemical composition of the waste. This is a process specific emission. The amount of CO_2 is typically determined by the content of the product that is incinerated, for every kg Carbon in the product, 4,4 kg of CO_2 is produced. This is a product specific emission. Process specific emissions are usually allocated to the materials according to the flue gas amount they create.

Making very detailed waste scenarios

With a structure as described here, you will see that the emissions from waste treatment really are dependent of the composition of your product. If you specify that there is 2kg of material, which is labelled as belonging to the waste type PVC, and if 50% of the waste is incinerated, the waste treatment called incineration will receive 1 kg of material as input.

Working with waste types simplifies you modelling, but also creates some distortions. Not all PVC contains lead as a stabiliser, and if you have only waste type PVC, you cannot see the difference between PVC with and without such stabilisers.

Two solutions can solve this:
1. Introduce more waste types for PVC.
   Do not use waste types at all, and let the waste scenarios divide the waste streams per individual material.

2. The latter solution is certainly the most precise, and this option is supported by SimaPro. One of the consequences is however that you will have to adjust all waste scenarios if you define a new type of PVC in the database.
How you define waste types and waste scenarios depends on how you would like to make the trade-off between precision and practicability. Ultimately this depends on your goal and scope

Waste treatments sometimes do have useful outputs, such as heat or materials that are reclaimed for incineration or recycling processes. SimaPro allows you to specify these useful outputs as a close looped recycling procedure. This means if you generate one kWh of electricity due to the incineration of a certain amount of waste, the environmental load that would "normally" occur if such an amount of electricity would be generated is subtracted[4].

[4] This also explains why there are frequently negative environmental loads in the end of life product stages

Disposal scenarios
In disposal scenarios a stream of disposed products is also split up, but this is done in three routes:
1. Products that are disassembled in a "disassembly".
2. Products that are reused.
3. Products that are treated in a waste scenario (see above).

For example, suppose you have organised a take back system for fax machines and that you expect the following scenario:

- 50% of the fax machines will not be collected. This means these are send to a waste scenario, which describes what happens to fax machines when they are disposed of. This scenario could for example describe that a certain percentage is incinerated and land filled. The emissions from land filling, incineration and if applicable materials recycling are described in waste treatments.
- 10% of the fax machines are in such a good condition that they can be reused directly. In SimaPro, you can define in a reuse record what efforts (processes, transports, etc) are needed to make this reuse actually possible. SimaPro will consider the reused products as being recycled in a closed loop model. By reusing 10% of the fax machines the production needed to fill the functional unit is reduced with 10% (this does not imply the actual production is reduced, the reduction refers to the production needed to have a proper functional unit).
- 40% of the fax machines are dismantled in a specialised dismantling facility. In SimaPro you use a Disassembly record to specify which parts are taken out of the returned machines, such as the drum, the housing and the power supply. In this record, you can specify the destination of these parts, and what happens with the remaining parts. Often these are send to another waste scenario, which describes how you deal with the remainder. The destinations of the disassembled parts are specified in other disposal scenarios. This means you can now define a further dismantling operation. For example, you can specify that the power supply is split into a fan, a transformer and to an electronic circuit.

Note that disassemblies can only work properly if you have defined the product as a set of subassemblies. So in the example describe here, you should for example specify the power supply as a subassembly, which consists of subassemblies like the fan, the transformer and the electronic components.

