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Handbook on Environmental Assessment of Products

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Preface to the series

The life-cycle perspective and life-cycle assessments are central elements in any product-oriented environmental initiative. Enterprises today need thorough and well-founded methods for life-cycle assessment. They also need simple, easily accessible methods which reflect a life-cycle perspective.

The best choice of method depends on the relevant objective, target group, intentions for publication, etc. All life-cycle assessments do, however, share one common feature: they should yield robust results. Results which provide a good basis for the decisions to be made.

During the last ten years, subsidies have been granted for a number of projects on life-cycle assessments and life-cycle perspectives. Similarly, the "Programme for Cleaner Products, etc., 1998 – 2002" will grant subsidies for new projects.

From the year 2000 onwards, the main results of projects on life-cycle assessments will be published as a "mini series" as part of the Environmental Protection Agency's series Miljønyt – Danish Environment Newsletter.

As the projects are completed, they will supplement the results of the 1996 EDIP project. The combination of the various tools and lessons learnt and the advice, assistance, and guidance provided will form a good basis for most life-cycle assessments.

Life-cycle assessment is such a comprehensive concept that it would hardly be possible to write a single book which covers all situations and all applications of life-cycle assessments. It is the hope of the Danish Environmental Protection Agency that this "mini series" can provide an overview of the support available to companies, organisations, authorities, and others who wish to adopt a life-cycle perspective in their work.

The Danish Environmental Protection Agency, May 2000

Contents

Preface

This handbook on environmental assessment of products contains guidelines on how to carry out simplified life-cycle assessments.

The handbook has been created for small and medium-sized companies. The objective is to enable persons with knowledge of general environmental issues to carry out much of the work themselves.

The handbook comprises three parts: an introduction, a so-called Cookbook, and a number of appendices. The introduction, Part A, contains three sections. You should familiarise yourself with its contents before carrying out any actual work. Part B, the Cookbook, contains specific instructions on how to carry out environmental assessment and can be used for support whenever an environmental assessment is prepared. The last part – the appendices – is used for reference purposes.

The actual method for simplification of environmental assessment, including the MECO principle, was developed by Henrik Wenzel and Nina Caspersen (from the Institute for Product Development) and Anders Schmidt (from dk-TEKNIK). Their work was carried out in connection with the project "Stimulation of small companies' work with cleaner products", as reported in Wenzel et al., 1999.

This handbook was prepared as a joint effort involving the Danish Technological Institute and the Institute for Product Development during the period 1999–2000. The contributors were Kirsten Pommer and Pernille Bech from The Danish Technological Instititute and Nina Caspersen, Stig Irving Olsen, and Henrik Wenzel from the Institute for Product Development.

The following companies participated in the preparation of this handbook:

A/S Kaj Neckelmann	Damixa A/S
Egen Vinding og Datter ApS	MetroTherm A/S
NJA Møbler A/S	Nordisk Wavin A/S
Olf Stadsing Danmark A/S	THERMOFORM A/S
UREFLEX A/S	VIKAN A/S

The handbook ties in with a work report which explains the simplifications applied in this handbook in relation to the EDIP method.

Part A Introduction

Introduction

The objective of this handbook is to provide instructions on how to carry out life-cycle assessments of one or more products in accordance with the life-cycle principle.

The handbook is based on the EDIP method, but a number of simplifications have been introduced in order to make the work easier while still ensuring reliable results. EDIP is short for Environmental Design of Industrial Products, in Danish UMIP – Udvikling af Miljøvenlige IndustriProdukter, a method developed by the Confederation of Danish Industries, five Danish companies, and the Institute for Product Development. This work was carried out during the period 1991 to 1996 with funding from the Danish Environmental Protection Agency.

The project "Stimulering af mindre virksomheders arbejde med renere produkter" ("Promoting small-scale enterprises' work with cleaner products") [Wenael et al., 1999] included the development of a very simple screening method for environmental assessments. Lessons learnt from that project have been incorporated into this handbook.

Emphasis has been placed on providing simple and specific instructions on how environmental assessments should be carried out. The objective of these instructions is to enable employees from small and medium-sized companies to carry out the tasks themselves.

1.1 Why carry out environmental assessments?

In recent years, there has been a shift in developments within environmental issues: attention is no longer focused on processes and production forms. Instead, most issues are approached from a product perspective.

A "product perspective" means that a broader perspective is adopted: in addition to considering environmental issues associated with the actual production carried out at companies, attention is also given to the raw materials used: what happened to them before they arrived at the company? The question of what happens to the product once it has left the factory is also considered, including its impact while in use and when it is disposed of.

This holistic approach – or life-cycle perspective – is the foundation for Danish environmental policies. It takes on more concrete form in the Danish Environmental Protection Agency's strategy and action plans for the years to come and is commonly referred to as the "Product-Oriented Environmental Initiative".

Environmental issues are becoming a competitive parameter for many companies. Many of the stakeholders, customers, etc., of companies are interested in the environmental conditions or environmental standards for production and products. The environmental standards of companies can be illustrated by means of an environmental assessment in accordance with the life-cycle principle.

The life-cycle principle is a crucial element within many contexts. It is at the root of the criteria for eco-labels, environmental consumer information labelling, and other environmental assessments of products where the intention is to communicate information from manufacturers to consumers.

Environmental assessments according to the
life-cycle principle are also gaining a firm foothold within production companies. For a number of years now, large-scale companies have addressed life-cycle aspect considerations in their product development, adjusting the materials used – both in terms of choice and quantity – on the basis of environmental assessments of the entire product life-cycle. The results of environmental assessments have also been used in connection with marketing.

1.2 How can small companies carry out environmental assessments?

1.2.1. Preconditions

Embarking on an environmental assessment requires some insight into and interest in environmental matters. It also takes time.

We recommend that environmental assessments are carried out in stages:

- Stage one can be carried out by the company itself, if it has an employee with experience of day-to-day environmental work. This step comprises the initial environmental assessment.
- Stage two requires significant knowledge about how environmental impacts are measured, and what they mean. Outside assistance will be necessary in most cases. This stage comprises the next steps of the environmental assessment and the expanded chemical assessment.

If a small company has one or more persons who has already worked with environmental initiatives, e.g. preparation of environmental permits, environmental reviews of companies as a prelude to environmental management, or similar knowledge of environmental matters, a lot of the work can be carried out without any outside assistance.

The Handbook provides instructions on where it would be relevant to incorporate consultants or experts, and where it would be advantageous for companies to carry out the work themselves.

1.2.2 Who should carry out the work?

It is important that the management has actively decided that there is a need to carry out environmental assessment. It is also important that the management helps define the task. The management should decide:

- What the environmental assessment should be used for and who will use it.
- Which product/products will be assessed.
- What resources the company will allocate in the form of man-hours from in-house staff as well as from external experts, etc.

Once these matters have been decided on, it is important to assign responsibility for the task within the company. One person should be appointed as responsible for the overall project. The people who are to take part in the work carried out should also be identified. They should be familiar with environmental issues, production conditions, and procurement.

For successful results, it is important that the person responsible for the task has a certain level of competence within environmental matters. The person responsible should know how to measure and describe inputs – incoming flows of materials and energy – as well as outputs in the form of emissions to air and water.

In some cases, it is necessary to compile quite extensive data. As a result, it is important that the person responsible has the ability to work systematically, to assign the relevant priorities to the efforts made, and to create an overview of all the details of the task.

Naturally, the timeframe for completion of an environmental assessment depends on the product(s) chosen, on the relative difficulty of obtaining data, and on the prior knowledge of environmental assessments among the project participants. Completing the first stage of an environmental assessment which involves a comparison between two relatively simple products will take approximately 100 hours the first time it is done.

1.3 What are the principles of LCAs?

The acronym LCA is short for Life-cycle Assessment. An LCA of a given product describes the most significant environmental conditions applying throughout a product life-cycle – right from the extraction of raw materials through production to use and disposal.

1.3.1 The method used

The main principles for carrying out an LCA are described in the international standards ISO 14040 to 14043.

The principles are based on four main elements. These are illustrated in Figure 1.1.

Figure 1.1
The main elements of an LCA

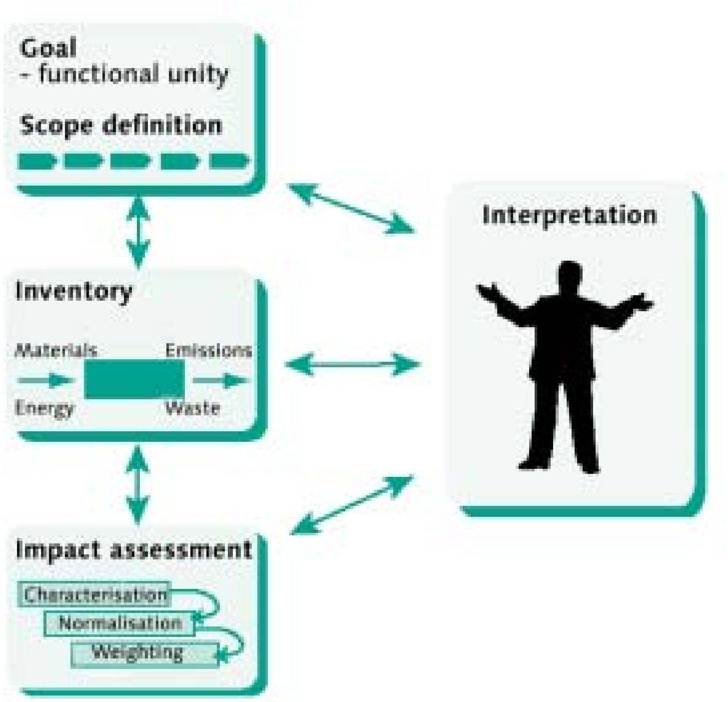


Figure 1.1 illustrates the usual progress back and forth between the various elements. For example, it is only natural to reassess the goals and scope definition once the inventory has been taken.

The principles used as the basis of this handbook take the four main elements as their point of departure. Start by going through these elements on a preliminary scale and draw your initial conclusions. You can then choose to establish a more detailed data basis and carry out the LCA for selected parts of a life-cycle or for the entire life-cycle. This is described in more detail in Chapter 2.

The four main elements and the most significant tasks within each element are described below.

1.3.2 Goal and scope definition

Start by establishing what you want to show with your environmental assessment. Identify what products the assessment should include, and what the results are to be used for.

It is very important to define the goal of the environmental assessment. You also need to be very clear on what you want to include in your impact assessment and what you wish to omit.

First the product and its performance needs to be identified. For example, the performance of a coffee maker may be to brew 1 litre of coffee twice a day for five years.

If two or more products are being compared, they all need to be defined. This is important, as only products with identical performances can be compared. The approach is described in the Cookbook (part B), section 1.3.

The scope is defined by describing the total lifespan of the relevant product or products. The lifespan of a product is commonly divided into five life-cycle phases:

- Raw materials phase
- Production phase
- Use phase
- Disposal phase
- Transport phase

The raw materials phase comprises extraction and processing of raw materials. This might, for example, involve extraction of iron ore which is then processed to form steel, or extraction of crude oil which is processed at a refinery to produce oil products. This is where you define which raw materials are included in the assessment.

The production phase comprises the company's activities in connection with production of the product itself. You should include all processes and activities that are important to the production of the product. The importance of these processes and activities is decided on the basis of consumption of raw materials, energy, and ancillary materials.

The use phase covers the activities that take place from the time the product leaves the company and until it is discarded. If the product in question is a refrigerator, its consumption of electricity is interesting. If it is a coffee cup, day-to-day cleaning is interesting. This phase is important for some products, whereas the use of other products does not involve issues of significance to the environment.

Disposal of the discarded product depends on the type of product in question. In Denmark, waste treatment of household waste and some industrial waste is mostly carried out by means of incineration. Recycling will be relevant for other types of discarded products. Often, the opportunities for recycling are determined by the choice of raw materials (metals can be recycled and reprocessed, while certain types of plastic cannot).

The transport phase comprises transport of raw materials to the manufacturer, transport from the manufacturer to the consumer, any transport taking place while the product is in use, and transport from the consumer to the place of recycling or incineration.

The Cookbook contains instructions on how to
define the scope of product life (Part B, Chapter 2).

1.3.3 Inventory

All incoming and outgoing flows during the product life-cycle must be identified. The incoming flows comprise the raw materials, ancillary materials, and energy used. The outgoing flows comprise emissions to air and water and waste. The main elements of the inventory are illustrated in Figure 1.2.

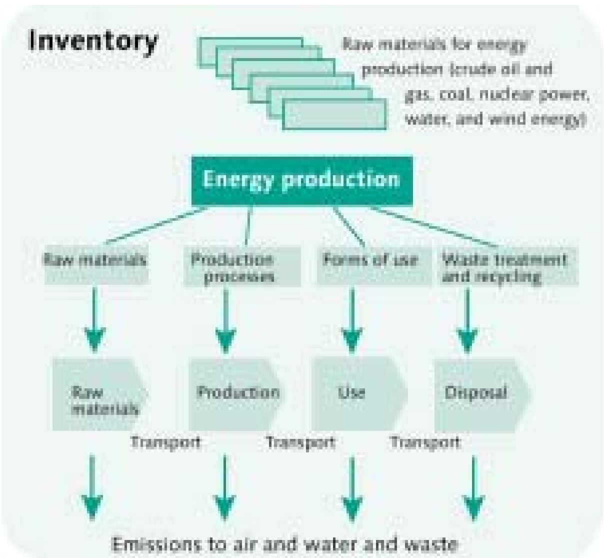
Energy, in the form of electricity, heat, and fuels, is used during the product's life-cycle. Generation of electricity and heat and extraction of raw materials for this purpose should be included in the calculations. This is illustrated at the top of Figure 1.2.

The inventory also involves assessment of the data used. The level of uncertainty associated with the data used and any lack of data should be considered.

The inventory is then interpreted with due consideration given to any uncertainties and lack of data. During this process, you should never lose sight of whether the original goal and scope definition is still appropriate for the work carried out.

A special PC tool has been developed for the EDIP method, consisting of a calculation programme with a database. The Handbook provides specific instructions on how to use a simplified version of the EDIP method which requires nothing more than a pocket calculator and a piece of paper. Also provided are instructions on when it may be relevant to use the PC tool, i.e. when a more detailed LCA is called for.

Figure 1.2
The main elements of LCA inventories



1.3.4 Impact assessment

The impact assessment involves three levels. These levels are based on the inventory and are arranged in logical succession. The three levels are known as:

- Characterisation
- Normalisation
- Weighting

The correlation between the three levels of the impact assessment is illustrated in Figure 1.3.

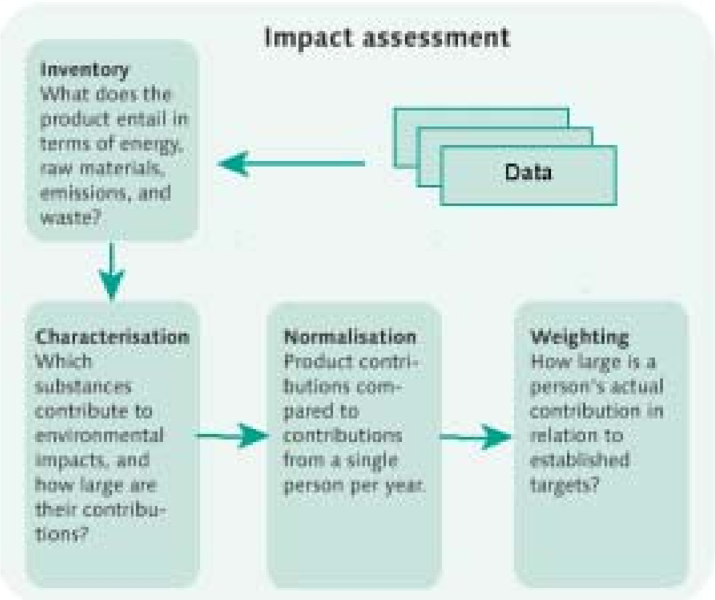


Figure 1.3
The three levels of the impact assessment

1.3.4.1 Charactarisation

The total inventory extends to material and energy consumption, emissions, and waste from the entire life-cycle of the product.

"Characterisation" means that the inventory is translated in terms of environmental impact. A set of environmental effects has been defined, with each effect illustrating the impact on certain conditions within the surroundings. Some effects show something about impacts in the immediate environment, while others demonstrate impacts within a wider perspective and yet others illustrate impacts on e.g. human beings.

Emissions and waste are classified in accordance with the environmental impacts to which they contribute. For example, carbon dioxide contributes to the greenhouse effect, while sulphur dioxide contributes to acidification. Some substances contribute to several impacts simultaneously. Calculations of environmental impacts are carried out by means of various units. The greenhouse effect, for example, is measured in CO2 equivalents. All emissions contributing to the greenhouse effect are converted into CO2 equivalents. This is precisely what is known as "characterisation".

The method used here groups the impacts into three categories: global, regional, and local impacts. The effects are illustrated in Table 1.1.

The incoming flows – consumption of raw materials and energy – are included in the inventory of resource consumption. The values for consumption of raw materials and energy are calculated for each individual type of material.

Each of these impacts "measures" different aspects of the environmental impacts. They cannot be compared directly, nor can they be assessed as a whole.

Table 1.1 Environmental impacts

Category	Impact	Substances contributing to the impact
Global	*Greenhouse effect*	Carbon dioxide and other greenhouse gases.
	Ozone depletion	CFCs and other, similar substances which degrade the ozone layer.
Regional	*Acidification*	Acidic compounds, mainly of nitrogen and sulphur, which cause acid rain.
	Nutrient salt loads	Emissions of nitrogen and phosphorus contributing to algae growth and oxygen depletion.
	Photochemical ozone formation	A mixture of organic solvents and nitrogen compounds which cause ground-level ozone.
Local	*Human toxicity*	Emission of toxic substances which may affect human beings in the short term.
	Eco-toxicity	Emission of toxic substances into the aquatic environment or into soil which may affect animals, plants, and other organisms in the short term.
	Persistent toxicity	Emission of toxic substances which are non-degradable or very slow to degrade. These substances affect human beings, animals, and plants in the long term.
	Waste	
	Bulk waste	Usually at landfills.
	Slag and ashes	Usually at special waste disposal sites.
	Hazardous waste	Requires special treatment.
	Radioactive waste	Requires special treatment.

1.3.4.2 Normalisation

Normalisation means that the environmental impacts are considered in relation to the average impact caused by a single person.

Normalisation of resource consumption means that the relevant consumption is considered in relation to the amounts of the relevant resource consumed by an average person during a single year. The environmental impacts are compared to the average contribution caused by a single person. During normalisation, calculations of resource consumption and environmental impacts are carried out in person equivalents.

The objective of normalisation is to provide targets for the relative size of environmental impacts and resource consumption in relation to the overall environmental impact. Normalised environmental impacts and resource consumption can be compared.

1.3.4.3 Weighting

The significance of resource consumption and environmental impacts seen within an environmental perspective can be expressed by converting the normalised person equivalents to a weighted person equivalent.

Weighting means that resource consumption for each individual raw material is placed in relation to the so-called supply horizon, i.e. the share of the resource available to a person and all his/her descendants at global level. The weighted resource consumption is calculated in Person Reserves, often expressed in milli-Person Reserves, mPR.

When weighting environmental impacts, each individual environmental impact is compared to the political reduction target (for Denmark or for the world). The weighted environmental impact is calculated in milli-person equivalent-targeted (often shown as mPEM).

When you carry out an impact assessment of a product, the most significant environmental impacts and types of resource consumption can be determined. It is also possible to identify the conditions which make them so significant.

When comparing two products, resource consumption and environmental impacts are compared individually. This makes it possible to identify the most significant impacts as well as the conditions governing the relative environmental impact of the two products.

This method recommends the use of weighted results. Weighted results incorporate an assessment of the relative significance of the environmental impacts.

Please note that the normalised and weighted results of the inventory are based on the principles of the EDIP method. If these results are compared to environmental impact assessments carried out in accordance with other methods, differences may occur.

1.3.5 Interpretation

Figure 1.1. illustrates how interpretation is relevant to each of the three other elements (goal and scope definition, inventory, and impact assessment).

When carrying out interpretation, it is important to:

- Compare the results of the impact assessment with the goals established
- Take into account the scope definition and preconditions established at the outset and during the course of the project.
- Take into account any uncertainties and lack of data in the inventory.

The impact assessment, based on weighted environmental impacts and resource consumption, must be interpreted and compared against the goal of the environmental assessment.

It will not always be possible to draw the conclusions you need. For example, lack of data, elements of uncertainty, or necessary delimitations may mean that it is impossible to identify differences or

similarities between two products. This is why figure 1.1. shows that it may be necessary to return to
a previous step to carry out additional work or adjustments.

1.4 References

The principles of the simplified method are described in Chapter 2, and Chapter 3 provides examples of what environmental assessments can be used for – and what they cannot be used for.

A more in-depth description of the actual method and its principles would be beyond the scope of this Handbook. For information on these issues, please refer to the EDIP books [Wenzel et al., 1996].

2. The simplified LCA

The life-cycle assessment described in this Handbook is different from the standard LCA in two crucial respects:

1. Data collection is limited, as attention is mainly focused on inputs (raw materials and ancillary materials)
2. Environmental assessment is carried out as the level of detail grows.

The main element of simplification concerns the preliminary environmental assessment. It is then possible to work towards an increasingly detailed LCA, although more detailed impact assessment will typically only be carried out for a limited area. This is the main concept behind the stepwise method – a key element of the simplified environmental assessment.

The simplification may be so pronounced that the end result is not a life-cycle assessment, but merely an environmental assessment based on the life-cycle perspective.

2.1 The principles behind the simplification

There is widespread agreement that the main elements of the LCA cannot be compromised. This is to say that you cannot decide to omit consideration of the goal and scope definition (see Chapter 1) or limit yourself to addressing specific phases of the life-cycle [Christiansen et al., 1998] when you wish to simplify the LCA. Rather, simplification is carried out by limiting the collection of data, which is usually the most time-consuming task.

The next principle of this simplification is to work step by step, continuously assessing whether the questions asked can be answered with sufficient certainty on the basis of the steps completed so far.

Examples of questions that help establish an overview of a product life-cycle would be:

- Where in the product life-cycle do the most significant negative environmental impacts occur?
- What activities cause the most significant negative environmental impacts?

Later, it may be relevant to ask more specific questions, e.g.:

- Is it better to use plastic than recyclable copper (for a specific component)?

The simplified environmental assessment is a tool for finding answers to such questions, but there may be considerable uncertainties involved. If so, more information must be collected and the procedure must be repeated.

The difference from a traditional LCA is that this additional data collection can be restricted to a smaller sub-segment of the life-cycle or product. If, for example, you are examining a water heater and it turns out that heat losses during the use phase is the most important issue, you can focus exclusively on collecting further data about that.

2.1.1 Why stepwise LCAs?

Working step by step is the key. This approach ensures that you do not work harder than is necessary. At the same time, the work carried out during the initial steps can be used later as the process develops. For each step, you must consider whether the conclusions that can be drawn might change if new information is introduced. If it seems likely that the conclusions would change, you should continue your work.

The process can be visualised as a pyramid:

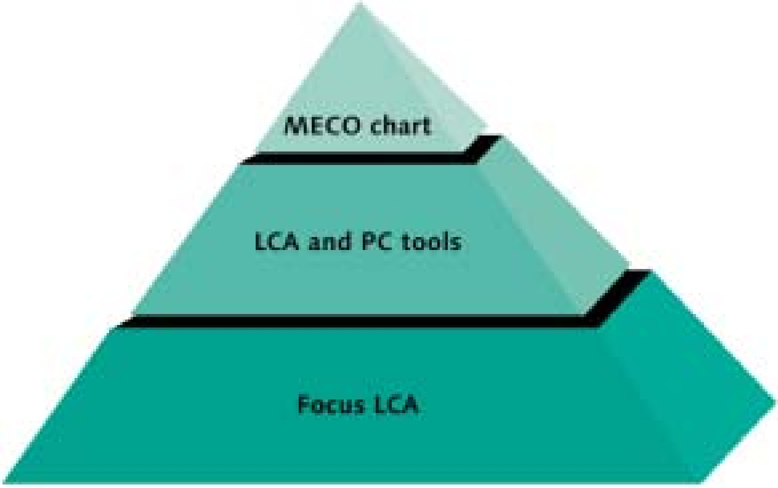


Figure 2.1
Stepwise structure of the simplified LCA

The MECO chart provides an overview of the relevant product life-cycle. It presents indicators for environmental impacts within the following categories: Materials, Energy, Chemicals, and Other. The MECO chart is prepared at the same time as the preconditions for the system and a description of the phases completed by the product. All this information can be used in subsequent work with environmental assessment by means of a PC tool. It just means that more data will be fed into the model. The Focus LCA is not addressed individually, as it is an extension of the environmental assessment in the PC tool. In Focus LCAs, extra data is collected to focus on individual areas.

The pyramid (figure 2.1) symbolises how the level of detail and the amount of work increases as you work your way towards the bottom of the pyramid. It also shows how each step always makes use of data and knowledge from the preceding steps. You can stop after the first step, or you can elect to continue.

The approach used in this Handbook is illustrated in figure 2.2. The figure shows the steps involved in environmental assessments and the places where it may be necessary to collect further data and information or to speak with others.

> It is important to remember that environmental assessments cannot be carried out without entering into dialogue with others from the company, a network outside the company, or an external expert. This must be done in order to ensure that the environmental assessment is reliable.

All steps are carefully described in Part B of this Handbook, also known as the Cookbook. For now, here is a brief rundown to provide an overview of the approach.

Step One (1) is to select the product and define the goal of the environmental assessment. The goal is very important, and discussion with others is particularly important as this stage. The final results will be compared to the goal, and if the goal is not sufficiently clearly defined, you have no way of knowing whether you have enough information. More details on this issue can be found in Chapter 1 in Part B.

The life-cycle of the product (2) is a description of what happens during the individual phases, i.e. raw materials, production, use, disposal, and transport. If you recognise large gaps in your data basis at this early stage, you should seek out more information. A more detailed description of the methods used for this purpose is provided in Chapter 2.

The information about the product life-cycle forms the basis for the preliminary environmental assessment (the MECO chart (3)). This environmental assessment takes the form of a chart illustrating the life-cycle phases and sources of environmental impacts in visual terms, see table 2.1. The guidelines on how to carry out simplified environmental assessments can be found in Chapter 3.

The MECO chart is used to carry out an inventory and an impact assessment at the same time. The advantage of the MECO structure is that the individual sources of environmental impacts do not, in fact, overlap, and that it covers all significant environmental issues. This means that it is possible to assess whether any weighting problems exist, e.g. between energy consumption and chemicals.

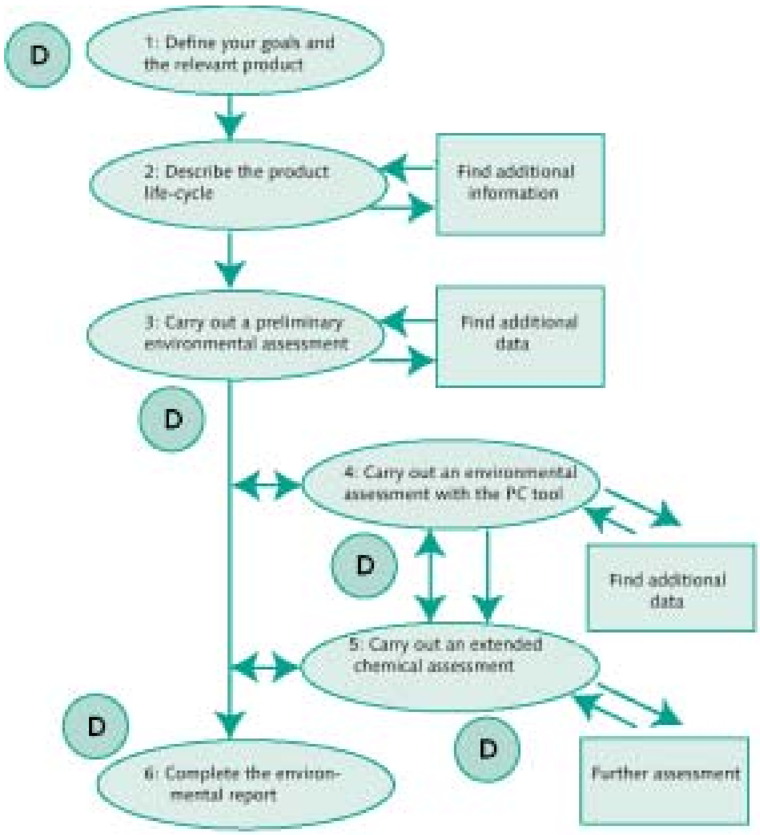


Figure 2.2
The steps of the simplified LCA. D stands for "Dialogue", i.e. a discussion with a relevant party. The numbers refer to the chapters in part B, which provide more in-depth descriptions.

The stages leading up to and including the MECO chart constitute the preliminary environmental assessment and the first step of the simplified LCA. At this point, it is important to pause and consider whether the chart provides a sufficient basis for making the desired conclusions, or whether you need to move on to the next step. A dialogue box has been inserted to emphasise that you need to discuss this with someone else. In particular, you should team up with an "expert" to decide whether you should move on to the extended chemical assessment or some other type of impact assessment which is outside the scope of this handbook.

Table 2.1
The MECO chart used for the preliminary environmental assessment

	Raw materials	Production	Use	Disposal	Transport
Materials					
Energy					
Chemicals					
Other					

You can also stay at the MECO chart level to find additional data.

It should be emphasised that the MECO chart comes with appendices with data (appendix B at the back of the book) that make it possible to fill in the chart using nothing more than paper, a pencil, and a pocket calculator.

Once the MECO chart has been completed, you need to assess whether you have a sufficient basis for answering the questions posed, or if you need to continue your work.

Possible reasons for wanting to continue an LCA by means of a PC tool (4) include:

- A desire to weight various environmental impacts
- A desire to have a model which can be adapted to suit similar products quickly and easily
- A need to make use of databases
- A need to incorporate greater detail as regards inputs and outputs than the MECO chart allows for.

The extended chemical assessment (Chapter 5) represents another opportunity for carrying out further work. No matter which environmental assessment you choose, the results must be documented in a report (Chapter 6).

The central element of the simplification is an assessment of the reliability of the LCA results in relation to the goal. The simplified LCA is based on the recognition that some conclusions can be made at MECO chart level, while others can only be made later. This means that you need to make your work target-specific, making conclusions only when your basis for doing so is sufficiently certain. Special attention should be paid to the fact that results which are to be used externally, i.e. outside of your company, must be very reliable.

2.2 Comparing ISO, EDIP, and the MECO chart

Table 2.2 features a comparison of the general principles for life-cycle assessment according to the ISO 14040 series, EDIP, and the MECO chart. Comparisons show that the overall principles for ISO and EDIP are identical, whereas the MECO chart differs from the others in terms of scope definition, data collection, and impact assessment.

The philosophy behind the principles of the MECO chart is that if an environmental assessment can be carried out in a simple way; that is exactly what you do. This is why a number of simplifications have been introduced when compared to ISO and EDIP. These simplifications make it easier to carry out environmental assessment, but also limit the potential uses of the result. Most companies will, however, benefit greatly from a simplified environmental assessment.

As regards data collection, minimum requirements (on the raw materials and production lists) have been defined for the MECO chart, but you can still add more data. The assessment of resource consumption runs parallel to the one carried out within EDIP, but apart from this, assessment by means of the MECO chart is simpler.

Energy is converted into primary energy and resource consumption values on the assumption that the energy consumed comes entirely from oil. This is a somewhat crude assumption, but it is useful when relating resource consumption from raw materials to energy consumption.

It is difficult to simplify environmental assessment for chemicals. Here, inputs (i.e. chemicals consumption) are also used as the basis. Each chemical is classified according to whether it is listed on the List of Dangerous Substances, the List of Undesirable Substances, or the Impact List. This is why it is often necessary to carry out an extended chemical assessment for products which contain many chemicals.

These differences apply only to the preliminary environmental assessment. When an LCA is carried out by means of a PC tool, you will mainly use existing data, and you may also be considering only a small part of the total product life-cycle. The extended chemical assessment falls outside the scope of the LCA, but the information gathered could be used to calculate factors for toxicity which could then be used later within the PC tool.

Table .2 Comparison between ISO, the EDIP method, and the MECO chart

	ISO	EDIP	Preliminary environmental assessment MECO chart
Goal definition	Must be defined.	Must be defined.	Must be defined.
Scope definition	All significant processes in the system must be included.	All significant processes in the system must be included.	Raw materials: significant raw materials are included. Production: Focus is placed on chemicals and energy consumption. Use: significant processes are included. Disposal: significant processes are included.
Data collection Input	All must be included (if possible). State the reason for any omissions.	All must be included (if possible). State the reason for any omissions.	Derived from the list of product composition and the processes associated with it (discards and production waste are not included).
Data collection Output	All must be included. The reason for any omissions in terms of quantity, energy, or the environment must be stated.	All must be included (if possible). State the reason for any omissions.	Outputs are represented by inputs. Outputs are, however, included if the information is easily available.
Impact assessment	Emissions, etc., must be collected in groups of environmental impacts. Environmental impacts are calculated on the basis of international models for substance contributions. Normalisation and weighting which relate environmental impacts to background loads can be carried out.	Emissions, etc., must be collected in groups of environmental impacts. Environmental impacts are calculated on the basis of international models for substance contributions. Normalisation and weighting which relate environmental impacts to background loads and the Danish reduction objectives will be carried out. Resources are assessed in relation to production per person and the supply horizon for each individual resource.	Assessment is carried out within these groups: Materials (resources and waste) Energy Chemicals Other Application of environmental indicators: Resources are converted into person reserves, as seen with the EDIP. Energy is converted into primary energy, which is in turn converted into person reserves. For chemicals, it is defined whether the substance is problematic on the basis of its appearance in various lists.
Interpretation	Must be included.	Must be included.	Must be included.

3. What can the environmental assessment be used for?

Companies have a wide range of objectives when carrying out environmental assessments. You should, however, be aware that different purposes equal different requirements in terms of documentation.

The LCA can be used for:

- Internal use in connection with product development
- Internal prioritisation of environmental initiatives (particularly in connection with environmental management)
- Improved dialogue between authorities and/or suppliers
- Internal training in connection with environmental management
- Environmental documentation aimed at customers, authorities, or in-house information
- Marketing

You should be aware that the requirements for documentation are more severe when the LCA is used outside of the company. If a company wishes to use an LCA as an internal prioritisation tool, either for environmental management or product development, the requirements are relatively low. In such cases, companies are free to set their own limits. If the LCA is to be used for marketing or environmental documentation, however, requirements for reliability, data quality, etc., are much higher.

3.1 Marketing

Marketing is typically defined as either active or passive. Passive marketing means that you have some information lying around in a drawer and will hand it out if asked. Such documentation usually concerns your product only and does not include comparisons with other manufacturers' products. Even though customers ask for such information themselves, you should still make sure that the documentation is solidly founded.

Example A3.1: Environmental information
For a given company, an order depended on whether it was able to document the environmental properties of its product. Fortunately, the company had previously carried out an environmental assessment which just needed a few updates. After two days, all documentation was ready, and the company got the order.

"Active marketing" comprises brochures or advertisements where manufacturers make claims about their environmental excellence. Regardless of whether manufacturers make a direct claim that they are better than their competitors, the messages may well imply that they are better than others. Such claims must be very carefully documented, and the Danish Marketing Practices Act lays down rules on this. [The Consumer Ombudsman, 1999]. A leaflet on environmental marketing explains them in the following terms:

If you wish to use general phrases like "environmentally friendly", "friendly to nature", "green", "nature", "clean nature", or "organic", you must first have completed a thorough account of the entire product life-cycle.

Life-cycle assessments must be carried out in accordance with recognised or generally accepted methods for the relevant product type. If such methods have not yet been developed for the area in question, this in itself constitutes a strong argument in favour of omitting general phrases such as "environmentally friendly" and the like.

We recommend that you team up with experts who can ensure the quality of your assessment if it is intended for marketing. Moreover, the MECO chart cannot be regarded as a "thorough account of the product life-cycle, carried out in accordance with recognised or generally accepted methods". The MECO chart can, however, be used to document reductions in energy consumption during the production phase and similar matters.

3.2 Environmental management

Environmental management does not require an LCA of the products manufactured by the company, but product life-cycles do come up in such discussions, and it would be natural to explore this area further once the environmental management system is in place. The data basis established will typically provide an excellent basis for continuing with LCAs.

If you wish to use LCAs while assigning priorities to environmental initiatives as part of environmental management at your company, it would, however, be a good idea to supplement your work by taking a look at working-environment issues as well. Similarly, noise issues are usually not included in an LCA.

Example A3.2: Assigning priorities to environmental initiatives
A company has introduced an environmental management system, but has difficulties assigning priorities to the initiatives taken.
An environmental assessment shows that the use phase of the product makes the most significant contribution to its overall negative environmental impact. As a result, actions to reduce the environmental impact of the use phase must be formulated. However, the environmental assessment also makes it clear that it is important to look beyond one's own fence. For example, greater use of subcontractors would lower the negative environmental impacts generated by the company itself, but the negative environmental impact of the actual product might increase.

LCAs are excellently suited as part of training programmes in connection with the environmental management system. For example, such training might include a presentation of an environmental assessment of a product manufactured by the company.

3.3 Product development

Applying an LCA during product development means that you have an opportunity to change the environmental properties of the product in question before it goes into production, rather than simply identifying the properties of an existing product.

You will usually start by preparing an environmental assessment of a reference product – i.e. an existing product – to identify the most important negative environmental impacts. The next step is to find the areas where the environmental impacts can be reduced. Opportunities for reduction are not always associated with the greatest environmental impacts. For example, refrigerators use energy for cooling purposes, but it would not make sense to reduce their energy consumption by increasing the temperature in them, as this would defy their purpose. However, heat losses can be reduced by improving insulation.

As you review a product, you have the opportunity to see it from a different angle. You will probably find yourself questioning certain procedures or choices – and it is likely that you will discover scope for improvements.

Example A3.3: Product development
The initial study of a given product revealed that extensive amounts of brass were used to manufacture it. Brass contains copper and zinc, both to them resources which are in short supply. It turned out that it was not necessary to use such large amounts of brass, and the quantities used were significantly reduced in the new model. The result was a cheaper and more environmentally friendly product.

3.4 LCA can be used for dialogue

LCAs typically lead to conclusions or discoveries which can be used in internal or external dialogue. For example, the environmental department at your company might need information as part of their dialogue with the procurement or product-development departments. The company might also want to use LCAs to establish a more positive dialogue with the authorities. Finally, environmental assessment can be used for dialogue within the product chain, i.e. the chain linking suppliers to the company to the customer. Once again, documentation requirements are stricter when the LCA is used externally, even if it is only used as a tool for dialogue.

Example A3.4: Environmental assessment as the basis for dialogue

The environmental department of a given company wished to improve the environmental properties of the company's product range, but had some difficulties in making other stakeholders within the company understand and appreciate what could be done. An environmental assessment of one of the products was made, and the product-development department was asked to supply lists of the materials and processes used and to make suggestions for product changes. In this way, the product-development department was suddenly able to see the environmental consequences of various changes. The result? People practically started competing in their eagerness to make the most efficient environmental improvements.

Part B Cookbook

1. Define the task

1.1 Describe the goal of the environmental assessment

The goal and scope definition of the environmental assessment depends on its intended use. When you need to decide whether you have reached a sufficient level of detail, you compare the environmental assessment with the goal definition. Instead of stating a goal such as "product development", it may be easier to relate to specific questions. Later, you need to decide whether the environmental assessment provides answers to these questions with sufficient certainty.

The questions you ask may focus on establishing an overview, or they may be target-specific. When you first carry out an environmental assessment, you will typically need to form an overview. It does not matter whether this overview will be used for product development, marketing, or something else entirely. Later, when you have identified the areas which are most significant to your product, you can ask more target-specific questions.

When you want to establish an overview, you might ask questions like these:

- Which sources cause the environmental impact?
- What phases should we focus on if we wish to reduce the environmental impact of our product?
- How do we achieve the best possible value for money in environmental terms?

Examples of target-specific questions would be:

- Would it be a good idea to replace the current insulation material with expanded polystyrene?
- Would the environmental profile be improved if the brass handle is replaced by a handle made from plastic?
- Would it be better to used water-based paint instead of paint based on solvents?

1.2 Choose your product

There may be several reasons for choosing a particular product. Examples of such reasons include:

- The product is very representative of the company and accounts for most of the production.
- The product attracts a lot of attention in environmental terms among customers. For example, it may be that a buyer's guide is underway for the product type.
- It would be easy for the company to assess this particular product, and the necessary data for environmental assessment is readily available within the company.
- The company is about to develop the next generation of the product and is interested in incorporating environmental concerns when developing the new product; this is to say that the product will serve as a reference for product development.
- The product is suspected of being problematic in environmental terms, and/or there is great scope for environmental improvements.

Other issues might also enter the picture, but the reasons stated above are typical. The decisive aspect varies, and not all conditions apply to any given product.

Consider the basis for your choice of product for the environmental assessment.

If you want to establish an overview and you are carrying out an environmental assessment for the first time, you would be well advised to choose your product carefully. When you embark on your first environmental assessment, it would be best to work with a product which can be handled with relative ease– one for which data is readily available. This will keep you from running into more obstacles than are absolutely necessary as regards data collection.

If you need to use the product as a reference for product development, you should carefully consider whether it can be compared to the planned new product. For example, will the service provided by the new product be the same as for the reference product? See section 1.3.

If your goal definition includes target-specific questions, you will probably already have chosen your product. If not, you may want to consider the points outlined above.

1.3 Define the service provided by the product

The first step of any environmental assessment involves defining and describing the service provided by the product. By this, we mean anything and everything that the product delivers when meeting the user's needs. Why does the customer buy the product? What does the product deliver?

1.3.1 What is comparable?

It is important to identify the service provided by the product because an environmental assessment always involves comparisons. First of all, there are no truly "environmentally friendly" products; only products which are less harmful to the environment than comparable products. All products are made from materials which require the consumption of resources and energy. Some products, however, use less than others and so are better for the environment.

Secondly, environmental assessments are made to be used. And when they are used, it is for comparisons: What can be done in a better way? What is our position compared to the competitor's product? Even if all you really want to do is to prepare neutral environmental consumer information about a product, comparisons enter the picture: the person reading this information will assess whether it looks good or bad.

When two products are compared, or when potential changes are compared with an existing product, the service provided by the two products must be identical. You cannot compare A with B and claim that A is more environmentally friendly if A does not even supply the same service as B, meaning that customers would never buy A instead of B.

Example B1.1: The service provided by products

Hospital coats (a fictional example)

A hospital buys coats to be worn by the staff, and these coats are washed every day. Coats are washed approximately 100 times before being thrown away. They are available in pure cotton and in a mixture of polyester and cotton. For certain coats made from a blend of polyester and cotton, the cotton fibres are gradually washed out, and once they have been washed 20 times they start developing static electricity, absorb less moisture and become increasingly transparent. This makes many nurses wear t-shirts underneath their coats, which is less frequently seen among nurses who are equipped with coats made from pure cotton. This is to say that the service provided by the coat went beyond being a hygienic and suitably warm hospital uniform: it also needs to feel pleasant against the skin, absorb moisture and preserve modesty. If you fail to realise this, you will think that a coat made from cotton can be compared directly with a coat made from a polyester and cotton blend. This is not, however, the case. A cotton coat must be compared to a coat made from polyester and cotton and x per cent of a t-shirt.

Paints (a fictional example)

We buy paint to decorate and protect surfaces. Paints can be water-based or turpentine-based. Let us say that you need 1.3 litres of turpentine-based paint, but only 1 litre of water-based paint to cover a given surface. The surface is, however, located outdoors, and water-based paints do not last as long outdoors as those based on turpentine. This means that you will need to repaint the surface twice as often if you choose water-based paint. This is to say that the service provided by the product is not just to decorate and protect the surface, but to decorate and protect the surface for X number of years. The duration of the product is part of the service it provides. We initially thought we were supposed to compare 1.3 litres of turpentine-based paint with 1 litre of water-based paint. This was not, however, the case. In fact, what we should be doing was to compare 1.3 litres of turpentine-based paint with 2 litres of water-based paint.

As you can see, it is important to identify the real service provided by the product. If you make a mistake here, your environmental assessment will be very nearly useless. So be careful when you describe the service provided.

Speak to your colleagues from Sales and Marketing about the service provided by the product. They will know a great deal about the requirements and desires of customers, including end users, as these aspects are important to overall sales and marketing strategies.

In the final analysis, the customer is the one who decides what the service provided by the product really is. Not you, not anyone else at your company, not even the person who invented or developed the product (even though it would probably be a good idea to ask that person if you can get a hold of him/her). Think back to the example of the hospital coat: the nurses chose to wear t-shirts when handed polyester/cotton coats. In this way, they indicated and decided that the coats made from cotton supply a service which the polyester/ cotton coats do not provide. See example B1.1.

1.3.2 What are the obligatory and positioning properties of a product?

You need to identify the important properties of the product. The properties which customers focus on. Some properties are known as obligatory properties; they are the ones which products need to have in order to be in the market. Obligatory properties can either be born out of legislation (cars must have brakes) or fixed customer requirements which almost all products within the market fulfil (hospital coats are white, TVs have remote controls). Other properties are known as positioning properties. They are the ones which can make the product more attractive compared to other products.

The company already knows the obligatory properties. They are either laid down in the law or so firmly established within the market that it would be unthinkable to manufacture a product which does not live up to them. The positioning properties vary much more in scope and strength: some are very important sales points, while others are more marginal.

To illustrate obligatory and positioning properties in more practical terms, a coffee maker is used as an example below.

Example B1.2: A description of the service provided by a coffee maker in terms of obligatory and positioning properties.

Obligatory properties	Positioning properties
Making coffee Keeping the coffee warm Meeting CE labelling requirements, including fire safety requirements	The time used to make coffee Volume Temperature Stand-by temperature Stand-by time/automatic switch-off function Ease of cleaning Design Moveable filter element See-through pot Coffee aroma Indication of volume on the pot Indication of water level on the coffee maker Price Durability Programme functions

1.3.2.1 What market segments and niches exist?

The market can be separated into segments and niches which rank the positioning parameters in varying orders. Within one niche, price, speed and ease of cleaning may be crucial (e.g. within sales to offices and canteens), while design and aroma may be crucial factors within other segments (e.g. private homes).

1.3.2.2 Which properties are important?

Start by making a list of all the positioning properties of the product, and then consider which properties are most important within the company's main markets. This initial list represents a brainstorming process, and it is important that you are not critical during this first phase. The most important properties must be respected – including those of any new versions of the product – but the less important ones might be replaced with others or excluded altogether.

Usually, extra functionalities cost money and have additional environmental impacts, and a product with more features than the customers want will usually make little business sense and harm the environment.

Note that some products have virtually no positioning properties, while others have many.

1.3.3 Define the functional unit

It is not enough to describe the service in qualitative service as shown in table 1.1. The service provided should not just be identical in nature, but also in scope, as demonstrated by the example with the paints.

When you attribute numbers to the scope of the service, we say that you are defining the functional unit. This comprises a total of three parts:

1. A quantity (amount, volume, etc.)
2. A duration
3. Qualities/properties

The customers must perceive these factors as comparable for products which form part of environmental comparisons. This is where the obligatory properties and the significant positioning properties are addressed.

Example B1.3: Hospital coats (a fictional example)
When we used hospital coat as an example above, we forgot to address the duration of the service (how long the coats last). For poorer qualities, coats made from polyester and cotton do not last as long as coats made form pure cotton. Where a poor-quality cotton coat will withstand 60 washes, a poor-quality polyester/cotton coat might only withstand 40 washes. This is to say that you will need 50 per cent more polyester/cotton coats as well as a certain number of t-shirts to ensure the same duration of service.