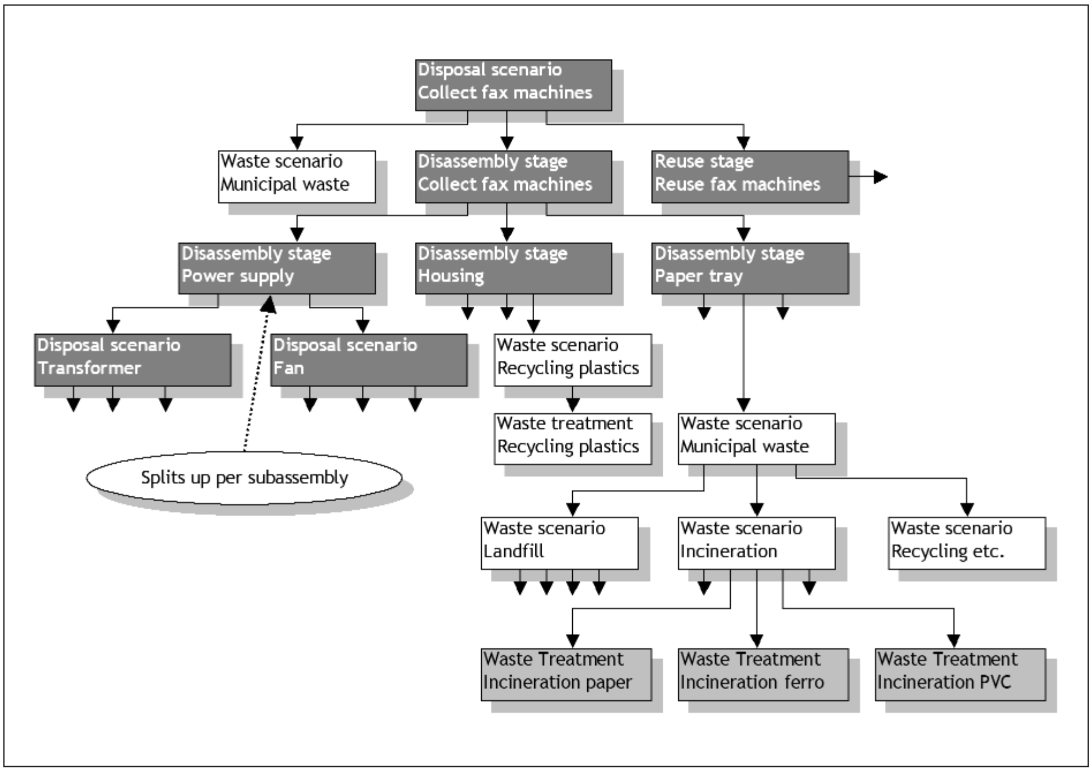


Figure 19
A disposal scenario specifies how products are distributed over different end of life options, such as disassembles, reuse and waste scenarios. A disassembly specifies how products are split up in different components, and to which destinations these are send to.

With the disposal scenario, the Reuse and the Disassembly options in SimaPro you can make very detailed and complex models of the end of life. It will require some experimenting to get to grips with these issues, but it is certainly one of the more powerful capabilities of SimaPro.

Therefore, as a summary we can present the following procedure to build up life cycles:

- Define a new product stage of the assembly type, and give it a name.
- Specify the materials that are in this product, by linking material production processes to the assembly. In many cases, such processes have links to other processes. SimaPro will automatically maintain these links.
- Specify the production and transport processes needed for this assembly.
- Define a new product stage of the life cycle type and give it a name.
- Link the assembly you just created to the life cycle.
- Enter the use processes, such as transport for distribution and energy use, by linking energy or transport processes to the life cycle stage.
- Enter waste or disposal scenarios to the life cycle stage. Waste scenarios are processes; disposal scenarios are other types of life cycle stages, which shall be described below. Waste scenarios are normally linked to waste treatment processes. It is sufficient to link the waste scenario, SimaPro will maintain the links to the waste treatment processes.
- In case you want to include auxiliary products or packaging, you can also define a life cycle for these products, and link this life cycle to the life cycle you are currently building. (not shown in the figure below).

The operations needed to link processes and product stages are relatively straightforward. You do this by double clicking the appropriate fields in the process and life cycle stages and then by selecting the process or product stage you want to link. This assumes the process you want to link to is already available. Consequently, you typically define process trees in SimaPro "bottom up".

6.5 Graphical representations of the process structure

So far, this manual uses schematic diagrams to present the process tree. However in SimaPro 5 you can also generate these automatically. From version 5.1 and up, there are even two ways to do so:

- Presenting data structures in an hierarchical tree (as with earlier SimaPro versions)
- Presenting data structures in a network, that can contain loops

The tree cannot be used for datasets that contain one or more loops, such as the input-output datasets; the network can be sued for all datasets. Both representations have some specific advantages and disadvantages.