Below is an example of how the functional unit can be described for a coffee maker.

Example B1.4: Functional unit for a coffee maker which is primarily sold to private, affluent homes.

	Obligatory properties	Positioning properties
Quantity	Making one litre of coffee twice a day	
Duration	Seven days a week for five years	
Qualities/ properties	Brewing coffee Keeping the coffee warm – temperature (82º Centigrade)	Brewing temperature (94º Centigrade) Maintaining the aroma Time needed for making coffee (8 minutes) Price (DKK 500 – 600) Stylish design Long life

In example B1.4 (the coffee maker), we have assumed that the product is mainly sold within the market segment "private homes", specifically within the niche "affluent homes".

This is the service which the coffee maker needs to supply in order to compete within this part of the market. New and more environmentally friendly products also need to deliver this service. Otherwise, the type of customer we cater to will not select them, and if they are not selected, no benefits to the environment will materialise. A more environmentally friendly product will only generate environmental advantages if it replaces another, more harmful product.

Below are a number of examples of definitions of the functional unit of a number of products. The products have been deliberately selected to create a table which can serve as inspiration within many different areas. Please note that positioning properties had only been defined for few of the products.

Example B1.5: Examples of definitions of functional units

Product/functional unit	Quantity	Duration	Qualitative properties
Water heater	Delivering 110 litres of water every day at a temperature of 55º centigrade	15 years	Meets the norm: NP-197-N Thermostat adjusted Safe-guarded against overflow An attractive appearance (positioning)
Drainage pipe	Leading away household wastewater in quantities of 2.2 and 46 l/sec at inclines of 1 and 400 per thousand, respectively, along a straight stretch of 10 m in length	80 years	Obligatory properties concerning peak loads or median capacity, tightness, natural purification, carrying capacity, and resistance to chemicals in accordance with DS standards
Water tap	Mixing cold and warm water to reach the desired temperature while also adjusting flow speeds	210,000 openings	Single-grip fitting. Must meet the requirements laid down in EN 817 and be VA approved
Cleaning agent	Treating 1000 m2 of linoleum flooring	1 year	Purity 4-5 Gloss 5 Durability 6-7
Chemicals for textile dyeing	Dyeing yarn	100 kg yarn	Specific quality and nuance (as dictated by DIN standards)
Foam for chair seats	Providing a seat for a single person at a workplace	10 years	Sufficient hardness and resistance to tears. Must meet fire requirements and successfully pass the tests laid down in BS 5852: part 2: 1998

1.3.4 Identify the secondary services provided by the product

By now, you should have a firm grip on what it is your product supplies, i.e. what your company should look at when optimising the product and improving its environmental characteristics. Selling this service – as described by means of the functional unit – is how your company makes a living. But the product almost always delivers a number of other services besides those initially conceived of by the company and customer. We call these services "secondary services". In most cases, secondary services are incidental, and they can typically be recovered, e.g. in connection with reuse.

Example B1.6: Reuse of raw materials from a coffee maker
When you manufacture a coffee maker, the end result is more than a just a coffee maker: it also constitutes raw materials for e.g. beer bottles (if the glass pot is placed in a recycling bin upon disposal) and for heat generation (if, for example, the plastic parts end up in a Danish incineration plant after disposal).

Example B1.7: Excess heat from electrical household appliances
One example of a secondary service would be excess heat from electrical domestic appliances, e.g. washing machines, computers, or television. Such appliances generate a lot of heat which helps heat our homes. In this way, they partly replace oil or other fuels used for heating. Of course, this benefit applies only in cooler climates; in warmer areas, the excess heat simply generates a need for more air conditioning.

1.3.5 Plan the secondary services when constructing your product

Secondary services become increasingly important as society strives to use all resources and all energy as efficiently as possible. Many companies are now taking the next logical step: when we know that the
raw materials will in fact be reused in some way, why not take this into account and plan for the best possible service right from the start, including secondary services? Society will benefit from this so much that the general development is sure to go that way.

2.Describe the product life-cycle

Once you know exactly what the product delivers to users and what its secondary services are, you need to find out what the environmental impacts of the produc are. The first step in this regard is to form an overview of the product life-cycle.

2.1 Define your task

A product life-cycle has five main phases: the raw materials phase, the production phase, the use phase, the disposal phase, and the transport phase. Transport can either be dealt with separately or be distributed among the other phases.

2.1.1 Where in the life-cycle are the significant environmental impacts found?

Begin by noting down the product life-cycle on a piece of paper. Try to form an impression of the significant and insignificant issues associated with the product life-cycle. Assess the total weight of the product and the types of raw materials used. Consider whether production of the product might entail particularly problematic processes or chemicals. Examples would be use of varnishes that emit solvents or particularly energy-intensive processes such as enamelling.

Look at the product lifespan: for most products, the use phase is much longer than the other phases. Thanks to modern technology, the total working time spent on making a coffee maker is less than an hour, while its expected lifespan is five years, perhaps even more. Try to apply proportions to the use phase. Consider the most likely route of disposal of the product: which materials will be recycled? Which

2.1.2 Use a chart for your planning

Think about how you can get the data you need, and how you will go about collecting data. You can use a chart such as the one for the coffee maker shown in table 2.1 as the basis for your deliberations and planning.

Table 2.1 Initial overview of the life-cycle of a coffee maker

Phase	Description	Where can data be found?
Raw materials phase	Total product weight: a couple of kg. Material contents: plastic, glass, steel, aluminium, copper (in wires), materials for the heating element (?) Packaging: cardboard (probably recycled).	Production department, raw materials and process lists.
Production phase	Most significant production processes: shaping the raw materials, e.g. aluminium moulding. Surface treatment of steel parts. Special processes/chemicals: heavy metals for surface treatment. Possibly other processes as well – check.	Production department, raw materials and process lists. Data on chemicals can also be found with the environmental depart-ment// occupational health service.
Use phase	Life span: estimated at five years on average. Sales by markets/countries (>80%): Denmark, Sweden, Norway, and Germany. <u>Operation</u> Operation data: a total of 2 x 7 x 52 x 5 = 3,640 litres of coffee made. Total time per litre: approximately 12 minutes. The coffee is kept hot (80ºC) for approximately 30 minutes on average. Energy consumption: 3,640 litres of coffee is heated from approximately 10ºC to boiling point. Heating losses from 1 litre of very hot water for a total of 1,820 hours. Raw materials consumption: 3,640 coffee filters and a quantity of coffee. Consumption of ancillary materials: no. <u>Maintenance</u> Energy consumption: decalcification involves heating of 2 litres of water to boiling point once a month (?) Cleaning of pot and machine with warm water – how often? Raw materials consumption: no. Consumption of ancillary materials: vinegar (for decalcification), soap/washing-up liquid (for cleaning).	Sales and marketing department Dealers Product-development department.
Disposal phase	<u>Ways of disposal, estimated average</u> (%) Disposal takes place through recycling stations or via household garbage bins. Landfills: estimated at 0% Incineration: estimated at 100% of all machines and 50% of all pots. Their energy content is utilised. Shredding: estimated at 0% Separation: estimated at 0% Recycling: 50% of all glass pots are estimated to be recycled Other: estimated at 0%	Possibly the sales and marketing department and the product-development department. Possibly with the local authorities, e.g. recycling depots. Possibly with knowledge institutes.
Transport phase	The coffee is transported 10,000 km. The raw materials for the coffee maker are transported 2,000 km to the manufacturer. The finished coffee maker is transported 100 km to the consumer. When the consumer eventually throws it out, it will be transported 5 km for disposal.	Possibly with the sales and marketing department.

Example B2.1: Sportswear
A company which manufactures sportswear switched to a type of fibre which reduced energy consumption by half in the manufacturing process. This was regarded as a considerable environmental improvement of the product. However, the company was subsequently asked how many times the garments were washed and tumble dried throughout their lifespan and about the differences between the old and new fibre types in terms of their ability to retain water, hence their impact on the energy needed to tumble dry them. It turned out that no account had been taken of this.

Some products are "active" during the use phase, e.g. energy-consuming products such as vacuum cleaners, computers, television sets, or pumps. For other products, the use phase involves very frequent maintenance, e.g. textile products or tableware. For such products, the use phase is almost always dominant. Other products are more "passive", which is to say that they do not have the same degree of impact on the environment during the use phase, e.g. furniture, newspapers, packaging, or paper cups. Even passive products may, however, involve some environmental impact during the use phase: furniture and other objects may need cleaning, maintenance, cooling, heating, drying or similar, and they may exercise an indirect impact on the environment because they form part of other systems. This is why you need to take a very careful look at the entire product life-cycle, trying to imagine all the processes the product goes through and the impacts it causes.

2.1.3 Information about disposal and transport

It can be difficult to obtain specific figures for disposal and transport. Waste from private households is disposed of through standard household waste or via a recycling depot. You can safely assume that all waste which is being disposed of as part of the standard household waste will be incinerated 100%. For waste delivered to recycling depots, you can use the values given in table 2.2. These values are approximate and should only be used if you do not have more detailed information to hand from other sources. Actual disposal will depend on factors such as:

- Opportunities for separation
- Collection systems
- Economically feasible reprocessing techniques

Table 2.2
Rules of thumb for disposal routes for raw materials disposed of via recycling depots

	Incineration	Reuse	Landfilling
Paper/cardboard (packaging)	25	75	0
Plastic	85	15	0
Metal	0	100	0
Glass	0	100	0
Non-flammable waste	0	0	100

2.1.4 What should be included?

You will often have to decide whether you should include minor parts of the product in your considerations, e.g. screws, oil, and similar. In the example of the coffee maker, you may also want to include coffee filters and the coffee itself. If you are not sure what to include, assume that anything which is influenced by the company's or the user's choices must be included.

There are no fixed criteria to decide on what should be included. What you need to do is to cover a significant part of the life-cycle. One possibility is to look at the product weight. For example, you may decide that at least 95% of the product weight must be covered by the environmental assessment. However, even small parts can contribute significantly to energy consumption and/or environmental loads, so just looking at the weight is not enough.

So we cannot say, for example, that screws should never be considered. If your environmental assessment concerns a screw, it is obviously significant. If, however, you have a product which contains 100 kg steel and has a chromium-plated surface, 20 grams of steel screws do not make much difference. Omitting them from your assessment does not matter, because steel does not contain scarce resources or hazardous/harmful substances.

2.2 Collect data for the product life-cycle

You now need to obtain data about the entire product life-cycle. For example, you may want to collect data in tables to make them easily accessible to others. This will also make it easier to show what you have included in your environmental assessment. Information on raw materials and production will often be available from the company production department. Many companies have a so-called raw materials and process list which includes all the data you need. Information on where the product is sold is often available from the sales and marketing department, while data on the actual use can be collected from the sales staff and product-development staff alike. It will often be necessary to obtain information on disposal of the product from other sources, e.g. from the local recycling depots, from dealers (who sometimes receive returns of old product when selling new ones), or from knowledge institutes.

Example B.2.2: The coffee maker

The use phase: You might be able to get data on the use process from the marketing department, but it will often be necessary to carry out calculations on the basis of specifications and rating plates. The heating coil of the coffee maker has an effect of 600 W, and it takes approximately 12 minutes to make 1 litre of coffee. This means that the energy consumed to make coffee is 0.660 kW times 0.2 hours times 3,640 litres, corresponding to around 440 kWh to make 3,640 litres of coffee throughout the product lifetime. The effect of the hot plate is 55 W. Each pot of coffee is kept warm for 30 minutes (on average), corresponding to 0.5 hours times 0.055 kW times 3,640 = 100 kWh. This equals an energy consumption of 100 + 440 = 540 kWh. You should also remember that the coffee and coffee filters are part of the use phase. You may well ask yourself if you really need to include these things when you are supposedly looking at the coffee maker and the coffee maker is the only thing manufactured by your company. However, as the choice of concept and construction of the coffee maker can affect the use of filters and coffee, they do need to be included in the assessment so that we can see the environmental consequences of any changes.

The disposal phase: Disposal can be presented as shown in table 2.5. In this example, the entire product is sent for incineration via the standard household waste, except the glass pots; we assume that 50% of all glass pots are recycled. We will compensate for the recycled materials in our calculations of the total impact assessment. The steel parts are assumed to be sent for incineration, but at the same time half of this steel is assumed to be separated out on a sorting conveyor belt by means of magnets. It will then be sent for recycling. The table includes the concept "compensation" – this will be explained later.

Components	Number	Raw materials	Weight	Manufacturing processes	Ancillary materials
Cabinet	1	Plastic, impact-resistant polystyrene	1.1	Die casting Pressure-die	Release agent
	1	Aluminium	0.1	Casting	Lubrication?
	1	Steel	0.3	Sheet-metal stamping Punching	?
Wire	1	Copper	0.02	Wire drawing	
	1	Plasticized PVC	0.02	Coating	
Glass pot	1	Glass	0.34	Glass moulding	
Handle	1	Plastic, impact-resistant polystyrene	0.02	Die casting	Release agent
Clamp	1	Aluminium	0.01	Rolling	?
Packaging	1	Cardboard	0.39	-	?

Table 2.3 Composition of the coffee maker and the manufacturing processes associated with it

Material/ component	Process			Ancillary materials
	Name	Unit	Quantity	Name
Entire product	Coffee-making			-
	• Electricity consumption	kWh	540	-
	• Coffee filters	kg	7.3	Bleach
	• Coffee	kg	290	Pesticides/fertilizer
	• Water	kg	3,640	-
	Cleaning	kg	50	Water (hot/warm)
	(machine and pot)	ml	25	Washing-up liquid
	Decalcification	kg	15	Acetic acid
	Compensation for heating	kWh	-360	-

Table 2.4 Use of the coffee maker

Table 2.5
Disposal of the coffee maker

Component	Process				Ancillary material
	Share	Name	Unit	Quantity	Name
Aluminium	1	Waste incineration, aluminium	kg	0.1	?
Polystyrene	1	Waste incineration, polystyrene	kg	1.1	?
	1	Compensation for heat generated by waste incineration	kg	-1.1	?
Glass	0.5	Waste incineration, glass	kg	0.17	?
	0.5	Melting, glass	kg	0.17	?
	0.5	Compensation for glass	kg	-0.17	?
Steel	1	Waste incineration, steel	kg	0.3	?
	0.5	Melting, steel	kg	0.15	?
	0.5	Compensation for steel	kg	-0.15	?
Copper	1	Waste incineration, copper	kg	0.02	?
Coffee filters	1	Waste incineration, coffee filters	kg	7.3	?
	1	Compensation for heat generated by waste incineration	kg	-7.3	?
Coffee grinds	1	Waste incineration, organic materials	kg	290	?
	1	Compensation for heat generated by waste incineration	kg	-290	?
Packaging	1	Waste incineration, cardboard	kg	0.39	?
	1	Compensation for heat generated by waste incineration	kg	-0.39	?

Include a conservative calculation of the significance of the total transport to get an initial impression of whether transport is important to the overall situation. In most cases, transport is not very important, and optimisation within this area can often be left to the logistics department. Transport for the coffee maker is illustrated in table 2.6.

Mode of transport	Distance, km	Quantity, kg
Transport of coffee, ship	10,000	90,0
Transport of raw materials for coffee maker, car	2,000	2.3
Transport of coffee maker to user, car	100	2.3
Transport of coffee maker for disposal, car	5	2.3

Table 2.6 Transport, coffee maker

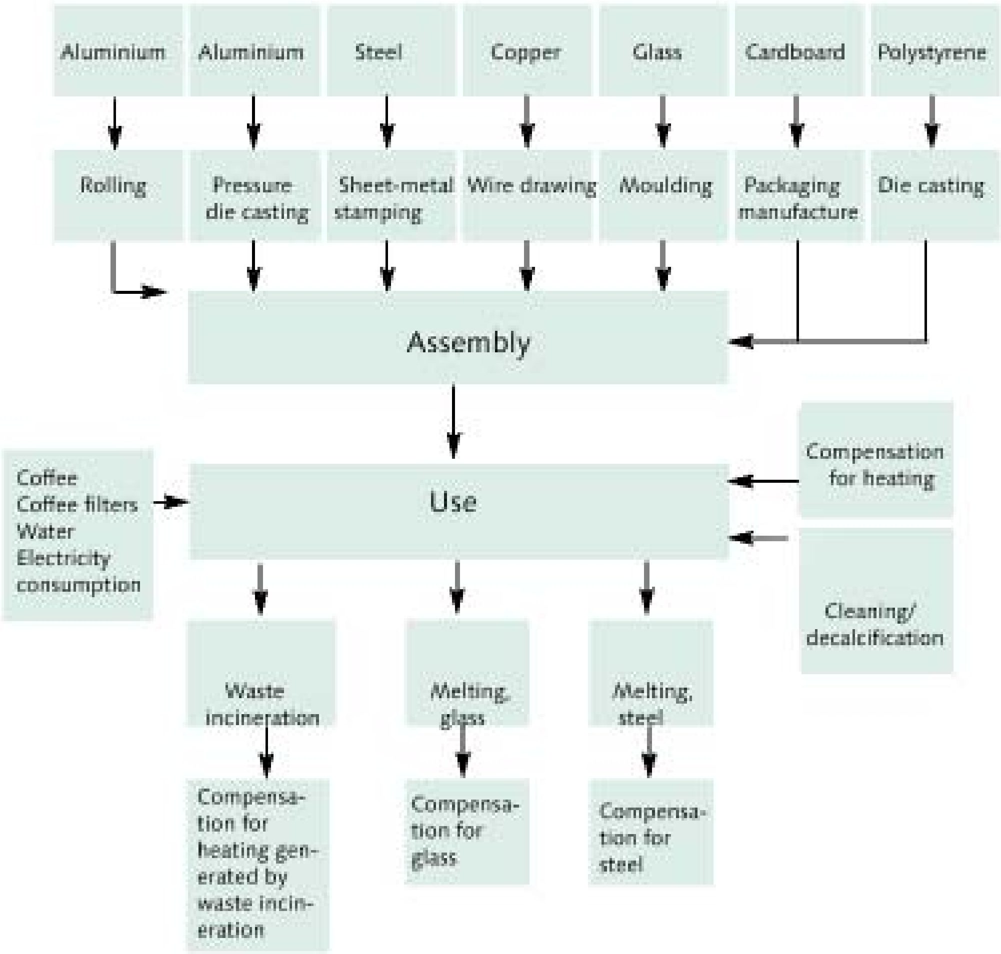
Tables 2.3-2.6, illustrated here by our example of the coffee maker, form the basis for your environmental assessment. They specify all the information you need about the product and its life-cycle. You will often need various data, particularly in connection with processes and ancillary materials – this is also illustrated in the example of the coffee maker. You will have to leave these matters aside for the present, but they should still be included in your basis for future work, as they will be addressed at a later stage.

It is important that you indicate very clearly what you have included in your environmental assessment. Place checkmarks in your tables or make a list of your omissions and assumptions.

2.2.1 Would a flow diagram of the product life-cycle be more suitable?

Would a flow diagram of the product life-cycle be more suitable? The raw materials and process list model can be useful for establishing an overview of the product life-cycle if the product in question comprises many separate components and/or raw materials. For simpler and more homogenous products, you can also choose to use a flow diagram. In some cases, such a diagram provides a better overview. You are free to choose whatever you feel is best in each case.

Figure 2.1
Overview of the coffee maker's life-cycle. Transport not included.



2.2.2 Compensation

In the previous section, we mentioned that the unintentional secondary services seen in connection with most products often have considerable impact on the environment. This kind of service appears where the system that you are looking (the product life-cycle and the processes it includes) affects or is connected to other systems. Secondary services reduce or eliminate the need for alternative ways of receiving the service in question. In order to take this into account, we need to compensate for such services. If, for example, metals are being recycled, you need to deduct production of a corresponding amount of metal from the overall result. This means that for the purpose of calculations, you will experience negative raw materials consumption during the disposal phase.

Compensation occurs most frequently within the following areas:

- Excess heat from electrical appliances and devices
- Electricity and heating generated by means of waste incineration
- Recycling

Excess heat is typically encountered during the use phase and constitutes a negative contribution. It is important to address excess heat separately, as this is one of the areas where your work can make a difference. For coffee makers and water heaters, excess heat represents the greatest scope for improvements.

In Denmark, the heat generated by incineration plants is utilised. The heat which can be utilised corresponds to the calorific value of the materials. Plastic and papier are high-grade fuels, while metals usually have no calorific value. The values can be found in Appendix B, table 2.1.

When materials are recycled, this is indicated by placing a – in front of the recycled materials during the disposal phase. Remember to include energy consumption for the recycling process in your calculations (e.g. melting). It is not enough to simply hand over the materials; they also need to be processed.

Remember that compensation can only be carried out in situations where, for example, materials are in fact recycled or are very likely to be recycled. It is not enough that they can be recycled.

Table 2.7
A product contains 10 kg plastic, of which 5 kg are recycled

Example B2.3: Compensation

A product contains 10 kg plastic, of which 5 kg are recycled.

	The raw materials phase	The disposal phase
Raw materials	10 kg plastic (resources)	5 kg plastic (resources)
Energy	10 kg plastic (energy)	Energy for reprocessing of 5 kg plastic

3. Carry out an initial environmental assessment

For the initial environmental assessment, you will be working with a MECO chart.

The MECO chart will help you collect your data in a systematic and easily accessible way. It helps create an overview of the environmental impact of your product.

You must prepare a MECO chart for each product included in your environmental assessment. In what follows, we will describe how to work with the chart for a single product.

The principles of the MECO model place the main emphasis on the materials, ancillary materials, and energy consumed throughout the product life-cycle. It is difficult to accurately calculate the emissions to air and water and waste generated during a product's life-cycle. Such flows can be included, but only to a limited degree.

In the following, we explain how the data you have already collected will be processed. This will be followed by instructions on how the processed data can be interpreted. Finally, we will look at whether you should proceed with your work and how.

3.1 Preparing a MECO chart

When preparing a MECO chart, your work will be based on the functional unit (part B, chapter 1) and the life-cycle you have outlined (part B, chapter 2).

When filling in the MECO chart, you need the product description outlined in chapter 2, a calculator, and Appendix B at the back of this book.

The MECO chart is shown in figure 3.1. You use it by filling in one row at a time. First, you fill in the row describing the materials used in all phases of the product life-cycle; then you move on to energy, and so on.

In the MECO chart, materials consumption is indicated in quantities measured in kg (or another suitable unit of measurement), and converted into resource consumption. Energy consumption is calculated in terms of primary energy and the resources spent on generating this energy. The rows detailing "Chemicals" and "Other" involve only one method of calculation each.

Figure 3.1
MECO chart

		Raw materials phase	Production phase	Use phase	Disposal phase	Transport phase
Raw materials	Quantity					
	Resources					
Energy	Primary					
	Resources					
Chemicals						
Other						

Sections 3.1.1 to 3.1.4 include instructions and examples to help you complete the MECO chart. Sections 3.1.1 and 3.1.2 include a number of formulae. These are marked with numbers, e.g. {1}, and are collected in an overview in appendix A.

3.1.1 Materials

Materials are calculated as the materials used to manufacture the product as well as the materials consumed in connection with use or maintenance of the product. The last step, disposal, may include reuse or reprocessing, e.g. of plastic or paper.

Begin by identifying the total material consumption for each phase, calculated by type of material. You already have the basic information necessary to do this from your data collection efforts, as illustrated in table 2.3 in chapter 2. Enter this information on the top line under the heading "materials".

Example B3.1: Material consumption for a coffee maker

From chapter 2, table 2.3, we have the following information for the raw materials phase:

Plastic, impact-resistant polystyrene (PS):

	1.1 kg + 0.02 kg = 1.12 kg
Plasticised PVC	0.02 kg
Glass	0.34 kg
Cardboard	0.39 kg
Aluminium (Al)	0.1 kg + 0.01 kg = 0.11 kg
Copper	0.02 kg
Steel	0.30 kg

From chapter 2, table 2.3, we have the following information for the production phase:

Release agent	quantity not calculated
Lubricant	quantity not calculated

From chapter 2, table 2.4, we have the following information for the use phase:

Coffee filters (paper)		7.3 kg
Coffee		290.0 kg
Water:	3,640 kg + 50 kg=	3,690.0 kg

From chapter 2, table 2.5, we have the following information for the disposal phase:

Glass, recycling 50%	-0.17 kg
Steel, recycling 50%	-0.15 kg

Other materials are all sent for incineration.
Transport phase: no materials consumption.
The above figures are shown inserted in the MECO chart in example B3.7

You now need to identify the resources/raw materials used for each material.

For some materials, you probably already know which raw materials are being used. For others, table B.1 in Appendix B may be helpful.

Example B3.2: Consumption of resources for production of a given material

Material	*Resource*
Polystyrene	Crude oil and gas
PVC	Crude oil and gas
Glass	Lime, kaolin and sand
Aluminium	Aluminium
Copper	Copper
Steel	Iron and manganese

Resource consumption is measured in milli-Person Reserves, abbreviated as mPR. With this conversion, account is taken of the fact that some materials are in plentiful supply, while others are scarce. Scarce resources are accorded greater weight than the plentiful ones, as it is more harmful to the environment to use 1 kg of a material which is in short supply than 1 kg of a material where there is plenty to go around.

For this conversion of materials consumption into resource consumption, use table B.1 in Appendix B.

Identify the quantity of your material(s) in kg and calculate the mPR value for each material. Some of the materials used will involve only a single
raw material (e.g. aluminium), while others involve more (e.g. steel).

Calculate:

{1} no. of kg of material [A] x mPR/kg for [A] = mPR for material [A]

Example B3.3: Conversion into milli-Person Reserves

Table B.1, Appendix B, includes the following conversion factors:

Aluminium:	1.5 mPR/kg Al
Steel, machine steel:	0.08 mPR/kg Fe; 0.05 mPR/kg Mn

When a given material comprises more than one raw material, calculations must be carried out individually for each raw material.

The milli-Person Reserves for 2 kg of aluminium and steel are calculated as follows:

Aluminium:	2 kg x 1.5 mPR/kg Al = 3 mPR Al
Stainless steel:	2 kg x 0.08 mPR/kg Fe + 2 kg x 0.05 mPR/kg Mn = 0.16 mPR Fe + 0.10 mPR Mn

Table 1 in Appendix B includes comments for some materials. These comments concern significant emissions or other important issues in connection with production of the materials. Transfer these comments to the MECO chart. If the comments concern waste, list them in the "Materials" row. If they are about emissions, list them in the "Chemicals" row. Other comments, for example about working-environment issues, should be listed in the "Other" section.

If you cannot find information about one or more materials used in your product, simply list the relevant material(s) on the MECO chart and then decide whether you want to do more about it later.

Example B3.4:	Resource consumption for the raw materials phase, converted into mPR
Polystyrene	1.12 kg x [0.02 mPR/kg crude oil + 0.02 mPR/kg natural gas] = 0.022 mPR natural gas
PVC	0.02 kg x [0.01 mPR/kg crude oil + 0.01 mPR/kg natural gas] = 0.0002 mPR crude oil + 0.0002 mPR natural gas
Glass	0.34 kg x 0 mPR/kg = 0 mPR
Aluminium	0.11 kg x 1.5 mPR/kg = 0.165 mPR Al
Copper	0.02 kg x 16.5 mPR/kg = 0.33 mPR Cu
Steel, machine steel	0.3 kg X [0.08 mPR/kg Fe + 0.05 mPR/kg Mn] = 0.024 mPR Fe + 0.015 mPR Mn
Cardboard	0.39 x 0 mPR/kg = 0 mPR

If materials are used during the production phase or use phase, calculations must also be carried out for all the relevant materials consumed there.

Example B3.5: Identifying the resources and materials used in the use phase of the coffee maker

During the use phase, a total of 7.3 kg coffee filters and 290 kg coffee are used. These "materials" are made from renewable resources and so need not be included in your calculations of materials.

Washing-up liquid and acetic acid is used for cleaning. The washing-up liquid is ignored because of the small quantities used. The acetic acid is assessed in the "Chemicals" section.

The use phase involves consumption of a total of 3,690 litres of water. Water is regarded as a renewable resource and is not included here.

This means that the use phase features no contributions to your calculations of materials consumption.

If your product involves reuse or reprocessing of materials during the disposal phase, your calculations must also take this into account. This is done by carrying out "compensation" for the recycled materials, measured in mPR. Use the formula applied during the raw materials phase.

Example B3.6: Reprocessing of materials in connection with disposal of the coffee maker

In the "coffee maker" example, it is assumed that 50% of the steel and glass is recycled. This means that compensation will be carried out for the following:

Steel, machine steel	-0.15 kg x [0.08 mPR/kg Fe + 0.05 mPR/kg Mn] = -0.012 mPR Fe -0.008 mPR Mn
Glass	-0.17 kg x 0 mPR/kg = 0 mPR

Enter the result of your calculations in the MECO chart in the row labelled "Materials". All results should be entered as the sum of each of the resources addressed.

Example B3.7: Materials consumption and resource calculations for materials

	Raw materials phase	Production phase	Use phase	Disposal phase	Transport phase
Quantities	PS: 1.12 kg PVC: 0.02 kg Glass: 0.34 kg Cardboard: 0.39 kg Aluminium: 0.11 kg Copper: 0.02 kg Steel: 0.3 kg	Release agent Lubricant	Paper: 7.3 kg Coffee: 290 kg Water: 3,690 kg	Reprocessing Glass: -0.17 Steel: -0.15 Waste incineration: 299.23 kg	
Resource consumption	Crude oil: 0.0222 mPR Natural gas: 0.0222 mPR Al: 0.165 mPR Cu: 0.33 mPR Fe: 0.024 mPR Mn: 0.015 mPR			Fe: -0.012 mPR Mn: -0.008 mPR	

3.1.2 Energy

Energy comprises energy consumption in the form of electricity, steam, heat, and other energy
as well as energy for transport. It also includes the energy contained within certain materials. Plastics, for example, contain a lot of energy – they can be burnt to release that energy, which can then be utilised. By contrast, substances such as sand contain no reusable energy.

The process energy used may be electricity or come from oil, gas and petrol. For the sake of simplicity, wind power, water power and nuclear power are not included in our calculations.

You need to identify the energy consumption and the type of energy used for each life-cycle phase of your product. In addition to this, you need to include the energy consumed to manufacture the materials. These figures can be looked up in the appendices.

The energy consumption outlined above is known as "primary energy". This figure needs to be converted into resource consumption. For the purposes of this method, we have chosen to calculate all energy consumption as consumption of crude oil reserves.

3.1.2.1 Energy consumption within the raw materials phase

Table B.2 in Appendix B lists the energy consumption necessary to extract a number of different resources and form them into usable raw materials.

Calculate the energy consumption for the raw materials used in the product. Energy consumption is calculated as primary energy by calculating:

{2} Amount of material [kg] x
Primary energy for the material [Mj/kg] =
Primary energy consumption [Mj]

Remember to include all raw materials – even those based on renewable resources.

Example B3.8: Primary energy consumption for materials production

The list of materials is from example B3.1.

The raw materials phase:

Polystyrene	1.12 kg x 90 MJ / kg	= 100.8 MJ
PVC	0.02 kg x 65 MJ / kg	= 1.3 MJ
Glass	0.37 kg x 10 MJ / kg	= 3.7 MJ
Cardboard	0.39 kg x 40 MJ / kg	= 15.6 MJ
Aluminium	0.11 kg x 170 MJ / kg	= 18.7 MJ
Copper	0.02 kg x 90 MJ / kg	= 1.8 MJ
Steel	0.3 kg x 40 MJ / kg	= 12.0 MJ
Total		= 153.9 MJ

3.1.2.2 The production phase

Calculate the process energy for the production phase by type of energy. Table B.3 in Appendix B may help you identify the energy consumption for the relevant processes. The table lists information on energy consumption for selected processes.

It is not always possible to clearly identify energy consumption for individual processes. Often, the total energy consumption of the entire company will be known, and this figure then needs to be reallocated, i.e. distributed among all the products manufactured. If the company cannot provide appropriate directions for such distribution, you can carry out a weighted distribution based on the number of products sold times sales price or stock turnover.

> If no data for the production phase is available, you can set the energy consumption at 30% of the corresponding energy consumption during the raw materials phase.

For energy-intensive processes, e.g. where large quantities of water are heated or cooled, the process-energy values may be very high.

When gas or oil is burnt and the resultant heat is utilised, the raw materials used to create this energy are utilised 100%.

Manufacture of electricity, however, entails relatively large losses at the power plant. Only 40% of the energy delivered to the power plant can be utilised as electricity.

If the energy consumption values have been calculated in the form of electricity, you need to convert this energy consumption into primary energy, measured in MJ. Use these formulae:

{3} Electricity consumption [MJ] x 2.5 = primary energy consumption [MJ]
{4} Electricity consumption [kWh] x 9 = primary energy consumption [MJ]

If you have identified energy consumption in the form of energy resources, you need to convert the energy consumption into MJ by using this formula:

{5} Energy resource [kg] x calorific value [MJ/kg] = primary energy consumption [MJ]

You can look up the calorific values of various energy resources in Appendix B, table B.4.

Example B3.9: Energy consumption for production of a coffee maker

Chapter 2 includes information on the processes used to manufacture the coffee maker.
Table B.4 in Appendix B states that pressure die casting of aluminium involves an energy consumption of 20-50 MJ/kg.
No data is available for the other processes. It is estimated that processing of materials accounts for 20 MJ/kg. As a total of 1.91 kg need to be processed for each coffee maker, this equals an energy consumption of 38.2 MJ in the form of electricity.
This electricity consumption is converted into primary energy; 38.2 x 2.5 MG = 95.5 MJ.

3.1.2.3 The use phase

The amounts of energy consumed during use of the product can be insignificant or very great. Energy consumption must be calculated by energy form and be converted into MJ.

Identify the direct energy consumption and consider whether you need to compensate for the energy savings caused by secondary services during the use phase – if there are any secondary services, that is.

Section 3.1.2.2 contains information on converting electricity consumption and energy resources.

Example B3.10: Energy consumption during the use phase for the coffee maker

The coffee maker consumes energy in the form of electricity: 540 kWh. 540 kWh x 9 MJ/kWh = 4,860 MJ primary energy.
In chapter 2, we saw that we compensate for the heat generated by the coffee machine in our total considerations. We do this to take energy savings into account. Here, 360 kWh are saved on heating. Homes are usually heated through consumption of oil.
360 kWh x 3.6 MJ/kWh = 1,296 MJ.
This is to say that the heat generated by the coffee maker makes for total savings of 1,296 MJ primary energy.
As a result, the total primary energy consumption during the use phase is 4,860 MJ – 1,296 MJ = 3,564 MJ.

You should also consider whether energy is consumed in connection with cleaning/maintenance of the product. You will have to make an estimate of such energy consumption, as the exact figure is rarely known – and it may not be possible to calculate it accurately at all. Remember to make a note explaining the reasons and assumptions behind your estimate.

Materials may also be consumed during the use phase – such materials must also be included in your assessment. Calculations are carried out in the same way as for energy consumption for materials during the raw materials phase. See section 3.1.2.1.

Example B3.11: Energy consumption for materials during the use phase for the coffee maker

Paper (coffee filters)	7.3 kg x 40 MJ / kg	=	292 MJ
Coffee	290 kg x 20 MJ /kg*	=	5,800 MJ
Total		=	6,092 MJ

*Estimated value

3.1.2.4 *The disposal phase*

Once you know how the product is disposed of, you can calculate energy consumption or energy development.

Plastic, paper, cardboard and other flammable, discarded parts of a product will be disposed of either via recycling or incineration. If such disposal takes the form of incineration, you must compensate for the heat generated in the energy accounts. This preliminary environmental assessment does not take into account heat losses and the like.

Heat generation is calculated by means of the calorific value

Calculate the energy contents for each material and enter the total heat generated in the MECO chart. Use the column labelled "calorific value" in table B.2 in Appendix B and calculate:

{6} Material [kg] x calorific value [MJ/kg] = heat generation [MJ]

Example B3.12: Heat generation upon disposal of the coffee maker

Heat generated by incineration in the disposal phase:

Polystyrene	1.12 kg x 40 MJ/kg	= 44.8 MJ
Cardboard	0.34 kg x 20 MJ/kg	= 6.8 MJ
Paper (coffee filters)	7.3 kg x 20 MJ/kg	= 146.0 MJ
Coffee grinds	290 kg x 15 MJ/kg*	= 4,350.0 MJ
Total energy contents		= 4,548.0 MJ

*Estimated value

In cases where disposal involves special treatment, you must ensure that the relevant energy consumption is identified and included in the total calculations. This might, for example, concern reprocessing of materials.

Table B.3 in Appendix B lists primary energy consumption values for a few, selected reprocessing processes.

If you do not have any information about the energy consumed in connection with reprocessing, you can set the value at 50% of the energy used to make the material from scratch.

Example B3.13: Energy consumption for reprocessing for the coffee maker

In our example with the coffee maker, we see that 50% of the steel and glass used to make the coffee maker is reprocessed. This consumes energy. Table B.3 in Appendix B has information on the energy consumed when reprocessing materials.

Primary energy consumption:

0.17 kg glass x 7 MJ/kg	= 1.2 MJ
0.15 kg steel x 40 MJ/kg	= 6.0 MJ
Total energy consumption for reprocessing	= 7.2 MJ

3.1.2.5 Transport

The energy consumption for transport is based on calculations of the amount of goods transported throughout the entire product life-cycle and the distances covered. These calculations are described in chapter 2, table 2.6.

The energy consumption per kilometre depends on the form of transport used. Table 3.1 shows the energy consumption associated with three different forms of transport.

Table 3.1 Energy consumption for transport

	Energy consumption
Train	0.0008 MJ/(kg x km)
Ship	0.001 MJ/(kg x km)
Truck	0.005 MJ/(kg x km)

Take the chart detailing the transported quantities and distances and table 3.2 as your basis for calculating the total energy consumption for transport. You do this by means of the following formula:

{7} The sum of:
{transported material [kg] x distance [km] x energy consumption[MJ/(kg x km)]} = total energy consumption[MJ]

Example B3.14: Energy consumption for transport for the coffee maker

Raw materials, car	2,000 km x 2.3 kg x 0.005 MJ/(kg x km)	= 23.0 MJ
Coffee, ship	10,000 km x 290 kg x 0.001 MJ/(kg x km)	= 2,900.0 MJ
Coffee filters, car	1,000 km x 7.3 kg x 0.005 MJ/(kg x km)	= 36.5 MJ
To end user, car	100 km x 2.3 kg x 0.005 MJ/(kg x km)	= 1.2 MJ
Disposal, car	5 km x 299.6 kg x 0.005 MJ/(kg x km)	= 7.5 MJ
Total for transport		2,968 MJ

3.1.2.6 Total statement

You now need to present a total statement, accounting for all the energy consumed for the various processes.

For products where transport is not a significant issue, we recommend that you adapt the MECO chart by removing the "transport" column.

Example B3.15: Primary energy consumption

	Raw materials phase	Production phase	Use phase	Disposal phase	Transport
Primary energy	154 MJ	96 MJ	6,092 MJ 4,860 MJ	7 MJ	2,968 MJ
Compen-sation		-1,296 MJ	-4,548 MJ		
Sum	154 MJ	96 MJ	9,656 MJ	-4,541 MJ	2,968 MJ

Net consumption of primary energy: 8,333 MJ

You now have to convert the energy consumption values into the equivalent consumption of oil resources. This is done by means of the following formula:

{8} Energy consumption [MJ] / 1,025 [MJ/mPR oil] = consumption of oil resources [mPR]

Enter the resultant values for energy resources, measured in mPR, in the MECO chart for each
life-cycle phase.

Example B3.16: Primary energy consumption, total

	Raw materials phase	Production phase	Use phase	Disposal phase	Transport
Primary energy	154 MJ	96 MJ	10,952 MJ	7 MJ	2,968 MJ
Compen-sation			-1,296 MJ	-4,548 MJ	
Sum	154 MJ	96 MJ	9,656 MJ	-4,541 MJ	2,968 MJ
mPR oil	0.15 mPR	0.09 mPR	9.42 mPR	-4.43 mPR	2.90 mPR

The net consumption of resources corresponds to 8.68 mPR oil.

3.1.3 Chemicals

In this connection, "chemicals" is a wide concept. Chemicals comprise chemical substances used in the product itself as well as all ancillary materials used throughout the product life-cycle. This will mainly concern ancillary materials used to manufacture the product, but ancillary materials used for e.g. maintenance during the use phase should also be included. If you know of any specific chemical substances which are being emitted or discharged into the environment, you should also include them in your assessment.

Take tables 2.3 – 2.5 in chapter 2 as your point of departure and prepare a list of all the ancillary materials and other chemicals used during the product life-cycle. Include information on the quantities used.

3.1.3.1 Information about chemicals

It is usually difficult to get exact information about the chemical substances found in a given product. It is, however, necessary to collect as much information as possible in order to assess the environmental impact.

> The most relevant information can be obtained from the suppliers' directions. All manufacturers and importers of hazardous chemicals must prepare such instructions.

Good supplier directions comprise 16 items, include a PR number (Product Register No.) and should not be older than two years.

Item 2 of suppliers' directions list the contents of hazardous substances, including information on the approximate quantities and a danger classification.

Appendix B includes an overview of individual danger categories. It also provides explanations of R phrases and S phrases.

If you need to look for more information about a substance, having a CAS number is helpful. CAS is short for Chemical Abstract Service, and each CAS number is unique for the chemical substance in question.

If you have a chemical name – in some cases a commercial name is enough – of the chemical you want more information about, you can often find help on the internet, e.g. at http://chemfinder.camsoft.com/. Here you can find information on substance properties, limit values, and so on.

You can also use the handbook entitled Hawley's Condensed Chemical Dictionary to find CAS numbers, explanations of abbreviations, and much more.

Example B3.17: Ancillary materials

Release agent

Consists of	60-100% crude oil distillate, labelled: Xn, R65

Lubricant

Consists of	60-100% crude oil distillate, labelled: Xn, R65

Bleach

Consists of	5% hydrogen peroxide, labelled: C, R34

Decalcifier

Consists of	30% acetic acid, labelled: C, R34

Washing-up liquid

No labelling required

3.1.3.2 Assessing chemicals

You should collect the information about all the chemical substances included in the product life-cycle in a chart as illustrated in table 3.2

Substance			Assessment		
Name	CAS no.	Use	Classification	The Impact List	The List of Undesirable substances

Table 3.2 Assessment of chemicals

Fill in the first four columns of the chart with the information you have.

The "Impact List" is a special list prepared by the Danish Environmental Protection Agency. It comprises approximately 1,400 substances which are regarded as particularly problematic due to their environmental and health-related properties.

As at 2000, the "List of Undesirable Substances" numbered approximately 60 substances. The relevant substances have been included on this list because they are widely used and because the Danish Environmental Protection Agency regards them as particularly problematic.

The "List of Dangerous Substances" comprises a very large number of substances which have been assessed by the EU in terms of the danger they represent to the environment and human health. These substances are known as classified substances. The List of Dangerous Substances is essentially a list of examples, but even so it contains many substances which are widely used.

Check whether any of the substances on your chart are included in these lists. If a substance appears in one of the lists, mark this in the table by checking one or both of the columns with the headings "Impact List" and "List of Undesirable Substances". If the substance appears in the List of Dangerous Substances, you should enter the substance classification in the relevant column.

The lists mentioned above do not address chemical substances which degrade the ozone layer, as these substances are already largely banned in Denmark. If, however, you are dealing with products such as cooling systems, fire extinguishers or foam insulation, you need to be aware of whether the substances are ozone-depleting. You can look this op in Appendix B, table B.7.

Example B3.18: Chart for assessment of chemicals, used for the coffee maker example

Substance			Assessment		
Name	CAS no.	Use	Classification	The Impact List	The List of Undesirable Substances
Crude oil distillates	64742-47-8	Release agent	R65		X
Crude oil distillates	64742-47-8	Lubricant	R65		X
Hydrogen peroxide	7722-84-1	Bleach	C, R34		
Acetic acid	64-19-7	Decalcifier	C, R34		

3.1.4 Other

Use the column "other" to note down any issues which are significant for the environment and which have not been addressed in connection with your work with raw materials, energy, or chemicals.

Relevant issues might involve working-environment issues or special conditions regarding noise or odours which have not been addressed in any of the other sections.

You should also think about whether you need to look at any other issues in connection with the external environment. For example, this might involve changes to or sequestration of large areas of land in connection with raw materials extraction or landfilling. If the extraction of raw materials involves use of energy from waterpower, it may be relevant to look at the changes made to large areas of land due to damming.

Example B3.19: Other issues (examples)

Raw materials:
For the coffee maker, it may be relevant to consider working-environment issues in connection with extraction and processing of the metals used. It might also be relevant to take a closer look at how the coffee is produced.

Manufacture:
The manufacture of the coffee maker involves moulding of polystyrene. This can cause problems in terms of the working environment. Some working processes can cause noise.

Use:
Acetic acid is used to decalcify the coffee maker. When heated, acetic acid gives off a strong smell.

Disposal:
Waste sorting often gives rise to working-environment problems. Shredding of products which contain metals causes noise.

Transport:
It may be relevant to look into special conditions in connection with matters such as transport of dangerous substances.

3.2 Interpreting the MECO chart

3.2.1 The MECO chart

Start by preparing a full MECO chart with all information as described in the last section if you have not done so already.

If your environmental assessment involves several products, the charts should look as similar as possible. It is important that you save any secondary charts for later, in case you need them for a more in-depth assessment.

It is important that you discuss your results with someone else – and this might well be someone who doesn't work at your company. For example, you might want to talk to someone from a company you work with, a network, a different company within your group, or something similar. The person you discuss matters with must know about the relevant product(s) and have some knowledge of environmental assessments. The objective of this discussion is to ensure that you have included all the significant aspects in your work.

Example B3.20: MECO chart for the coffee maker

Below is a total MECO chart for the coffee maker used in our example:

	Raw materials phase	Production phase	Use phase	Disposal phase	Transport phase
Raw materials Quantities	PS: 1.12 kg PVC: 0.02 kg Glass: 0.34 kg Cardboard: 0.39 kg Aluminium: 0.11 kg Copper: 0.02 kg Steel: 0.3 kg	Release agent Lubricant	Paper: 7.3 kg Coffee: 290 kg Water 3,690 kg		
Resource consumption	Crude oil: 0.022 mPR Natural gas: 0.022 mPR Al: 0.17 mPR Cu: 0.33 mPR Fe: 0.0024 mPR Mn: 0.015 mPR			Fe: -0.012 mPR Mn: -0.008 mPR	
Energy Primary	154 MJ	96 MJ	9,656 MJ	-4,541 MJ	2,968 MJ
mPR (crude oil)	0.15 mPR	0.09 mPR	9.42 mPR	-4.43 mPR	2.90 mPR
Chemicals	Fluorides used when manufacturing aluminium. Heavy metals used when making copper. Vinyl chloride monomers used for making PVC.	Crude oil distillates (undesirable?) Hydrogen peroxide (C, R34)	Acetic acid (C, R34)		
Other	Extraction of metals, working environment issues	Die casting of PS, emanations	Decalcification, odours from acetic acid	Not known	No comments

3.2.2 Interpreting the information on materials

The assessment of resources, measured in mPR, takes into account whether the materials used in the product have been made from scarce or plentiful resources. As a result, the assessment can be used directly for environmental comparisons.

> Remember that the assessment includes only non-renewable resources such as metals and plastic. When converting figures into mPR, only known reserves have been taken into account, and so the calculations of mPR are subject to some uncertainties.

All materials consumption in this initial environmental assessment has been calculated for new resources. This makes for a conservative assessment if it is possible to use reprocessed materials in the relevant product. For example, it is important to use new aluminium if you wish to exploit the conductive properties of this material, whereas it would be perfectly possible to use reprocessed aluminium for e.g. a coffee maker.

If the MECO chart features waste, you should be aware that various categories of waste cannot be immediately compared.

> You can compare impacts measured in mPR between the individual life-cycle phases of a given product.
>
> You will also be able to compare impacts measured in mPR for the same life-cycle phase for two or more products.