6.5.1 Using the tree

A tree is generated by selecting a process, or a product stage and pressing the button. SimaPro will automatically generate the optimal layout of the tree. From version 5.1 and onwards, it will make a selection of the processes that contribute most to the environmental load; the other processes are cut off. How this environmental load is determined depends on the impact assessment method you have currently selected. If you select a method that allows for calculating a single score, this will be used. If your method does not, one of the impact categories will be used. You can always change the cut-off and the impact category later.

In the figure below an example of such a tree is generated.

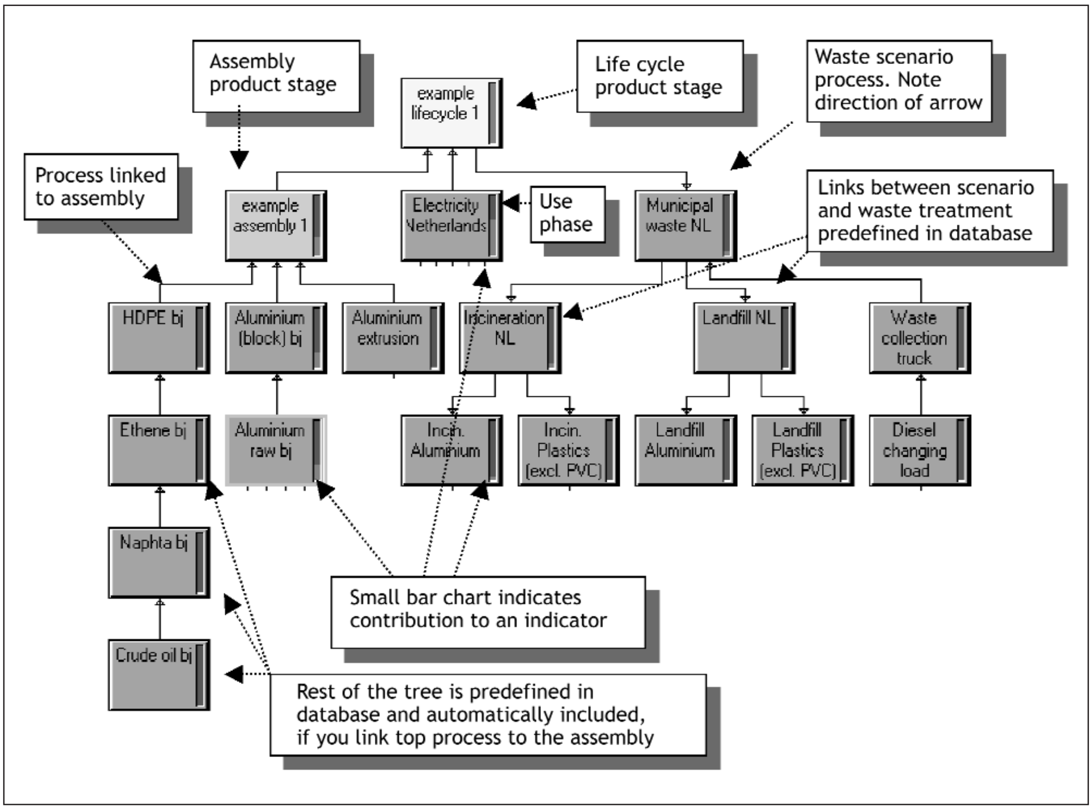


Figure 20
Graphical presentation of a fictional life cycle that is automatically generated by SimaPro using the Process tree command.
Except for the two product stages at the top of the screen all boxes refer to processes

An advantage of the tree is the relative simplicity of the hierarchical structure. However there are also disadvantages. For instance:

- Trees tend to become very big. Many tomes we find that a tree in the LCA seems to have 50.000 processes, while in fact the number of DIFFERENT processes is below 200, this is because processes repeat themselves so often
- When a certain process, like "electricity" Europe occurs several times in the tree it will be presented several times. This means that you easily overlook the contribution of this process. Often such a process will not be seen, as each "occurrence" of the process contributes less than the cut-off level, while the sum of all "occurrences would be above the cut off.
- Process tree's that have so called loops cannot be shown. For instance, in order to let trains run, diesel is needed, however, train transport is used to transport diesel. Therefore, in many cases processes refer back to themselves. Also for input output datasets such problems exist
- You cannot "see" recycling loops

For these reasons we also developed the Network representation. If you try to make a tree of a structure that contains one or more loops, SimaPro will automatically show you the Network presentation.