When carrying out your comparisons, you should take note of any comments in the "other" box in connection with materials.

> Remember to take into account any lack of data and insecurities. If significant materials which form part of the product are not listed in Appendix B.1, you will have to seek assistance to carry out this calculation. You could, for example, contact one of the knowledge centres working with LCA.

A given value for resource consumption should be 50% greater than a comparable value before you can conclude that a significant difference exists.

Example B3.21: Materials consumption for the coffee maker
The MECO chart shows that the raw materials phase and the use phase are the most significant phases in this regard.
The information on quantities shows that the largest amounts of raw materials are used during the use phase (coffee and water).
The weighted inventory shows that the raw materials phase is the most harmful in environmental terms. Consumption of copper and aluminium are the most important elements.

3.2.3 Interpreting energy figures

The energy consumption has been measured in terms of process energy and the energy contents of the materials used.

You can choose to look at energy consumption measured in MJ, or you can look at the consumption of energy resources measured in mPR.

For example, you can prepare energy balance sheets measured in MJ for two different products and compare them.

The calculations on energy resources measured in mPR can be used for comparisons with other resource consumption under "materials".

Remember to take into account lack of data and insecurities. If significant materials or processes which form part of the product life-cycle are not listed in Appendices B.2 – B.5, you will have to seek assistance to carry out this calculation. You could, for example, contact one of the knowledge centres working with LCA.

A given value for energy consumption should be 50% greater than a comparable value before you can conclude that a significant difference exists.

Bear in mind that the primary energy consumption has been converted into oil consumption. This makes for a very conservative assessment. Energy can be generated from other, less environmentally harmful raw materials.

Even so, energy consumption measured in mPR tells us something about the resource consumption involved, and so these figures can be used to carry out comparisons with the resource consumptions calculated under the heading "materials".

Example B3.22: Energy consumption for the coffee maker
The MECO chart for the coffee maker shows that the energy consumption during the production phase is on the same level as consumption during the raw materials phase (154 MJ). The greatest energy consumption takes place during the use phase (9,656 MJ), but significant energy is also released when the coffee maker is finally disposed of by means of incineration (4,541 MJ). The large consumption of energy is mainly the result of the energy used to produce the coffee and the electricity consumed by the coffee maker.

The energy consumption for transport (2,968 MJ) is very high seen in relation to the raw materials and production phases. As energy consumption for transport usually involves consumption of oil, resource consumption has not been overestimated in this regard.

When comparing the various figures, energy consumption calculated as resources is significantly higher than the resource consumption associated with materials.

3.2.4 Interpreting chemical figures

To interpret the figures established for chemicals, you should use your additional chart, as illustrated in table 3.2, in addition to the MECO chart.

3.2.4.1 Chemicals lists

If a substance is listed in the List of Undesirable Substances, this is a clear indication that the substance has problematic properties in terms of the environment and/or working environment. It is likely that the substance will be banned or subject to stringent regulation in the short or longer term.

If a substance is listed in the Impact List, this signifies that it has undesirable properties in terms of the environment or working environment. The substance may be subject to regulations in the near future.

The List of Dangerous Substances is a list of examples. It comprises a wide range of substances which have primarily been assessed on the basis of their impact on human health. For some substances, assessment of environmental issues has also been carried out.

If a given substance does not appear in the List of Dangerous Substances, this does not mean that the substance is insignificant. All you can conclude from such an
absence is that you know nothing about its properties.

3.2.4.2 An initial sorting

You can use the three lists mentioned above to carry out an initial sorting of the impacts on the environment and working environment associated with the substances found in the life-cycle of your product. In what follows, we describe one possible way to sort substances into one of three categories: type 1, 2 or 3.

Type 1:	Highly problematic substances Substances included in the List of Undesirable Substances and the Impact List. Ozone-depleting substances, cf. Appendix B, table B.7.
Type 2:	Problematic substances Substances included in the List of Dangerous Substances for reasons other than that they are flammable or pose a risk of explosions. Substances about which you have no information.
Type 3:	Less problematic substances Substances which are only included in the List of Dangerous Substances because they are flammable or pose a risk of explosions. Substances which have very little harmful impact on the environment.

Example B3.23: Initial sorting of chemicals for the coffee maker.

The ancillary materials associated with the coffee maker are listed in B3.17. The initial sorting for these substances reveals these categories:

Acetic acid	Problematic substance
Crude oil distillate	Highly problematic substance
Hydrogen peroxide	Problematic substance

Table 3.3 shows some examples of assessments of chemicals. As it will appear, the substances cadmium and chromium are designated as highly problematic, as they are toxic and are listed in both the Impact List and the List of Undesirable Substances. Xylene and 2-propanole are less harmful to the environment than the two metals, as will be apparent from their classification and type.

Name	Cadmium (e.g. cadmium chloride)	Chromium(VI) (e.g. chromium trioxide)	Xylene	2-propanole
CAS no.	10108-64-2	1333-82-0	106-42-3	67-63-0
Classification	T, R45-48/23/25	O,T,C,N R49-8-25-35-43-50/53	Xn, R10-20/21-38	F, R11
The Impact List	X	X		
The List of Undesirable Substances	X	X		
Type	Highly problematic substance	Highly problematic substance	Proble-matic substance	Less problematic substance

Table 3.3 Examples of assessments of chemicals

Exactly how many substances you choose to assess further depends on your overall goal, the relevant quantities of the individual substances, and the number of substances involved. Begin by including the most important substances; you can supplement this later if you wish.

3.2.4.3 Impact on human beings and the environment

As an aid to interpreting the importance of the chemicals, you might want to carry out further assessment of what happens to a given chemical during and after use - what are the possibilities for exposure to the relevant chemical? (Human exposure and/or environmental exposure). Even if you do not calculate the quantities involved, the results may well indicate where the chemicals might be problematical.

If several chemicals or ancillary materials are used during a product's life-cycle, or if large quantities are used, it is important to be clear on how they may affect their surroundings.

During use, some chemicals may give rise to problematic working-environment conditions. In other contexts, the impact on human beings will be minimal.

A number of ancillary materials will follow the product, e.g. paint. Others will be regarded as waste after use, e.g. discarded roller oil, and yet others will be emitted with wastewater from the company, e.g. alkaline degreasing agents.

Figure 3.2 Chart for assessment of the impact of a given substance

Substance:			
Does the substance follow the product (yes/no)?			
Type:			
Impact on the surroundings			
Working environment	Air	Water	Waste

Use a chart like the one illustrated in figure 3.2 for each chemical or ancillary material that you choose to assess in greater detail. State the substance name in the first line of the chart.

You need to assess whether the chemical follows the product during its lifetime, thereby creating potential problems in connection with disposal. Enter a "yes" or "no" in the second line of the chart.

Then state which type you believe the chemical to be (highly problematical, problematical, or less problematical).

If you find that the substance affects the working environment, put an X in the appropriate box. If you do not know its impact, put a question mark instead.

The three boxes marked "Air", "Water", and "Waste" are used to assess how the substance enters the environment. If you know where the substance ends up, place an X in the appropriate box(es); if you are unsure, put a question mark instead. If, for example, you know that the substance emitted is not emitted into air, put a minus in the relevant box. Once all boxes are filled in, you have linked your previous sorting of the substance (identifying it as type 1, 2 or 3) and your knowledge about its fate in the environment.

The substances which have been identified as highly problematic or problematic and which are also emitted or discharged into the environment pose the greatest potential environmental threat and should be assessed in greater detail. Conversely, substances which are less problematic and which are not emitted pose only a minor threat to the environment.

Example B3.24: Assessment of a substance emission

Substance:	Naphtha, hydrogen-treated light		
Does the substance follow the product (yes/no)?		Yes	
Type:	Highly problematic substance		
Impact on the surroundings			
Working environment	Air	Water	Waste
X	X	÷	÷

Chapter 5 presents the semi-quantitative EDIP screening method which you can use to assign priorities to the substances which need to be assessed in greater detail.

The following conditions for environmental impacts can be used to carry out a rough interpretation of the significance of chemicals in relation to energy generation. For some of the most toxic of the highly problematic substances, the environmental impact of an emission of 1 g into the environment corresponds to the total environmental impact of the production of 1,000 – 10,000 MJ electricity (produced in Denmark). For the less dangerous, but still highly problematic substances, the corresponding figure would be approximately 10-100 MJ Danish electricity, whereas the problematic substances correspond to 1-10 MJ and the environmental impact of less problematic substances corresponds to that of less than 1 MJ Danish electricity.

You should always assign priorities to any substances which you have identified as type 1 substances, as well as any type 2 substances which appear in large quantities. For such substances, you should go on to carry out an actual chemical assessment – see chapter 5.

3.2.5 Other

Under the heading "other", you may have listed a number of different issues for which no specific instructions can be given.

Working-environment issues may concern noise or repetitive work in connection with production. They may involve allergy problems in connection with products that contain nickel, or emissions of solvents associated with certain paints. Ergonomic problems caused by poorly designed chairs may also be an issue.

Other issues might include use of large areas of land in the manufacture of vegetable oils or other, similar products. Energy generation based on waterpower also requires use of extensive areas.

One common feature of the issues listed above is that they are difficult to measure. You will have to make do with looking at these issues in a qualitative manner.

If you believe that the issues listed are significant to the overall impact assessment, or if you have any doubts about their importance, you should contact an expert to get advice on how to continue. See section 3.4.

3.3 Did you get answers to your questions?

You are now about to examine whether the MECO chart for your product(s) gives you the answers to the questions you asked when you defined the goal of your environmental assessment.

> First of all, you should go through the MECO chart to see if you should have forgotten anything. If so, you will have to supplement and complete the chart as appropriate.

It is a good idea to always go through your work with someone else, explaining the various assumptions you have made. If your company does not have a person with relevant qualifications among the staff, you will have to consult with someone from outside the company.

The interpretation of your results and the overall assessment in relation to the objective of your work depends on how your assessment is to be used. This is why it is important to correlate your original goal with the uncertainties associated with the MECO chart.

If the goal is that your work should be used internally at the company in connection with product development, the requirements for documentation will be relatively modest.

Example B3.25: Comparing goals and results
If the purpose of the environmental assessment of the coffee maker is to assess the materials used to manufacture it, the MECO chart can provide an excellent indication of where the majority of the raw materials involved are consumed. Here, you will see that aluminium and copper account for the most significant consumption. It should, however, be noted that the relatively high energy consumption entails much greater consumption of energy resources (crude oil).

Use table 1 in Appendix B to see which materials are regarded as less resource-intensive.

If you want to use a comparison between two products for marketing purposes, thorough documentation is crucial.

An environmental assessment carried out by means of a MECO chart will usually not provide sufficient documentation if the results are to be used externally. In such cases, it is also important to have an external expert review the materials.

3.3.1 Insufficiently clarified issues

If you have many insufficiently clarified questions, or if you feel something is missing, you will have to decide what sort of additional information you need.

It is important to distinguish between issues caused by:

- The preconditions
- Data uncertainty
- Lack of data

3.3.1.1 Preconditions

If the unclarified issues concern the product and the scope definition established for it, you will have to review the preconditions you made earlier. Perhaps you need to include more.

For example, you may need to find more information about the most common form of disposal for your product. If you do not know what the most common form is, but know that there are two options, you will have to consider both of them. Prepare a MECO chart for both options to assess whether the difference matters.

In other cases, you may face several options. In that case, you will have to establish some assumptions and see what their consequences are by preparing MECO charts – one for each option.

3.3.1.2 Data uncertainty

In order to be able to assess and compare your results, it is important that you carry out an assessment of the uncertainties associated with your results. There are two types of important uncertainties.

One type of uncertainty concerns the various figures measured. This kind of uncertainty will typically appear in connection with inventories of consumption of chemicals or energy. If you know the level of uncertainty, or if you can make an estimate of it, you should use the relevant figures. If you do not know the level of uncertainty, you should assume that all measured figures are subject to uncertainties of 25% and other figures are subject to uncertainties of 50%.

The second type of uncertainty has to do with the type of data you have been able to obtain. If your work has involved use of empirical figures or other figures from literature, variations in relation to your particular product(s) can be very significant. If you cannot assess this uncertainty yourself, you should assume that the figures may vary by a factor of 100%.

3.3.1.3 Lack of data

If you have difficulties in obtaining information about all the materials used to manufacture your product, or if other information is missing, you must try to assess the consequences of leaving out those elements.

For example, your lack of data may have to do with plastics. Most types of plastic are very similar. They are mainly made from oil and gas, the energy necessary to produce them is more or less the same for all types, and they have almost identical energy contents. In such cases, we recommend that you start by considering the total quantities: carry out calculations in the MECO chart to see whether it is important to know the exact type of plastic involved. If the precise nature of the plastic is important, you will need to seek further information – see section 3.4.

3.3.2 Where do you go from here?

You can continue your work in several different ways. The options described in this Handbook are outlined in figure

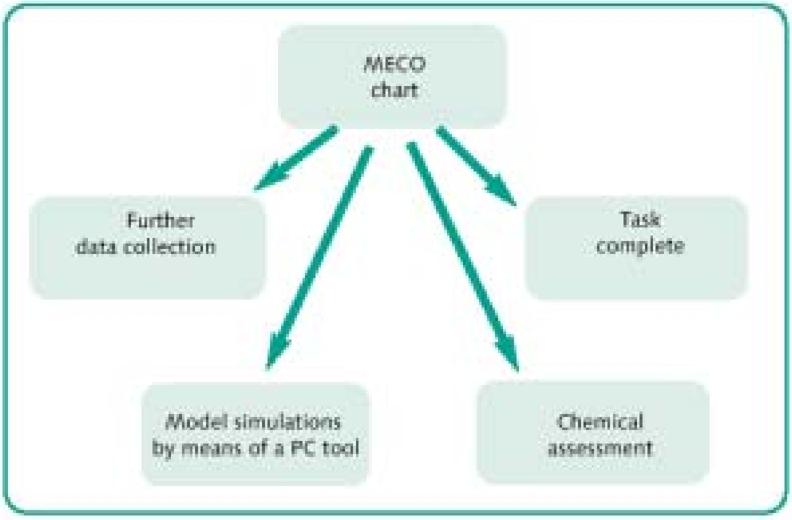


Figure 3.3 Options for further efforts once the MECO chart is complete

Examples of other possible assessments would be working-environment assessments, workplace assessments or risk assessments focusing on accidents and emissions into the surroundings. These possible types of assessment will not be addressed in any more detail in this Handbook.

Before you make your final decision, you should consult with another person. This could very well be an external person with experience within the area.

The following contains some instructions which can be used as rules of thumb as you choose your next course of action.

3.3.2.1 Task complete

If you find that the MECO chart answers your questions with sufficient certainty in relation to the goal definition, your task is complete.

Please note that the MECO chart does not focus on outputs such as emissions and waste.

The MECO chart is suitable for providing a first indication of the most significant issues associated with the life-cycle of a given product. It also provides an excellent basis for choosing between various materials in connection with product development or for internal information within your company.

Example B3.26: Significant issues in relation to product life-cycles

For the coffee maker, the MECO chart clearly shows that the energy consumption is greatest during the use phase, and that this phase is more important than the raw materials phase in terms of resources.

The MECO chart also shows that transport (primarily of coffee) is very significant to the total energy consumption.

As regards the raw materials used to manufacture the coffee maker, aluminium and copper account for the greatest environmental load. If the amounts used of these quantities can be minimised, the negative environmental impacts will also be reduced.

If you have the answers you were looking for, you are now ready to proceed to chapter 6. This chapter features recommendations on how to present your work.

3.3.2.2 Further data

If your review of the MECO chart shows that you need more data to describe the system or data about materials and energy, please consult section 3.4. Here, you will find instructions on how to find additional data.

> Example B3.27: Uncertain data
> If the goal of your work is to document the environmental impacts of the coffee maker in operation, the data bases for coffee filters, coffee, and heating as a result of energy losses are all estimated on a rather flimsy basis. Here, more data is called for!

Once you have obtained the additional data you need, you must enter them into your MECO chart and once again assess whether you need to continue your work.

3.3.2.3 Model simulations by means of a PC tool

If you want your assessment to be based on calculations of inputs and outputs, you should consider using a PC tool.

It may also be relevant to carry out a model simulation by means of the PC tool if you want to consider various changes to the product. This will make it possible to carry out the calculations in a more efficient manner.

Example B3.28: Product changes and assessment of emissions
If you wish to consider alternative materials for the manufacture of the coffee maker, it may be relevant to carry out a model simulation. It may be possible to replace copper and aluminium with other materials, or to use them in smaller quantities. By choosing a different design or mode of production, it may also be possible to separate out the materials and reprocess the metals.
The MECO chart showed that use of the coffee maker involves considerable energy consumption. Of the approximately 10,000 MJ consumed in total, half is used for coffee filters and half is used for electricity consumption. Model simulations are also relevant if you wish to assess the emissions and waste quantities generated.

If the MECO chart shows that a number of chemicals and ancillary materials are significant, you should carry out a chemical assessment and then later consider whether you wish to proceed with the PC tool.

Please read chapter 4 before you begin. Reading chapter 4 will make you familiar with a number of issues which you need to consider before making your final choice.

3.3.2.4 Chemical assessment

If, by following the instructions in section 3.3.1.3, you have found out that chemicals and ancillary materials are significant to your environmental assessment, you should carry out a proper chemical assessment.

Example B3.29: Products where chemical assessment is important

- Cleaning agents
- Pesticides, etc.
- Paints and varnishes
- Dyes and colouring agents

A common feature of these products is that they are made of a number of chemical substances, and that large percentages of the product enter the environment during the use phase.

It is difficult to provide specific instructions on when it is relevant to carry out chemical assessment instead of a detailed LCA or as a supplement to a detailed LCA. The most important parameter for this choice is whether the chemicals in the product can be expected to have significant negative impacts on human health and the environment in relation to the raw materials contained within the product itself.

As a rule of thumb, chemical products should be looked at by means of a chemical assessment, as a large percentage of such products are often emitted into the environment (examples include: paint, car maintenance products, household chemicals).

Please read chapter 5 before you start. It may be crucial to carry out a chemical assessment, but this can also be very difficult. You should consider having the entire chemical assessment – or parts of it – carried out by consultants/knowledge centres.

Once a chemical assessment has been carried out, you may want to proceed by using the PC tool. We recommend that you contact a knowledge centre which works with LCA in order to clarify this issue.

3.4 Find additional data

You will almost always need to seek additional data to supplement those already obtained.

In connection with expansions of the MECO chart, it would be most relevant to seek further information from the supplier of the materials and ancillary materials used.

If the supplier is also the manufacturer of the materials, you will be able to obtain excellent information about the contents of a given material or ancillary material. If the supplier acts only as dealer or importer, you may have to contact the actual manufacturer instead.

- For metals, it is important to identify the main component and any added materials.
- For plastics, it is important to identify the main component, any fillers and other additives as well as any residues of heavy metals and other impurities that may have an impact on the environment.
- For renewable resources, such as paper made from wood or oil made from plant seeds, it is important to obtain information on which substances and materials are used for manufacture. For example, paper production involves the use of chemicals as ancillary materials, and these ancillary materials account for more than 20% of the weight of the finished paper.
- In Denmark, the best documentation for chemicals is, generally speaking, a Danish Material Safety Data Sheet. You can requisition such safety sheets (often called MSDSs) from manufacturers or importers.
- If you need information in connection with the raw materials phase, e.g. information on the manufacture of a metal or manufacture of a particular kind of plastic, you will have to contact a knowledge centre for an expert opinion.
- Information about energy issues, energy consumption or energy contents in raw materials can be obtained on the Internet. Even so, it will often be necessary to seek advice from a knowledge centre.
- If you need conversion factors to calculate mPR values, you will have to contact a knowledge centre with experience of establishing such factors.

Of course, it is always possible to seek information on the Internet. Generally speaking, however, the data found on the Internet will usually not be given in a form which renders them suitable for your purposes.

At the website of the Danish Environmental Protection Agency, you can search for reports and projects which involve life-cycle assessments of one or more products. If one or more of these projects are about your product type, you may find relevant information that way. Some project reports are available at the website (http://www.mst.dk), while others can be ordered from Miljøbutikken.

4. Carry out environmental assessment with a PC tool

By filling in the MECO chart, you have now established a paper model for the environmental assessment of your product.

The information about consumption of material and energy, waste, and emissions to air and water can be converted into environmental impacts by preparing a model in a PC-based tool.

This chapter is based on the Danish Environmental Protection Agency PC tool – the EDIP PC tool (beta version 2.11, 1998 – which was developed on the basis of the EDIP method [Wenzel et al., 1996].

4.1 Advantages of the PC tool

There are certain advantages to modelling your environmental assessment in a PC tool:

- The model is constructed systematically
- It is possible to draw data from a database, thereby reducing the need to collect further data
- Waste and emissions to air and water are included in the calculations of environmental impacts
- It is easy to carry out subsequent adjustments if e.g. new, more detailed information on inputs and outputs become available or if e.g. one ancillary material is replaced by another.
- It is easy to introduce changes, which means that the expected environmental impact of a future change can be compared to the “old” product.

It should, however, be borne in mind that use of any PC tool will always require a lot of resources in the form of training on how to use the software, PC capacity, and expenses for purchasing licences for the selected tool – prices vary considerably from tool to tool.

4.2 Before you begin

If you have decided to carry out model simulations in a PC tool, the MECO chart provides a good place to start. In the MECO chart, you have already identified some of the areas which affect the environmental impact of the product. You can choose to model the entire life-cycle, or just parts of it. If the entire life-cycle is not modelled, it is important to make sure that the most significant areas – in environmental terms – have been identified in the MECO chart. Partial modelling will typically be carried out when comparing two very similar products: model simulations will only be prepared for those parts of their life-cycles which are different from each other. You do, however, need to be aware of certain issues.

4.2.1 Choosing a PC tool

Choosing a PC tool is not always easy, as there are many different tools available on the market today. It is, however, important to identify what the tool should be able to do and which data are important to facilitate the easiest possible modelling process.

Data collection requires many resources. This is why an extensive database can save time if you do not already have all the data necessary for the product. It is also a good idea to spend a little time finding out what the PC tool requires from users. This will give you some indication of the time necessary to be able to carry out model simulations with the tool. In 2000, the most common PC tools in Denmark were:

- EDIP PC tool (beta version)
- Simapro

The EDIP PC tool comes with a manual with step-by-step instructions on how to use the tool [Pedersen, M.A., 1998]. This manual provides instructions for installation and use of the calculation programme and the database.

For Simapro, a set of manuals is available. These manuals describe the software structure and how it should be used. They also describe the database and the programme functions [PRé Consultants B.V.].

If you want to know more about the PC tools available on the market today, please refer to the article "Results of a test of LCA software with statistical functionality" [Weidema, B.P., 1997]

Below are instructions on modelling, interpretation, and other issues related to use of a PC tool.

4.2.2 Data

The type and quality of data in the database associated with the PC tool should be carefully examined. You should consider issues such as:

- Age
- Uncertainty
- Transparency – can you see how the figures were arrived at?
- The method used
- Sources – do the data come from a specific process, or are the figures averages?

Use your review to decide whether the database contains information which covers your needs.

These issues should be addressed; partly to establish an overview of what data you still need to find, and partly in order to be able to determine the uncertainty of the results of the environmental assessment.

4.2.2.1 Data for production of materials or for processes

Data for production of materials or for processes can be divided into data for a particular process, measured at a specific company, and general average data. The more data you can find directly related to your product, the better – such data reduces the level of uncertainty. Mostly, however, the data in PC-tool databases will be general data.

As regards production of materials, it will often only be possible to obtain general data. It can also be difficult to determine where the materials have been manufactured if they are bought from an international dealer who trades in the same product types from several different countries. One example would be steel plates, where it is often difficult to trace the origins of the raw steel.

Data for production processes will largely be available from your own production department. If the database is used, it will often feature data from a specific process carried out at a specific manufacturer. In such cases, you will have to assess whether the data or parts thereof can be used for your product.

Please note that data for production processes vary widely from one company to another. Even though you find the relevant process in the database, large variations may still occur.

If you cannot find any data for the exact process used, you may use data for a corresponding process. Such estimates should be used with caution. For example, you need to be aware that some emissions or waste types can be quite atypical, and that energy consumption values can differ. Even so, data from PC-tool databases can form a good basis for educated guesses.

The same process may well show considerable differences from one company to the next. This is why you should always review the process-related data in the database to make sure that the values for waste generation and consumption of ancillary materials and energy correspond reasonably closely to the substances used for the processes associated with your product.

4.2.2.2 Impact factors

Data in the form of impact factors are necessary in order to be able to calculate the environmental impact of a given substance. The impact factor expresses how much the emitted substances contribute to the relevant environmental impact. The impact factor is used for characterisation, see 1.3.4 in part A.

The impact factors for a number of substances constitute part of the database of the PC tool. Before you carry out a model simulation, you should check whether the database includes factors which are relevant to the substances found in your product.

If the impact factors are not in the database, you must assess whether the environmental impact of the substance is significant, i.e. whether it is necessary to calculate an impact factor for the relevant substance.

We recommend that you consult an environmental expert to assess the significance of the impact factor for the substance. The actual calculation of the impact factor itself should be carried out by an expert.

In addition to impact factors, the PC tool uses normalisation and weighting factors. These factors are used to convert the environmental impacts identified during characterisation to normalised and weighted results. As the method is based on an interpretation of the weighted results, it is important that the database includes these factors as well.

Please note that for some resources, no weighting factors appear in the database. The weighting factor is an expression of the seriousness of the relevant resource or environmental impact. If no weighting factor is given, this means that the relevant resource will not feature in your weighted environmental profile.

4.2.2.3 Data quality

The age of the data is significant, particularly if the data concern processes or products with short lifespans.

Remember to be critical of data which is more than 5-10 years old. Check whether significant technological progress has been made within the area, or whether there are large geographical differences in relation to the processing or production of the product.

It is important to ensure that the database contains as much of the data you need as possible. Partly to save time, but also to reduce the elements of uncertainty in your environmental assessment.

When reviewing the database for data, you should be aware that the quality and quantity of data varies from tool to tool. Creating a model simulation for your product in the PC tool will become easier in direct proportion to the quantity of data – with relevance to your product – available in the database. More data means that you can save time on data collection and on entering data into the database.

4.2.3 Other issues

4.2.3.1 Outputs

Before you begin the actual modelling, you need to supplement your MECO chart with information on the most significant outputs associated with your product. These outputs take the form of waste and emissions to air and water. This means that when modelling e.g. a coffee maker, you need to include coffee grinds and the used coffee filters as waste.

If a given material, process, or type of energy consumption exists in the PC tool, waste and emissions will usually be included in the calculations automatically. You should check whether this is the case for all the most significant materials and processes, making sure that all outputs are included – and are included only once.

The emissions (e.g. CO2, SOx, NOx) caused by the energy used to make coffee throughout the coffee maker's lifetime must also be included in the use phase. If data is drawn from the database, these emissions will automatically be included.

4.2.3.2 Compensation

Here, "compensation" has to do with the part of your product system which you do not have to "pay for" in environmental terms. This means that some materials and some energy will be deducted from the total impact, either because they are recycled/reprocessed, or because they perform secondary services as described above. You need to take compensation into account when working with PC tools, just as you do in connection with your MECO chart. In chapter 3, example B3.6 features one example of a simplified way of compensating for materials, etc.

A distinction is made between systems (or materials) where materials are recovered and systems (or materials) where heat is recovered.

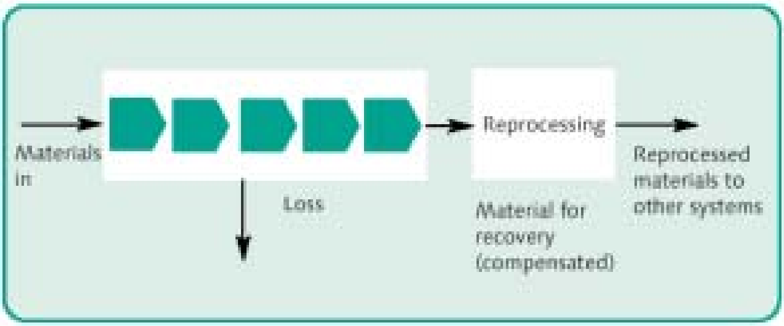


Figure 4.1
System with recovery of materials

Figure 4.1 illustrates a loss of materials during the product life-cycle. This may occur in the form of waste during production or in the form of incorrect disposal of the product when it is discarded. Table 2.2 (chapter B.2.) provides some rules of thumb on disposal routes for materials; these can be used if you do not know the method of disposal used.

Reprocessing is the first step of recovering the discarded product. Reprocessing materials such as glass, plastic, and paper/cardboard involves a so-called quality loss. This loss expresses a reduction in the quality of the material caused by reprocessing.

Table 4.1 illustrates the quality factor for a number of materials. This quality factor is to be multiplied by the quantity of the reprocessed material. The result is the actual useful quantity of reprocessed material, and this is the quantity which will be used for compensation. The compensation will be incorporated in the disposal phase.

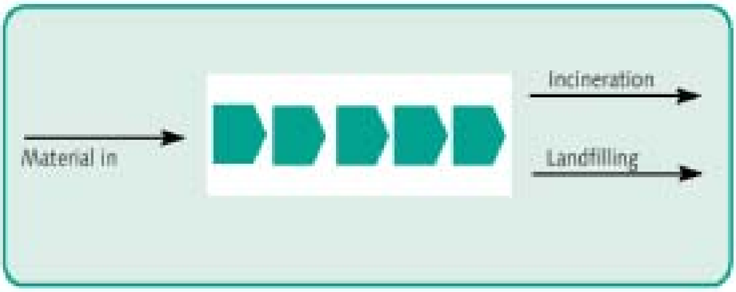
Material	Factor
Paper/cardboard	0.8
Glass	0.9
Metals	1
Plastic	0.8

Table 4.1
Quality loss associated with reprocessing

In addition to the quality loss, you need to remember to include the actual reprocessing process in your model. Table 3 in Appendix B provides some data for the process energy used for reprocessing – these data can be used if you do not know the actual energy consumption figures. In cases where the energy consumption for reprocessing is not known, it is recommended that you use 50% of the energy consumed during the production phase as an estimated figure.

The quantities of materials sent for reprocessing are taken either from the relevant production system or from the right-hand "column" in table 2.5 (chapter 2) under "disposal".

Figure 4.2
System without recovery



Incineration of products (plastic, paper, etc.) generates energy. This energy can be used for e.g. heating and so needs to be offset against the total environmental impact of the product in order to compensate for the positive contribution made. You should make sure that you offset this energy in your model simulation. Once again, compensation will occur during the disposal phase.

Energy recovery is calculated as the calorific value times the quantity of materials incinerated. The quantities of incinerated materials are taken from the relevant product system or calculated on the basis of the percentage listed in table 2.2 (chapter 2) under "disposal".

For products which comprise several materials, the calorific value must be estimated on the basis of the dominant materials used in the product. For mixed household waste, the calorific value can be set at 15 MJ/kg.

Example B4.1: Calculating the energy released as heat when incinerating plastic

Incinerating 200 g polypropylene plastic generates energy, and you need to compensate for this energy in your assessment. The amount of energy to be compensated for is calculated like this:

0.2 kg x 40 MJ/kg = 8 MJ

4.2.4 Modelling in the PC tool

This leaves the actual modelling in the PC tool. We recommend that you base your work on the MECO chart you prepared earlier. It can be helpful to prepare a flow diagram on the basis of the MECO chart.

Such a diagram gives you a better overview of what happens during the various life-cycle phases – where the inputs come from and where they end. Figure 4.3 shows a flow diagram for a coffee maker.

The flow diagram shown in figure 4.3 is different from the one featured in figure 2.1. The diagram in figure 4.3 has been chosen because it is consistent with the structure and system of the

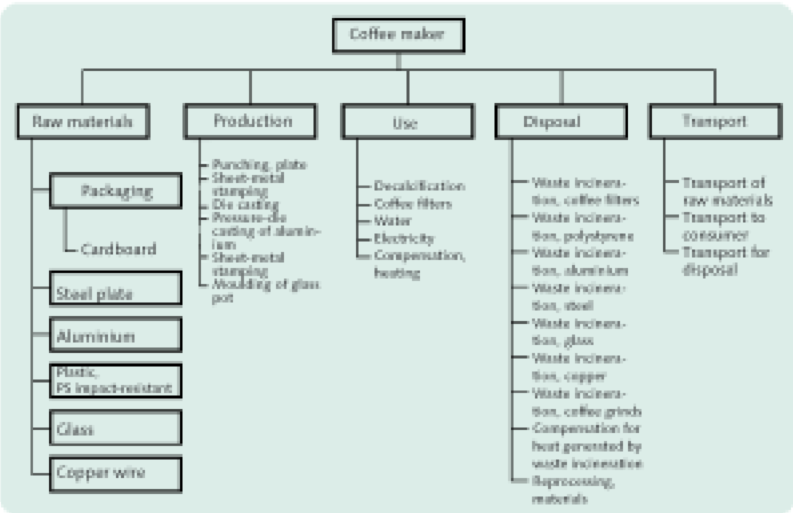


Figure 4.3
Flow diagram for a coffee maker

When you carry out modelling in the EDIP PC tool, you should refer to the manual for descriptions of how to proceed. The manual describes what you need to take into account, how to model your product, and how to handle data for a particular process, etc.

> It is a good idea to check and ensure the quality of your model by letting others read it and offer comments – preferably before the modelling by means of the PC tool is initiated.

Figure 4.4 shows the steps of the modelling. First, the product life-cycle is described, then modelled. Following this, the PC tool will calculate the environmental impacts and resource consumption.

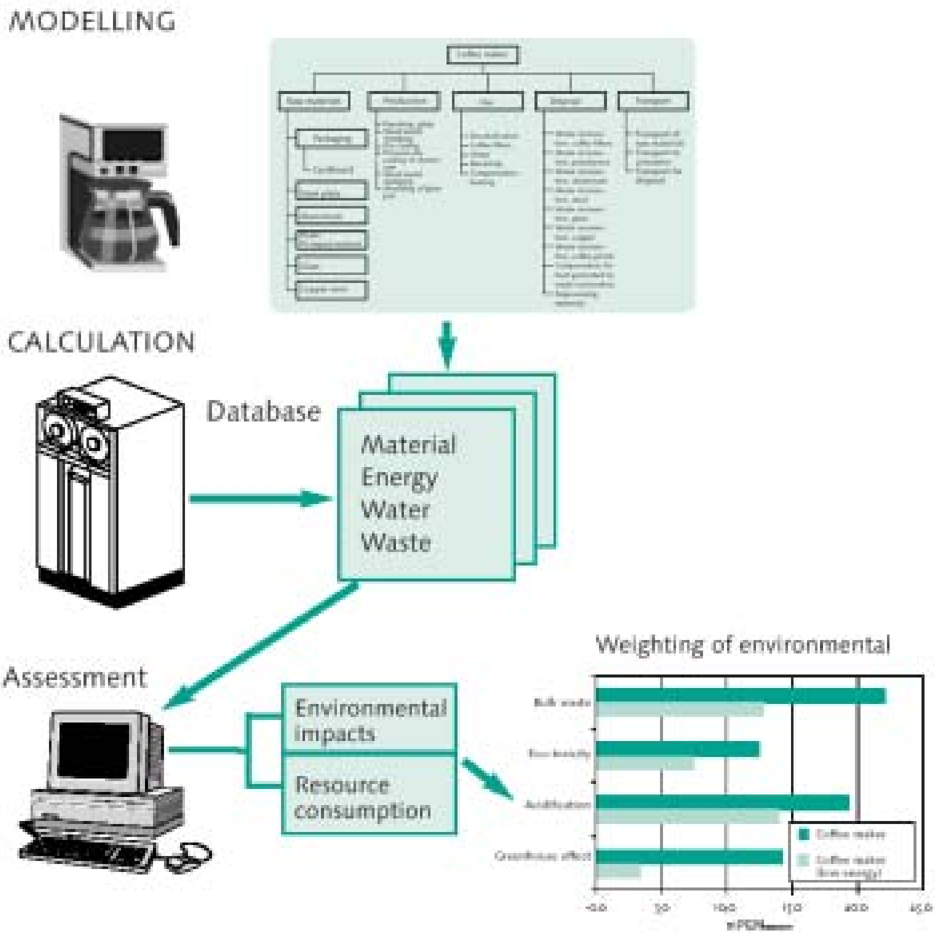


Figure 4.4
The stages of modelling

Modelling in the EDIP PC tool is based on a hierarchic structure of your model, as illustrated in example B4.2. The example shows the model for a coffee maker.

Example B4.2: Hierarchic model (coffee maker) in the EDIP PC tool

The processes marked * were not in the database and so have been established in connection with the modelling. Furthermore, it should be noted that the energy consumption values for production of coffee filters and coffee are estimated values, and that use of washing-up liquid during the use phase has been omitted.

1 coffee maker
1 Material phase
1.12 kg plastic, polystyrene
0.02 kg plastic, PVC
0.11 kg aluminium (primary)
0.3 kg steel plate (89% primary)
0.34 kg glass (primary)
0.02 kg copper wire, 0-1 mm
0.39 kg packaging, cardboard (reused)

1 Production phase
0.2 m punching, metal sheet, 1-2mm
0.3 kg stamping, 1-2 mm
1.14 kg die casting, 10-100 g PA
0.11 kg pressure-die casting, aluminium
0.34 kg moulding of glass pot*
1 kg natural used for stoking (1-50 MW)

1 Use phase
15 kg acetic acid
540 kWh Danish electricity
1 compensation to compensate for heating effect*
-38.3 kg gas oil for stoking 1-20 MW per kg
3,650 kg tap water, Danish
7.3 kg coffee filters*
1 kg cardboard (84% primary) per kg
290 kg coffee*
1.85 kWh global electricity per kg

1 Disposal phase
0.11 kg waste incineration, aluminium
1.12 kg waste incineration, polystyrene
1.12 kg heat recovered from incineration w. losses, polystyrene*
-0.867 kg gas oil 1-20 MW per kg
0.02 kg waste incineration, PVC
0.02 kg heat recovered from incineration w. losses, PVC*

0.394 kg gas oil 1-20 MW per kg
7.3 kg waste incineration, coffee filters
7.3 kg heat recovered from incineration w. losses, cardboard*
-0.329 kg gas oil 1-20 MW per kg
290 kg waste incineration, coffee grinds*
290 kg heat recovered from incineration w. losses, coffee grinds*
-0.44 gas oil 1-20 MW per kg
0.39 kg waste incineration, packaging, cardboard
0.39 kg heat recovered from incineration w. losses, cardboard*
-0.329 gas oil 1-20 MW per kg
0.3 kg waste incineration, steel
0.15 reprocessing process, steel*
-0.15 kg reprocessing 50% w. losses, steel*
0.17 kg waste incineration 50%, glass
0.15 reprocessing process, glass*
-0.15 reprocessing 50% w. losses, glass*
0.02 kg waste incineration, copper

1 Transport phase
2,900,000 kgkm ship (raw materials)
11,900 kgkm ship (raw materials)
230 kgkm lorry (to consumer)
1,498 kgkm lorry (to incineration)

Generally speaking, the procedure will, of course, depend on the choice of tool. It will also, however, depend on the person doing the modelling – after all, we all have our ideas about the best ways to go about things. We do, however, recommend that the people involved in the modelling agree on the structure. That makes it easier for others to read and understand your model.

Once the modelling has been carried out and any missing, important impact factors have been entered into the database, the PC tool can calculate resource consumption and environmental impacts. This is to say that the PC tool carries out characterisation, normalisation, and weighting.

4.3 Interpret the environmental assessment in the PC tool

When you model your product by means of the PC tool, you will get a range of values for calculated contributions to various environmental impacts and resource consumption. These contributions are given in PE (Person Equivalents) and PR (Person Reserves) for environmental impacts and resource consumption, respectively.

In weighted results, the following units are used:

- 1 PEM corresponds to the average annual contribution which one person may make without exceeding the politically determined reduction targets for the year 2000 in the world (W) and Denmark (DK).
- 1 PR corresponds to the amount available of a given resource to a single person and his/her descendants in perpetuity.

Please note that resource consumption is calculated per year in the PC tool, whereas it is calculated for the entire product life-cycle in the MECO chart.

You can choose to present your results as normalised or weighted results by means of the EDIP PC tools. The simplified environmental assessment method in this Handbook is based on a presentation of weighted results. The weighted results give an assessment of the seriousness of the environmental impacts and resource consumption associated with your product.

If you need to use the results in a situation where the weighting factors in the chosen PC tool are not immediately recognised, you can choose to continue your work based on the normalised results.

In the EDIP PC tool, the weighting factors are based partly on the known supply horizon for non-renewable resources, and partly on the politically determined reduction targets for a number of environmental impacts.

4.3.1 The cause of the environmental impact of the product

In the interpretation, the cause of the individual environmental impacts must be identified and described. You should first consider the size of the individual impacts and assess which are large, and which are small. Then you should move on to determine the cause of the relatively "large" impacts.

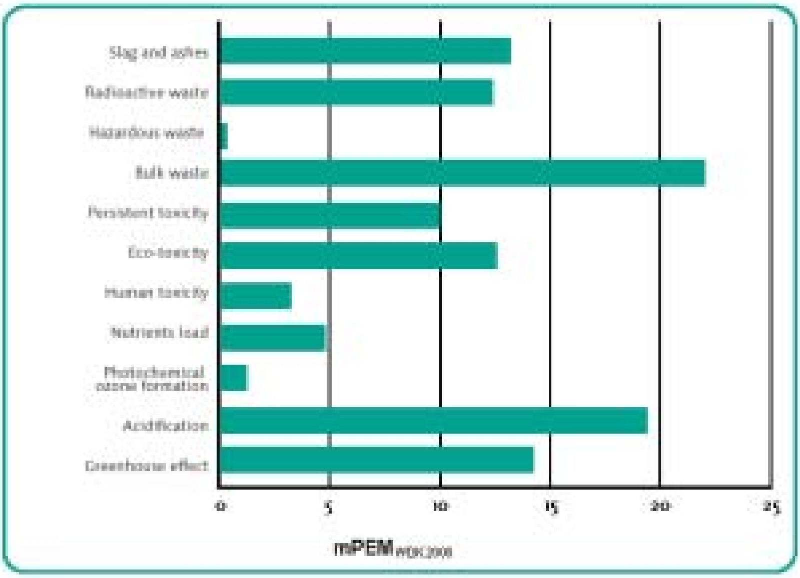
Typical causes and resultant environmental impacts:

- Energy consumption will typically cause acidification, greenhouse effect, nutrients loads, and human toxicity. It will also generate waste types such as slag, ashes, and radioactive waste.
- Consumption of materials will drain resources and generate certain types of waste.
- Consumption of chemicals will often cause environmental impacts such as toxicity for human beings and the environment as well as photochemical generation of ozone.

The weighted resource consumption and environmental impact potentials for the example with the coffee maker are calculated in the EDIP PC tool, and the results are presented in figures 4.5 – 4.6.

The unit mPEM stands for milli-person equivalents, targeted. mPEMWDK2000 means milli-person equivalents, targeted in the world and Denmark for the year 2000. The unit mPRW90 means milli-person reserves identified in the world in relation to the reference year, 1990.

Figure 4.5 Weighted environmental impact potentials per year for the coffee maker (with a lifespan of five years)



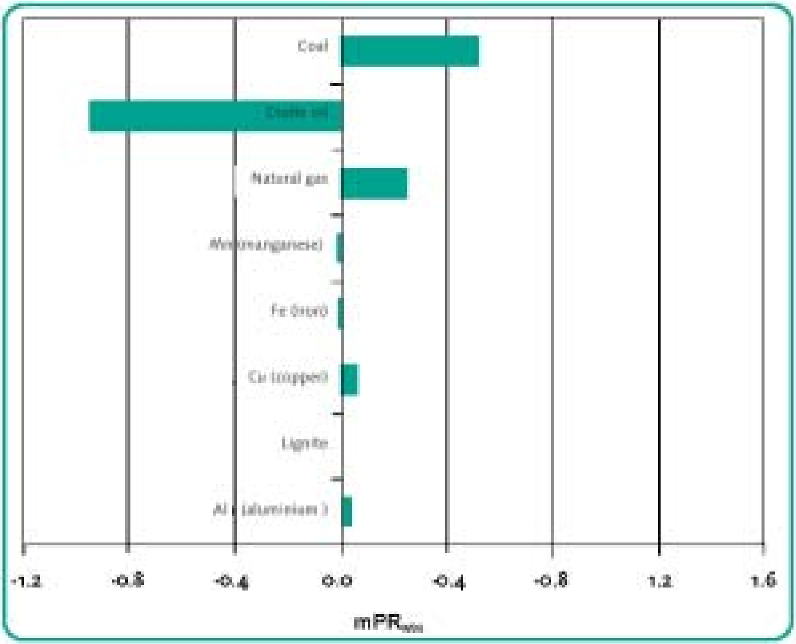


Figure 4.6
Weighted resource consumption per year for the coffee maker (with a lifespan of five years)

Figure 4.6 shows considerable consumption of coal and natural gas. These resources are primarily used to generate Danish electricity, which is used to manufacture the coffee filters used during the use phase as well as for the actual coffee-making. The net consumption of crude oil is negative because we compensate for the heat generated from waste incineration during the disposal phase in the final result.

Figure 4.6 also shows that the use of a comparatively small amount of copper in the wire for the coffee maker entails a greater draw on resources than the use of aluminium, even though more aluminium is used. This is because copper is a scarce resource and so has been weighted higher than aluminium. Copper primarily contributes to eco-toxicity (see figure 4.5), whereas aluminium contributes to eco-toxicity and to the greenhouse effect and bulk waste (i.e. household waste, construction waste and similar waste disposed of at a municipal landfill. Such waste is characterised by not containing any substances that are dangerous to the environment).

Figure 4.5 shows that the most important environmental impacts concern the energy-related impacts such as greenhouse effect, acidification, human toxicity, and waste.

The EDIP PC tool shows many impacts, and of course not all of them are equally relevant to your environmental assessment. This is why we recommend that you select impacts which are relatively large for the next step of your work: the interpretation of the environmental assessment. We suggest that you select 3-5 impacts for further treatment. You should not, however, choose three waste categories.

4.3.2 Assigning impacts to phases with EDIP PC tools

Using an EDIP PC tool gives you the chance to assign the environmental impacts to the phases of the product life-cycle: raw materials, production, use, disposal, and transport.

4.3.2.1 Where are the most significant impacts found?

The opportunity to assign the various impacts to each phase will help make the causes behind the impacts more visible. You will be able to see how large a part of e.g. the greenhouse effect is caused during the raw materials phase or production phase. This is illustrated in figures 4.7 – 4.8, where the coffee maker's contributions to environmental impacts and resource consumption have been assigned to their relevant phases. For example, the figures show that the contribution to the greenhouse effect stems primarily from the use phase.

Identifying the cause of the environmental impact will give you an overview the materials, processes, etc. which make up the environmental profile of your product. This overview can make it easier to point out the areas where changes could result in significant environmental improvements of your product.

All the figures below are also examples of how the results of the environmental assessment can be presented. It is a good idea to show the results divided into the various phases. Please note that the more impacts you show, the harder it will be to read your results. In the example with the coffee maker, four environmental impacts have been selected: greenhouse effect, acidification, eco-toxicity, and bulk waste. These four impacts were chosen because they are relatively large when compared to the other contributions (see figure 4.7). The resource consumption values have been selected on more or less the same basis – which is to say that the largest were chosen. In addition to this, the largest non-energy-related drains on resources have also been selected – copper and aluminium in this specific case.

In order to make comparisons of several products more easily accessible, it may be a good idea to show the environmental profiles of all the products in a single graph.