6.5.2 Using Networks

A network is generated by pressing the button while you have selected a process or product stage. In a network, each process in only represented once, irrespective of the number of times it is used in the tree. This means you can easily identify the importance the importance of each process.
It also means that one process can have many links with other processes, which makes the picture look more complex. The biggest advantage is that you can use looped data structures. The figure below shows you an example for rail transport. In addition, here an indicator (on the right side of the boxes) is used to show the relative contribution of the environmental load

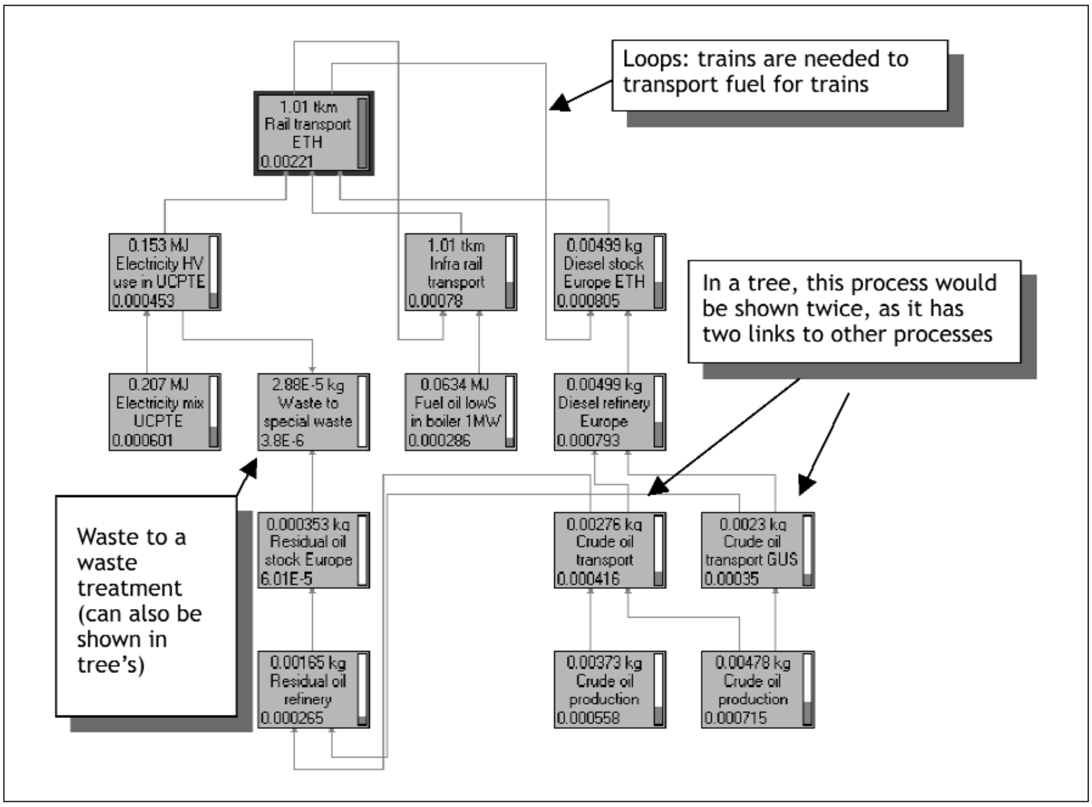


Figure 21
Example of a network representation that contains loops, here the average mix of electric and diesel trains is shown. Only the most relevant of in total 500 processes are displayed

6.6 Understanding the structure of the database

Once you start working with SimaPro you will start to change the data in SimaPro, and if you are not carefully managing the data quality in the database, you risk that this data will become increasingly unreliable. In this paragraph, we will describe some of the risks and we will give suggestions for a proper database management.