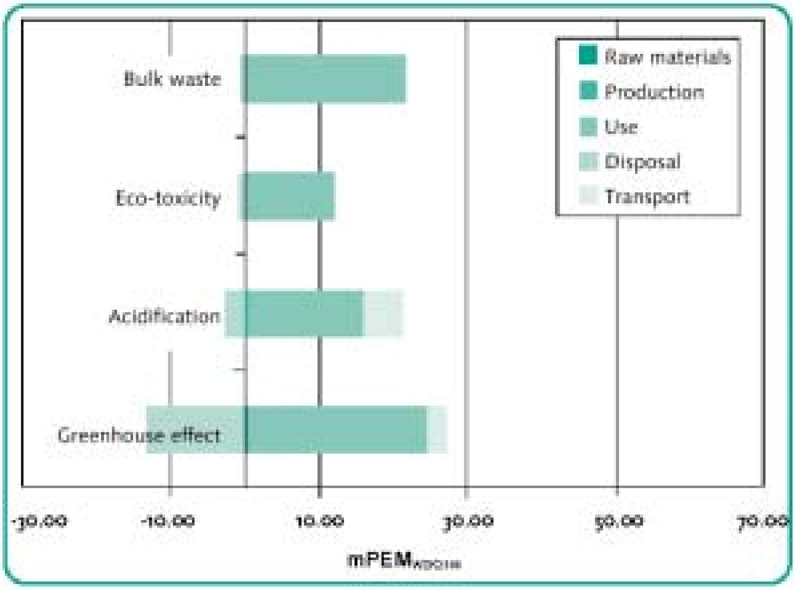


Figure 4.7 Weighted selected environmental impact potentials per year for the coffee maker, by life-cycle phase

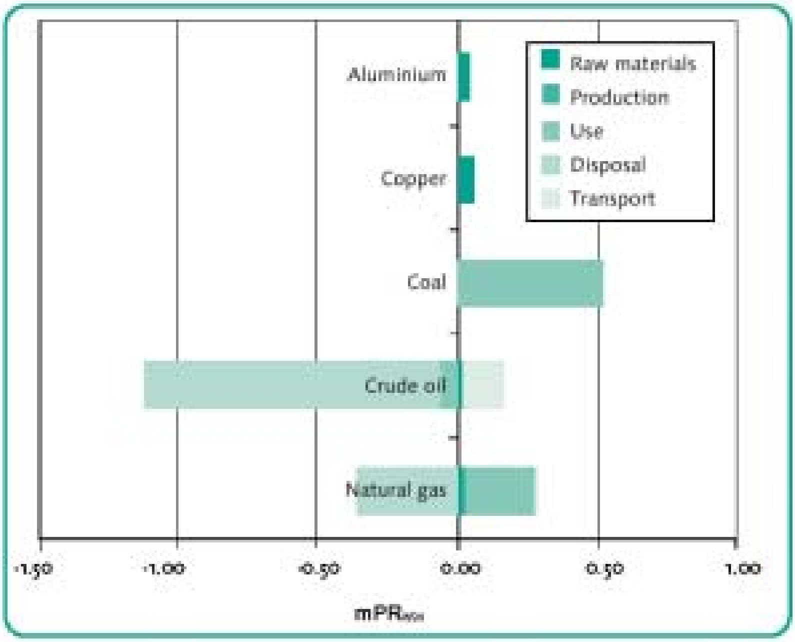


Figure 4.8 Weighted selected resource consumption values per year for the coffee maker, by phase

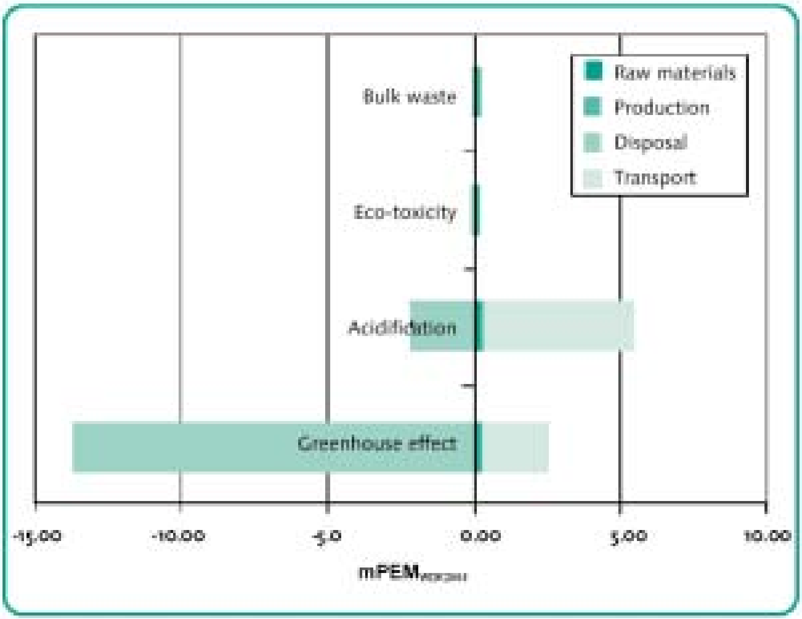
The listings by phase in figures 4.7 and 4.8 show that the use phase accounts for the majority of all environmental impacts and resource consumption. This is not surprising, as experience shows that energy consumption during the use phase often overshadows all the contributions from the other phases.

The elements for which compensation is made (the negative impacts shown in the figure) come from the heat and materials reprocessed during the disposal phase. This is to say that the total contributions are established by deducting the contributions from the reprocessed energy and materials from the contributions from the other phases.

4.3.2.2 Other impacts

In the example with the coffee maker, we have seen that the use phase is the most important in terms of environmental and resource consumption. If we omit the use phase from the overall picture, it becomes easier to identify the contributions made by the other phases of the coffee-maker's life-cycle. See figures 4.9 and 4.10.

Figure 4.9 Weighted selected environmental impact potentials per year for the coffee maker, by phase. The use phase has been omitted.



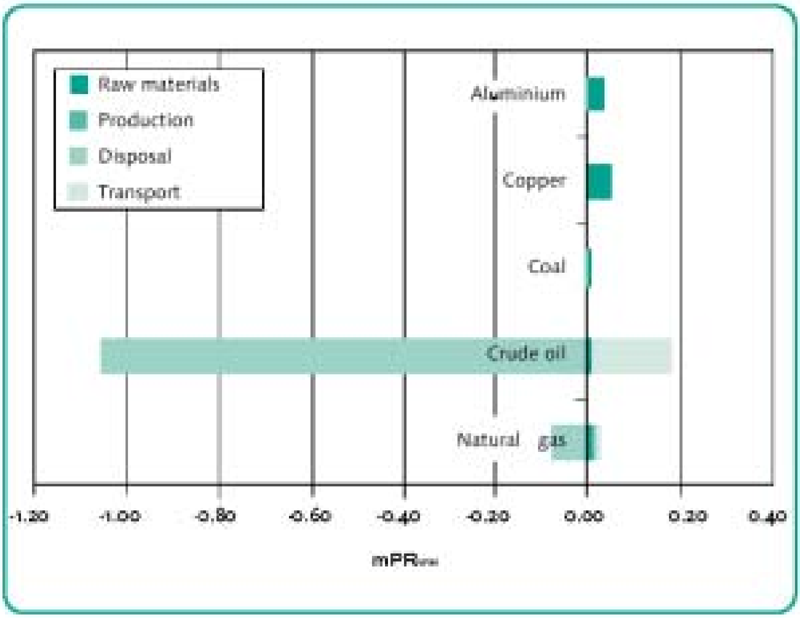


Figure 4.10 Weighted selected resource consumption values per year for the coffee maker, by phase. The use phase has been omitted.

Leaving out the use phase in figures 4.9 and 4.10 establishes a clearer overview of the contributions made by the other phases. Please note that the scale of the y-axis is now different. As might be expected, the disposal phase is also significant. After all, the coffee maker is made from materials which entail a relatively high degree of heat recovery upon incineration.

The production and raw materials phases make only small contributions. The contributions from the production phase come primarily from the energy used in the different processes. The contribution from the raw materials phase stems from the materials used to manufacture the product.

The transport phase makes a greater contribution than the other phases. In total, the transport featured in the coffee-maker example is of little significance. Often, the transport phase is omitted, as it is usually only significant for products which are transported far and have short lifespans and/or are transported by plane.

4.3.3 Comparing two products

If you wish to compare two products, A and B, we recommend that you compare individual impacts and resource consumption values for each product.

4.3.3.1 General instructions

If product A involves an impact contribution which is 50% greater than the corresponding contribution from product B, this obviously means that product B is preferable as far as that particular impact is concerned. If the difference between the two products is less than 50%, it will usually not be possible to determine with absolute certainty which product is best in environmental terms. This is due to uncertainties in connection with data, calculations, etc.

It may be helpful to divide the environmental impacts into three types: global, regional, and local impacts. This gives you the opportunity to assign priorities to the environmental impacts depending on the company's location, policies, etc. If, for example, the company is located in an urban environment, this entails certain requirements in terms of the impact on the immediate surroundings. Such requirements are different to those applying to a company located in a field with 10 km to the nearest neighbour. Example B4.3 illustrates one such comparison.

Example B4.3: Comparing products A and B

Environmental impact	Product A (mPE)	Product B (mPE)	A-B*	Environmental impact type
Greenhouse effect	41	70	_	Global
Acidification	20	33	~	Regional
Nutrients load	100	37	+	Regional
Eco-toxicity	47	2	+	Local
Human toxicity	17	23	~	Local
Dangerous waste	55	6	+	Local

* +: product A is more harmful to the environment than product B

- : product A is less harmful to the environment than product B

~: there is no difference between the environmental properties of the two products

Once your comparison is complete, you will have a number of pluses and minuses to be assessed. Whether one product is better than another depends very much on which environmental impacts you regard as the most important. It may, for example, be crucial that your product does not have a strong toxic effect on the aquatic environment. If, for example, your company is located near a very sensitive aquatic environment, it would be most appropriate to choose product B in this particular case (due to its low eco-toxicity). It may also be that the environmental policy at your company is to aim for as little impact on the greenhouse effect as possible. If so, product A would the best choice in this particular case.

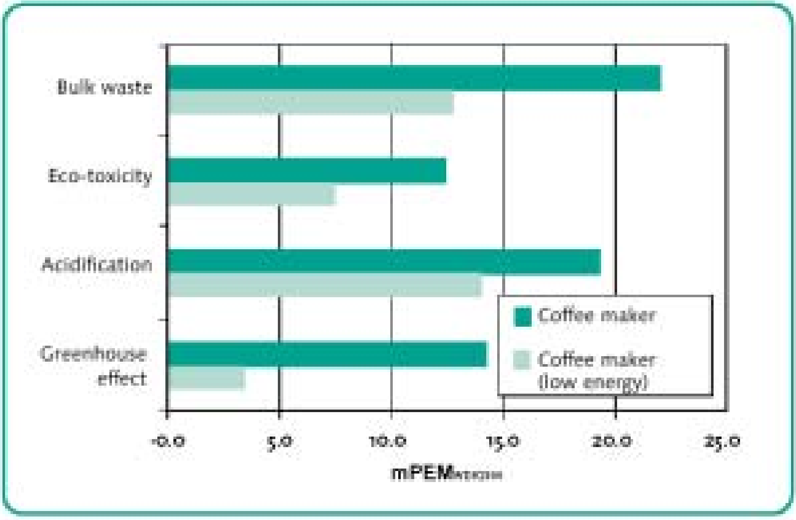
As illustrated in example 4.3, many factors apply when comparing two products. Often, both products will offer certain advantages within different areas.

For products with very similar life-cycles, you can simply assess the differences between them. If the difference between two products is that one is made from 5 kg of aluminium and the other is made from 2.5 kg plastic, you can settle for simply assessing the environmental impact of the raw materials phase, the production phase, and the disposal phase for the two products and then compare your results. This method is, however, only useful in cases where the objective of the environmental assessment is to decide which of the two products is best for the environment within a single, highly specific area. Such an assessment says nothing about the products' total impact on the environment or the resource consumption associated with them. Nor does the assessment say anything about the nature of the environmental impacts which the products contribute to. This means that an environmental assessment of this kind does not tell you much about the overall environmental impact of the products.

4.3.3.2 Example

The following shows an example of a comparison between two coffee makers. The difference between the two products is that one features lower energy consumption (200 kWh) during the use phase than the other product (the reference product), which has a corresponding energy consumption rate of 540 kWh.

Figure 4.11 Environmental impact potentials per year for a comparison between two coffee makers with energy consumption rates during the use phase of 200 and 540 kWh, respectively



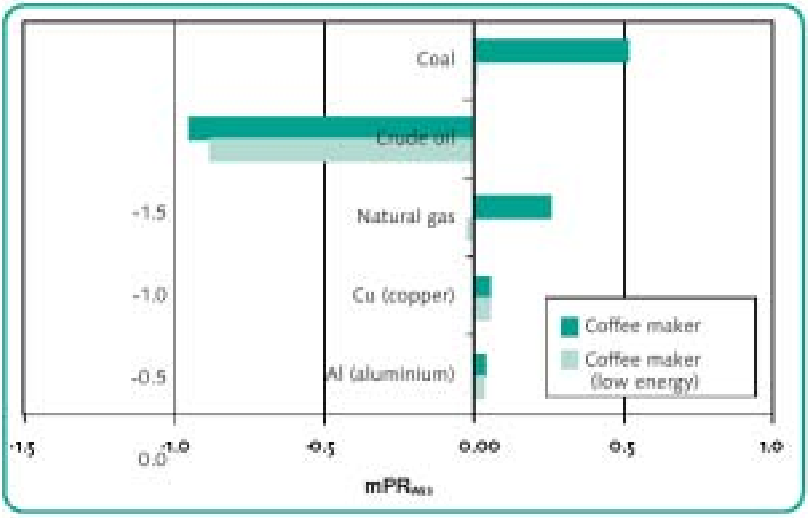


Figure 4.12 Resource consumption values per year for two coffee makers with energy consumption rates during the use phase of 200 and 540 kWh, respectively

As expected, figures 4.11 and 4.12 show that the energy-related impacts are smaller for the coffee maker with the low rate of energy consumption. The difference may not appear as large as you would expect; this is because large quantities of energy are also expended on making coffee filters and coffee.

The example also illustrates that a manufacturer (in this case of coffee makers) cannot influence every aspect of the product life-cycle. Here, for instance, a reduction in energy consumption in connection with the coffee filters would improve the environmental profile of both coffee makers.

4.3.4 Uncertainties

Interpretation also includes an assessment of the uncertainties in your calculations. You should be aware that even small changes in your basic data can cause large changes in the environmental impacts calculated. You need to take this into account in your interpretation.

If your work involves data of inferior quality, you should consider how changes in these data could affect the overall result.

For example, the interpretation of your environmental assessment will not change if the change concerns the energy consumption for a process in the manufacture of a product which has a very large energy consumption compared to the other phases.

It may, however, affect your environmental assessment if you are working with a plastic product that contains lead and where it has not been possible to include this lead in your assessment because of insufficient data about the quantities.

4.4 Were your questions answered?

The interpretation of your environmental assessment should hopefully provide you with answers to the questions which caused the environmental assessment to be initiated in the first place. However, the results of the environmental assessment are not always sufficiently clear and unambiguous. For example, you may discover that the uncertainties associated with the data used are so significant that it is impossible to make decisions based solely on your environmental assessment. In such cases, it may be necessary to take the next step, possibly by collecting more data or by having more impact factors calculated.

For example, we might imagine that you have tried to compare two different types of plastic to identify the one with the least harmful impact on the environment. If your comparison shows that there is no difference between the two types of plastic, this may be because your assessment has not included data about additives, pigments, special ingredients, etc. In order to determine which of the two types of plastic is least harmful to the environment, it will be necessary to proceed by collecting data about the missing substances and by having an expert calculate impact factors which were not included the first time around.

In other cases, it may be sufficient to simply collect further data. You will typically have to collect further data in cases where you can see that a specific area – such as a process, a material, etc. – is very significant to the result of your environmental assessment. If some of the data used within this area are not specific or are exclusively based on assumptions, you should try to obtain more specific data. It may also be that your MECO chart includes notes about emissions or issues which you have not been able to include in your modelling. If these issues are significant to the overall environmental profile, you should collect further data. Section 4.5 contains more inspiration on how to collect extra data.

4.5 Collect more data

If it is necessary to collect more data in order to obtain clearer answers from the environmental assessment, several options are open to you. Depending on the specific requirements involved – e.g. product and process relations, uncertainties, data age, etc. – data can be found in these places:

- Suppliers, customers, and other contacts
- Sector organisations
- Databases/literature
- Knowledge centres

If you do not find the data you need, it may be necessary to use data from a similar process, or to make an estimate for e.g. the energy consumption for a process on the basis of your knowledge of the energy consumption for another process. In most cases, this option is regarded as preferable to using no data at all. Even so, it may only be possible to obtain data for impact factors from experts at knowledge centres.

The reference list includes examples of databases and other relevant literature where you might find useful data.

4.5.1 Suppliers

The more product-specific your data needs to be, the more relevant it would be to ask your suppliers for their environmental data. Experience shows, however, that it takes a long time for suppliers to obtain the data you want. It is always important to phrase your questions as accurately as possible to avoid any misunderstandings about the data you need.

4.5.2 Sector organisations

If your supplier cannot give you the data you need, it may in some cases be useful to ask the relevant sector organisation. If you are lucky, they may have collected data which apply to the sector, or perhaps they can refer to someone who has the data you need. One example would be the Association of Plastics Manufacturers in Europe, APME. Within this sector, the manufacturers have chosen to publish general data on the manufacture of individual types of plastic seen within a life-cycle perspective.

4.5.3 Databases and literature

Various databases and literature can also be helpful. The type of data found in this way is, however, mostly general in nature, and is not always recent. Please note that such data usually predates the date of publication by 1-5 years.

4.5.4 Knowledge centres

Finally, you can ask the experts. It can be a good idea to draw on their experience and experience with data collection. This will often reduce data uncertainty.

5. Carry out an extended chemical assessment

The preliminary environmental assessment may show that the environmental and health-related impacts from the product are mainly associated with one particular phase, or that special issues overshadow the other environmental impacts. Examples would be working-environment problems in connection with production or emissions of chemicals during use of the product.

This chapter focuses on one such situation: use of chemicals. It will provide you with an overview of what you can do if your product contains many chemicals that end up in the environment. Emphasis is placed on how you assess whether the emission of chemicals is the most important aspect of the product's environmental impact. The chapter presents criteria which you can use to carry out this assessment. You will also gain insights into what you yourself can do; for example, you can find data on the chemical contents of your product.

Assessing chemicals is difficult. Do not despair it the task appears daunting at first. You should be aware that you may well have to go to experts for help.

5.1 Expand the chemical assessment

First of all, it is important to determine when chemicals are so significant that the main focus should be on assessing them, either instead of an LCA or as a supplement to an LCA.

As we were preparing this Handbook, we looked at two examples where the products being assessed were cleaning agents and dyes. After a preliminary environmental assessment, it was decided that the chemicals were so important to the environmental impact that a chemical assessment should be carried out instead of an LCA.

The examples did not give rise to much doubt, partly because the products consisted of chemicals which are emitted 100% to the environment after use, partly because they belonged to product groups (cleaning agents and surface-active substances) where previous LCAs have demonstrated that their most significant impacts occur during the disposal phase. It can be more difficult to carry out this assessment in other cases. Chapter 3, sections 3.2.4 and 3.3 contain more detailed descriptions of what criteria you should apply in this assessment.

Often, it will not be relevant to carry out an actual chemical assessment of substances which are used by subcontractors because the quantities are relatively small. If it is relevant after all, this will be apparent from the detailed LCA.

Example B5.1: Products where focus should be on chemical assessment and products where chemicals are relatively insignificant.

Products where chemicals are very significant:

- Cleaning agents, detergents, etc., where eco-labelling criteria (particularly those of the Nordic Swan Label) have determined that the properties of the contents are more significant in terms of environmental impact than the rest of the life-cycle, partly because they are emitted into the environment after use.

Products where chemicals are less significant:

- Active products where energy consumption during the use phase is often the most important environmental factor. One example would be a water heater.

As illustrated in figure 2.2 in section A, the process used in the simplified LCA stresses that you should work with a colleague, a consultant, or similar to discuss your options on the basis of the data collected before making your final choices. When you need to choose whether to carry out chemical assessment, it is important that you enter into such dialogue.

5.1.1 Screening for harmful impacts on health and the environment

In the preliminary environmental assessment (the MECO chart), you established an initial overview of the chemicals in the product. You can now use this overview as a basis for screening the chemicals for dangerous properties, so that you focus your efforts on the most significant chemicals.

When you prepared the MECO chart, you identified the chemicals featured on various lists - i.e. the chemicals which are regarded as particularly dangerous. The screening makes it possible for you to assign priorities and to determine which chemicals have the most harmful properties – i.e. which chemicals should be subjected to more detailed assessment.

It may, however, be necessary to assess other chemicals, e.g. because they are used in large quantities in the product or because they have harmful properties which are not identified in the lists. In the example with the cleaning agent, there was a desire to assess the product in relation to the criteria for the Swan Label. Thus, it was necessary to assess surface-active substances which are not included in the lists, but which may be harmful to aquatic organisms, because this is part of the criteria for the Swan Label.

The results of a screening should include an identification of the following issues:

- What substances are dangerous?
- In what quantities do they appear?
- What are the risks of human beings or the environment being exposed to the substances?

The interpretation of the MECO chart saw the introduction of a qualitative method which is based on the initial classification of the chemicals into type 1, 2 or 3.

Here, we present a semi-quantitative method for carrying out this screening. We have chosen to recommend the EDIP screening method, developed as part of the project “Environmental Design of Industrial Products” [Wenzel et al, 1996].

Other methods are, however, available, e.g. MUP [Schmidt et al, 1994] and UPH [the Danish Technological Institute, et al, 1996]. In some cases, it may be advantageous to use these methods – for example if you have prior knowledge of them.

5.1.2 The EDIP screening method

The EDIP screening method is described in detail in the method description of the EDIP method [Hauschild, M., 1996], but will be briefly summarised here.

The EDIP screening method has been developed to look at harmful impacts on health and the environment, and the EU’s danger classification of chemical substances has been used as the point of departure [the List of Dangerous Substances]. This danger classification is supplemented by other lists as regards impacts on health. Specifically, the Danish Working Environment Agency lists of carcinogenic and allergenic substances are used, as are their lists of substances which damage reproduction or the nervous system. However, not many companies have these lists on their bookshelves, and the information is not available on the Internet. Consequently, these lists have been omitted. The List of Undesirable Substances and the Impact List have both, however, been included in the screening method.

The method looks at the possibility of human beings and/or the environment becoming exposed to the relevant chemical (exposure) and the harmful effect of the chemical, if any (impact). This is done by assigning scores for exposure and impact, respectively.

The score for exposure is partly based on whether the substance is emitted or not, and partly on whether the substance can be expected to stay in the environment because it is not degraded (non-biodegradable) or is expected to accumulate in living organisms (bioaccumulating).

The score for impact is a measure of the toxicity of a substance if human beings and/or the environment are exposed to it.

The total score is arrived at by multiplying the two scores. The two figures are multiplied because the toxicity of a given substance is regarded as having greater impact on the environment if the substance is emitted regularly, is non-biodegradable or is bioaccumulated.

Example B5.2: Comparing two types of varnish

Paints and varnishes are typical examples of products where a chemical assessment can be important. For a comparison between an epoxy-based varnish and a "standard" alkyd varnish, the safety data sheet lists the following contents and classifications (PLEASE NOTE: this is a fictional example):

Epoxy	CAS no.	Classification
Bisphenol A diglycidylether	1675-54-3	Xi; R36/38, R43
Neodecanoic acid, oxiranylmethyl ester	26761-45-5	Xi; R43, N; R51/53
Benzyl alcohol	100-51-6	Xn; R20/22
TRIS(dimethylaminomethylenediamine)	90-72-2	Xn; R22, Xi;R36/38

Alkyd	CAS no.	Classification
Butylacetate	123-86-4	R10
Butanole	71-36-3	Xn; R20, R10
1,2,3-trihydroxybenzene	87-66-1	Xn; R20/R21/R22
1-methoxy-2-propanole	107-98-2	R10

5.1.2.1 EDIP exposure score

The score for exposure is a combination of the expected emissions (yes/no) and the possibility of undesirable long-term impacts on the environment.