The SimaPro database is structured in three main parts:
1. Project data. Here you store all specific data for the project you are currently performing. Except for the light version you can create any number of projects in your database, in order to keep all you data apart and to facilitate the archiving of project you do not longer want to keep.
2. Library data. This contains data to serve as a resource for your projects. The structure of libraries is very similar, but the intended use is different.
3. General data. Here the common supporting data for all libraries and projects is stored, such as unit conversion factors and the central list of substance names.

Libraries and projects can both store the following data:

Definition of the goal and scope for this particular project or library
- Definition of the desired data quality profile for this particular project or library
- Process data
- Product stage data
- Impact assessment methods
- Data on interpretation of the results
- Scripts
- and some other data types not discussed here

This means both the library and the project can contain all relevant data for a particular LCA study.

Normally you should not edit the contents of libraries, as it is important to maintain a reliable resource for your future projects. If you need to edit data, it is strongly recommended to copy the data from the library into a project, and make the change there. (Always document such changes in the comment fields). In the Light version, you cannot change libraries. In the multi-user version, only the database "manager" can change data in the libraries.

Libraries tend to have their own "methodological character" as they are usually coming from one single source. Some libraries are typically relevant for Europe, some for the US, while others for example represent data from one country only; other differences could be in the way system boundaries are applied. For example in the ETH, library capital goods are in principle included for energy and transport systems.
The "character" is described in the goal and scope section of the library and in the setting of the data quality indicators. It is good practice to critically analyse which libraries you consider to be suited for a certain project. SimaPro supports this. In each project you can include or exclude certain libraries. If you exclude a library, this information cannot be used in the project. (You can always change this setting while the project is developing).

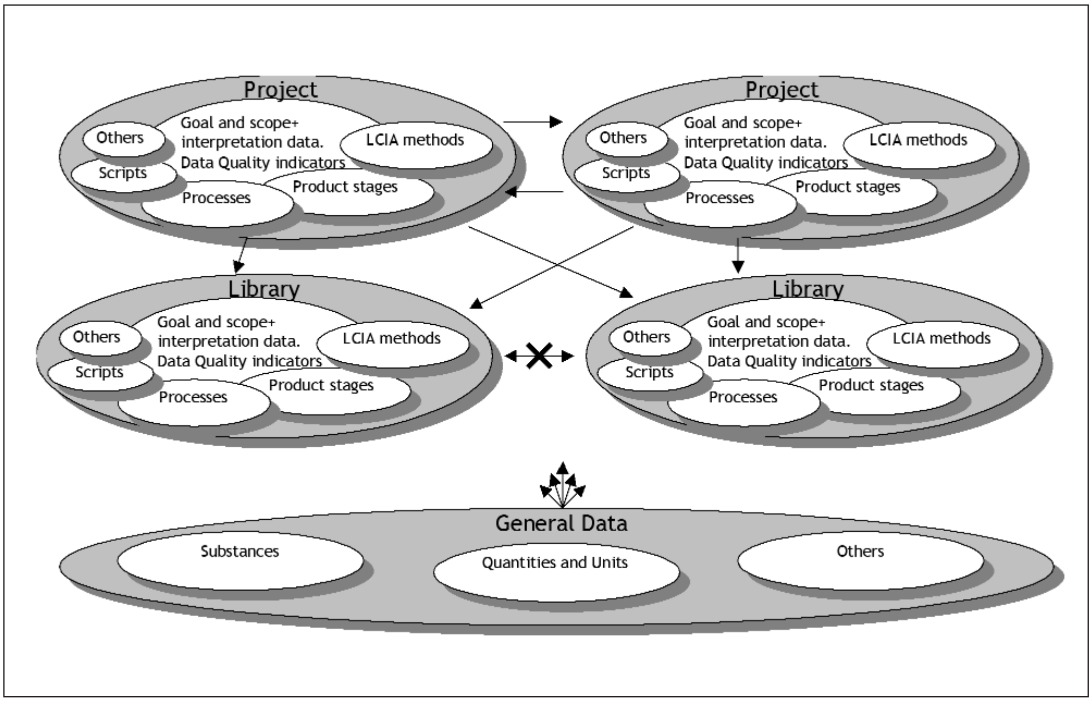


Figure 22,
Graphical representation of the database structure.
The arrows indicate dependencies. Not all data types are specified, they are referred to as others.

7 Index

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