From the classification of chemical substances, these two risk phrases can be used:

R 53: May cause long-term adverse effects in the aquatic environment.
R 58: May cause long-term adverse effects in the environment

These R phrases were developed to classify the degree of danger to the environment, but are also relevant to human beings in our capacity as organisms within the ecosystems. The two R phrases listed above are assigned to substances within the List of Dangerous Substances when the substance is difficult to degrade and/or is accumulated in fat tissue. The score for exposure is shown in table 5.1.

Exposure score = the score for the expected emissions + the score for biodegradability and/or bioaccumulation.

If you lack knowledge and data about exposure, assign the exposure score 8.

If both exposure values are 0 (total exposure score = 0), the exposure score 1 is used instead of 0.

Table 5.1 Exposure score. The two scores are summed up and are subsequently multiplied with toxicity scores. If both exposure values are 0 (total exposure score = 0), the toxicity score is multiplied by 1 instead of 0.

	Expected emissions		Classified with R53 (non-biodegradable) or R58 (log POW ≥ 3)	
Score	Yes	No	Yes	No
	4	0	4	0

If the substance in question is not included in the List of Dangerous Substances, you will have to assess the risk of undesirable long-term effects yourself. This can be done by means of the parameter $\log P_{ow}$, which stands for the distribution coefficient for octanole-water (or $\log K_{ow}$). Among other things, this parameter indicates whether the substance will be accumulated in fat tissue.

If you know the CAS no. of the substance, you can try to find the logPOW on the internet at http://esc_plaza.syrres.com/interkow/kowdemo.htm, where you can also find calculated values. You can also find the logPOW on other websites, e.g. at chemfinder (http://www.chemfinder.com) or HSDB (http://sis.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB).

Example B5.3: Score for exposure for the two types of varnish, see example B5.2:

For the two varnishes, it is assumed that all substances are emitted. This means that the first element of the exposure score is set at 4 for all substances in the two products.

The total exposure scores for each substance used in the two products are:

Epoxy:	
Bisphenol A diglycidylether	4 + 0 = 4
Neodecanoic acid, oxiranylmethyl ester	4 + 4 = 8
Benzyl alcohol	4 + 0 = 4
TRIS(dimethylaminomethylenediamine)	4 + 0 = 4
Alkyd:	
Butylacetate	4 + 0 = 4
Butanole	4 + 0 = 4
1,2,3-trihydroxybenzene	4 + 0 = 4
1-methoxy-2-propanole	4 + 0 = 4

5.1.2.2 Eco-toxicity score

As regards toxicity towards organisms which live in the environment – the so-called eco-toxicity – a distinction is made between toxicity towards organisms in water (aquatic eco-toxicity) and toxicity towards organisms in soil (terrestrial eco-toxicity). This is why a score is given for each of these. The total score for eco-toxicity is established by combining the toxicity towards aquatic organisms (R50-R52 either alone or in combination with other R phrases) and the toxicity towards terrestrial organisms (R54-R57 either alone or in combination with other R phrases). The two scores are added to form a total score for the danger posed to the environment. Criteria and score values can be found in table 5.2.

The total score for eco-toxicity = the score for aquatic eco-toxicity + the score for terrestrial eco-toxicity.

If no data is available for the substance, use the score 8 unless the substance is well-known and does not have any significant harmful effects (e.g. kitchen salt or water).

Table 5.2 Scoring for eco-toxicity. The two scores are added up and are subsequently multiplied with the score for exposure.

Aquatic eco-toxicity		Terrestrial eco-toxicity	
(R50 ...) LC50≤1 mg/l	4	R54 Toxic to flora or R55 Toxic to fauna or R56 Toxic to soil organisms R57 Toxic to bees	4
(R51 ...) 1 mg/l < LC50 ≤ 10 mg/l	2		
(R52 ...) 10 mg/l < LC50≤ 100 mg/l	1		

If you suspect that a non-labelled substance should be labelled with one of the R phrases for danger to the environment, you should have the properties of that substance examined in relation to the criteria for classification of the danger to the environment. Many substances have not been assessed and classified in accordance with these criteria. If you do not have detailed knowledge about how to go about this task, you should consult with experts.

If a substance is listed in the List of Undesirable Substances or the Impact List, use an eco-toxicity score of 8.

If no eco-toxicity data are available for the substance, apply an eco-toxicity score of 8 (4 for the aquatic environment and 4 for the terrestrial environment. If, however, the substance is well-known and is regarded as having no significant harmful effects (e.g. water or salt), apply a score of 0.

5.1.2.3 Total score for danger to the environment

- The total score for danger to the environment = the exposure score x the eco-toxicity score. This means that the total scores will be as illustrated in table 5.4.
- Generally speaking, substances with a score of 16 or more are regarded as potentially critical and should be more closely assessed.

	Eco-toxicity score 0	Eco-toxicity score 1	Eco-toxicity score 2	Eco-toxicity score 4	Eco-toxicity score 6	Eco-toxicity score 8
No emissions and not classified with R53 or R58 (Score: 1)	0	1	2	4	6	8
Expected emissions or R53, R58 (Score: 4)	0	4	8	16	24	32
Expected emissions and R53, R58 (Score: 8)	0	8	16	32	48	64

Table 5.3
The total score for danger to the environment is established by multiplying the score for exposure and the score for toxicity

Example B5.4: Score for danger to the environment for two types of varnish, see example B5.2

The score for eco-toxicity has been established for each ingredient by looking at R phrases in relation to table 5.2. Following this, the total score for the danger to the environment has been calculated by multiplying the exposure score by the eco-toxicity score.

	Exposure score x eco-toxicity score = danger to the environment score
Epoxy:	
Bisphenol A diglycidylether	4 x 8 = 32
Neodecanoic acid, oxiranylmethyl ester	8 x 2 = 16
Benzyl alcohol	4 x 0 = 0
TRIS(dimethylaminomethylenediamine)	4 x 0 = 0
Alkyd:	
Butylacetate	4 x 0 = 0
Butanole	4 x 0 = 0
1,2,3-trihydroxybenzene	4 x 0 = 0
1-methoxy-2-propanole	4 x 0 = 0

We can see from the scores for the danger to the environment that the two substances Bisphenole A diglycidylether and Neodecanoic acid, oxiranylmethyl ester are problematic: the scores for these substances are 16 or more.

5.1.2.4 Score for human toxicity

Generally speaking, we have much greater experience with and knowledge about various types of impact on human beings than on organisms within the environment. Naturally, the scoring system reflects this fact. This means that the chart for assigning scores for toxicity towards human beings is more nuanced and detailed than the corresponding chart for the danger to the environment.

Scores are allocated on the basis of the relevant danger classification for health and R phrases (from the List of Dangerous Substances). The chart with criteria for allocating scores is shown in table 5.4.

If the substance appears in the List of Undesirable Substances, assign a score of 8 to it. If it is included in the Impact list, assign a score of 4.

If the substance is not included in any of the lists and no data on it is available, assign a toxicity score of 4.

If, however, the substance is well-known and is regarded as having no significant harmful effects (e.g. water or salt), assign a score of 0.

Many substances have not been assessed and classified in accordance with these criteria. Therefore, the same applies here as for danger to the environment: if you suspect that a non-labelled substance should be labelled with one of the R phrases for danger to health, you should have the properties of that substance examined in relation to the criteria for danger classification. If you do not have detailed knowledge about how to go about this task, ask the experts.

Table 5.4
Score for human toxicity. The table shows the criteria for allocation into categories on the basis of the List of Dangerous Substances. The score for a given substance will be the highest score reached by it in this chart.

Impact type	Score 0	Score 1	Score 4	Score 8
General	Well-re-searched substances which are not classified	Irritant and corrosive substances	Corrosive or toxic sub-stances and substances with allergenic or neurotoxic effects and substances which cause irreversible damage	Very toxic substances and substances with carcinogenic, teratogenic, or mutagenic properties and substances which cause serious organ damage
Acute toxicity	No classification	Xn; R20-21-22	T; R 23-24-25	Tx; R26-27-28
Irritant, corrosive	No classification	Xi; R36-37-38	C; R34-35-41	
Allergenic	No classification		Xi; R43	R42
Irreversible damage/organ damage (including neurotoxicity)	No classification		Xn; R40 or R48 combined with R20-21-22T; R39 combined with R 23-24-25, R33	T; R48 combined with R23-24-25Tx; R39 combined with R26-27-28
Genotoxicity (mutagenicity)	No classification			T; R46 (M1)Xn; R46 (M2),R40 (M3)
Carcinogenic properties	No classification			T; R45, R49(C1 or C2),Xn; R40 (C3)
Reproduction toxicity Terato-genicity	No classification			T; R60 or R61 (Rep1 or Rep2) Xn; R62, R63 (Rep3), R64

5.1.2.5 Total score for danger to health

The total score for the danger to health = the score for exposure x the score for human toxicity. Thus, the substance being examined will have a score as illustrated in table 5.5.

As with the danger to the environment, all substances with a score of 16 or more are regarded as potentially critical and should be assessed in greater detail.

Table 5.6
The total score for the danger to health is established by multiplying the scores for exposure and toxicity

	Toxicity score 0	Toxicity score 1	Toxicity score 4	Toxicity score 8
No emission and not classified with R53 or R58 (score:1)	0	1	4	8
Expected emission or R53, R58 (score: 4)	0	4	16	32
Expected emission and R53, R58 (score: 8)	0	4	32	64

Example B5.5: Score for the danger to health for two types of varnish, see example B5.2

The score for human toxicity has been established for each ingredient by looking at R phrases in relation to table 5.4. Following this, the total score for the danger to health has been calculated by multiplying the exposure score by the toxicity score.

	Exposure score x toxicity score = score for the danger to health
Epoxy:	
Bisphenol A diglycidylether	4 x 4 = 16
Neodecanoic acid, oxiranylmethyl ester	8 x 4 = 32
Benzyl alcohol	4 x 1 = 4
TRIS(dimethylaminomethylenediamine)	4 x 1 = 4
Alkyd:	
Butylacetate	4 x 0 = 0
Butanole	4 x 1 = 4
1,2,3-trihydroxybenzene	4 x 1 = 4
1-methoxy-2-propanole	4 x 0 = 0

We can see from the scores for the danger to health that the two substances Bisphenole A diglycidylether and Neodecanoic acid, oxiranylmethyl ester are problematic: the scores for these substances are 16 or more.

5.1.2.6 Carrying out the screening

It will be easy for you to find much of the information for the screening yourself, but we recommend that you seek help to carry out assessments of substances which are not featured in any lists. This is recommended because such work often involve estimates that require a thorough knowledge of chemical assessment.

When you have found the relevant information, screening is carried out as illustrated above and in examples B5.2-5. Substances with a score of 16 or more should be assessed in greater detail. You should also decide whether some substances are used in such quantities that they should also be assessed in greater detail despite a lower score –

for example if a given substance accounts for 50 per cent of the product.

5.1.3 Detailed assessment of chemical substances with high scores

Now you have identified the substances which should be assessed in greater detail. To do so, you will have to obtain information which demonstrates how dangerous the chemical substances are, and what the chances are of people and the environment becoming exposed to the substances.

Unless you already have detailed knowledge of how to carry out such assessment, you should seek expert advice for this task.

5.2 Interpreting the chemical assessment

The screening of the chemicals can primarily be used to assign priorities to any substances that need more detailed assessment. The scores can also to some extent be used directly if you combine them with data about the quantities used of the relevant substances. You should, however, be aware that the uncertainty associated with the assessment is greater for scores than for detailed assessments. Consequently, scores cannot be used to support decisions with the same weight as detailed chemical assessments.

Once you have found data on the chemical substances in the product, it can be assessed whether use of the chemical substances entails a risk of harmful effects. As was mentioned above, it is particularly important to assess what harmful impacts the substances may have, in which situations human beings and/or the environment can be exposed to the chemical substances, and in what quantities. Unless you already know exactly how to assess and interpret such data, we recommend that you look to relevant experts for assistance.

The danger posed by the substances is assessed on the basis of their potential harmful impacts and the doses necessary to produce such impacts.

Exposure to the substances is assessed on the basis of the substances' physical and chemical data, and on the basis of knowledge/data about patterns of use in the relevant situation (is the substance discharged along with wastewater? Is it vented into air via ventilation? etc.). As the quantities used are also assessed at the same time, it is possible to assess the level of exposure for human beings and/or the environment with greater accuracy.

On this basis, it is possible to assess the risk of human beings and/or the environment becoming exposed to the chemical substances to such a degree that harmful impacts may occur.

The interpretation of this assessment depends somewhat on the overall objective. If, for example, two products are being compared, it would be relevant to assess which of the products poses the least risk of harmful impacts. If the objective is to bring about environmental improvements to a single product, it would be relevant to identify the chemical substances for which substitutes might be found.

There will be quite a lot of uncertainty associated with such an assessment, partly about the level of exposure for human beings and/or the environment, and partly about the toxicity of the substance. It is rarely possible to indicate the level of uncertainty with much precision, but it is important to be aware where uncertainties exist in the assessment.

5.3 Did you get answers to your questions?

Does the assessment you have carried out provide a sufficient basis for extracting answers and making decisions? Or is it necessary to proceed with further data collection and/or assessment? The answer to this question depends partly on the goal defined for the assessment, and partly on the importance of the decisions to be made.

It may, for example, be necessary to proceed if the assessment shows that there is a risk of harmful impacts, or if the data basis is uncertain. If, however, you find that the doses which human beings and/or the environment can be exposed to are much smaller (by a factor of several sizes) than the doses which cause harmful effects, there is no reason to carry out additional work.

If the assessment is actually a comparison, the results are only satisfactory if the assessments of all alternatives are on par with each other.

Is the assessment satisfactory?

- Have you obtained information about all relevant chemical substances?
- Do you know enough about the use of the chemical substances to be able to assess the exposure?
- What uncertainties are there? And how great are they?
- Seek export assistance for an actual risk assessment of chemicals.

Example B5.6: Varnishes

The substances which scored high scores in examples B5.2-5 – Bisphenol A diglycidylether and Neodecanoic acid, oxiranylmethyl ester – have been assessed in greater detail.

The bisphenol is highly allergenic. It is particularly dangerous to health during manufacture, i.e. within the working environment, as it hardens relatively quickly and so ceases to be a health hazard after that time. If the substance is to be used, special attention should be paid to working-environment issues.

It was not possible to find further information about neodecanoic acid, oxiranylmethyl ester in the most commonly used databases. Additional work should be carried out to ensure a better assessment of the possibilities of exposure. If it turns out that the substance entails great risk of exposure, research of the available literature should be carried out to find more information.

5.4 Find additional data

By now, you have decided – possibly with assistance from colleagues and/or experts – whether the present assessment basis is sufficient for your purposes. You now need to determine what the assessment should be supplemented by: what data do you need to support your conclusions? And which are the weakest links in your assessment?

If you yourself had the background knowledge necessary to carry out these assessments, you should now consider whether it is time to involve experts/consultants. Such experts can often provide more in-depth knowledge and have access to further data.

It may also be that there is a need to seek information from relevant suppliers of chemicals, or to examine the incidence of chemical substances in e.g. wastewater or the working environment.

If you need to make the assessment more detailed and to find more data, we recommend that you seek out experts within the area.

6. Complete the environmental assessment

You have now carried out your environmental assessment and obtained a result which is to be compared against the goal of the assessment and the preconditions it was based on.

If the goal, preconditions, and result match up, the actual environmental assessment is complete. We recommend that you let someone else review your environmental assessment for quality-assurance purposes before you present it to a wider audience.

If the assessment is for internal use only (e.g. for product development or prioritisation of environmental efforts), you can simply let a colleague with knowledge of environmental matters read your assessment.

If, however, your environmental assessment will be used for external purposes (marketing, environmental documentation aimed at customers or authorities), you should observe the instructions in ISO 14040 and use an external expert on LCAs. This expert is to document that your assessment has been carried out in accordance with all current requirements on life-cycle assessments.

6.1 Instructions on reporting

When reporting your work, you will often be expected to include everything and to keep your account brief and clear. This can be very difficult. The following provides some specific recommendations which you may find useful.

Basically, it is important that those reading your report can see what you have done. This is why you need to include everything. Start by collecting all information about basic data and calculations in one or more appendices. Explanatory texts would be helpful.

It should be possible to read the actual report without having to refer to the appendices all the time. That is why you need to place the most important data, results, and graphs (if any) in the report while referring to the relevant basic figures in the appendices.

You should carefully describe all the assumptions and omissions you have made during your work. Review them critically before you describe your results.

In order to be prepared to answer "critical" questions, as well as to be able to recall the basis for your results later, it is important that you have extensive documentation of your work. Include explanations for your choices.

Bear the reader in mind as you write your report. If it is to be used internally, it will probably not necessary to include detailed accounts of your production conditions. If, however, your report will be read by customers or authorities, you will often have to provide this information as well.

If you are unsure about how to prepare your report, you can use the suggestions given in section 6.2.

6.2 Suggested contents of your report

In the following, we present some recommendations on what your report should include. The suggestions take the form of items listed in a table of contents.

The proposed table of contents is divided into three main areas: the MECO chart, PC modelling, and Chemical assessment. This makes it easy to identify the items which are relevant to your presentation, depending on the steps included in your environmental assessment.

In your assessment, you may have used background data which cannot, for one reason or another, be published. We recommend that you collect such information in an appendix which can easily be removed from the report if necessary.

6.2.1 Reporting the MECO chart

If you have carried out your environmental assessment of one or more products by means of chapters 1 to 3 and the MECO chart, you can use the following outline for your report:

1. Introduction
   - Briefly describe the company and its main activities
2. The goal of the environmental assessment
   - List the questions asked as part of the goal definition, and state why you wish to find answers to these questions.
3. Choosing the product and functional unit
   - Describe the chosen product(s). You may want to present a “functional unit” chart as illustrated in example B1.4. If two products are being compared, it is important to point out the differences between them.
4. Preconditions

   4.1 Scope definition
   - What issues have not been included? Examples would be transport and production of certain ancillary materials.

   4.2 Assumptions/omissions
   - List the areas where it has been necessary to apply assumptions or where it has not been possible to obtain data.

   4.3 Data quality
5. Describe the life-cycle of the product(s)
   - Describe the five phases of the product life-cycle. Diagrams can be helpful. You should clearly describe the significant issues included in each phase, as well as what has been omitted.
6. Presenting the MECO chart(s)
   - Present the chart(s) and provide explanations for them.
7. Interpreting the MECO chart(s)
   - Here, the significant issues associated with your product should be pointed out. Also state why they are significant. If you are comparing several products, you should identify the differences and explain the causes. Comment on the results in relation to items 2, 3, 4 and 5.

8. Suggestions for further efforts
   - Describe the activities you plan to initiate on the basis of the results of the environmental assessment – e.g. changes to a product or a process.

Appendix A: Data
Appendix B: Calculations

6.2.2 Reporting PC modelling

If you have carried out your environmental assessment of one or more products by means of chapters 1 to 4, the MECO chart, and PC modelling, you can use the following report outline:

1. Introduction
2. The goal of the environmental assessment
3. Choosing the product and functional unit
4. Preconditions
   - 4.1 Scope definition
   - 4.2 Assumptions/omissions
   - 4.3 Data quality
5. Describe the life-cycle of the product(s)
6. Presenting the MECO chart(s)
7. Interpreting the MECO chart(s)
8. Description of the modelled system(s)
   - Describe how the modelled system has been established and where the data are from.
9. Description of supplementary data
   - Explain the origins of data which is not from the database
10. Graphic presentation of the result
    - Show the results in diagram form and use text to explain their content. The diagrams chosen must help clarify the causes of the most significant environmental impacts and resource consumptions.
11. Discussion of the most significant environmental impacts
    - Explain which environmental impacts and resource consumptions are the most important. Point out where they appear in the product life-cycle.
12. Interpreting the results of the modelling

- Here, you should point out the significant issues associated with your product. State why these issues are important. If you are comparing several products, you should point out any differences and explain the reasons behind them. Comment on the results in relation to items 2-5 and 8-11.

13. Suggestions for further efforts
    - Describe the activities you plan to initiate on the basis of the results of the environmental assessment. You may, for example, wish to make changes to a product or a process, or plan an environmental declaration.

Appendix A: Data
- Used for the MECO chart
- Used for the PC modelling

Appendix B: Calculations made with the PC tool

If you have obtained data on materials or processes from experts and you have used results based on this information as data in your PC model, you should include a note to this effect as part of Appendix A.

If you have chosen to carry out a chemical assessment and have subsequently gone on to carry out modelling by means of the PC tool, you can still use the outline presented above: simply add a description of the chemical assessment under item 9. You should include basic data for the chemical assessment – in the form of data from literature - as well as the assessment itself in a separate appendix.

6.2.3 Reporting the chemical assessment

If you have carried out your environmental assessment of one or more products by preparing a MECO chart and carrying out a chemical assessment in accordance with chapters 1-3 and 5, the following report outline can be used:

1. Introduction
2. The goal of the environmental assessment
3. Choosing the product and functional unit
4. Preconditions
   4.1 Scope definition
   4.2 Assumptions/omissions
   4.3 Data quality
5. Describe the life-cycle of the product(s)
6. Presenting the MECO chart(s)
7. Interpreting the MECO chart(s)
8. Description of the chemical substances being assessed
   - Describe which chemical substances have been selected for further assessment – and why.
9. Chemical assessment
   - Here, you should describe the preconditions, data quality, and methods used in the chemical assessment as well as the results. As the assessment will often have been carried out by an expert, we recommend that it is reproduced in full. Alternatively, you can prepare a short summary and include the full assessment as an appendix.
10. Interpretation of the chemical assessment
    - This is where you point out the significant parts of the assessment. Explain why they are important. The results of the chemical assessment must be compared with the results from the MECO chart.
11. Suggestions for further efforts
    - Describe the activities you plan to initiate on the basis of the results of the environmental assessment. You may, for example, wish to substitute one substance for another, make changes to a process, or prepare an application for permission to use an eco-label.

Appendix A: Data used for the MECO chart
Appendix B: Chemical assessment – substance data from literature and assessments

6.3 Using the results in actual practice

You will often need to present the results of your environmental assessment very briefly. For example, you may wish to present the results at an internal meeting or as a brief text in a sales leaflet or data sheet aimed at customers.

Take the report you prepared in accordance with the instructions in section 6.2 as your point of departure. When making your brief account, focus on the following:

- The goal of the environmental assessment
- The preconditions
- The conclusions that can be drawn from your assessment

It is always important to explain the objective of the environmental assessment – why was it carried out? This has an impact on the results.

Preconditions and conclusions are closely linked. It is very easy to over-interpret results. This is why it is important to present the limitations and data used during your assessment alongside the final conclusions.

Make sure that you take into account any data uncertainties, missing data, and other omissions when comparing two or more product systems.

A drawing of the product system and an illustration of selected results can be a good way to present selected, general results.

You can choose to present your MECO chart in a more easy-to-read format by including only the most significant contributions to environmental impacts. In such cases, you should always remember to specify that the chart in question is an excerpt only.

When presenting selected environmental impacts addressed by means of the PC tool, you should remember to state why you have chosen the relevant impacts, and which conclusions you have drawn.

It can be very difficult to make a brief presentation of a chemical assessment. Choose the most significant chemical(s) and present the environmental impacts they entail.

Finally, you can also choose to describe the improvements carried out at your company on the basis of your environmental assessment or chemical assessment. Examples of such improvements would be waste separation, reduced materials consumption, substitution of chemicals, etc.

6.4 What's next?

The goal of the environmental assessment you have just completed reflects the reasons why you and your company decided to carry out the task in the first place. The environmental assessment represents a good beginning for product-oriented environmental efforts.

You and your company have now learnt your first lessons. Hopefully, you will have obtained enough experience to be able to carry out your next environmental assessment in an even better, easier, and more efficient manner.

In the years to come, more and more companies will face increasing requirements for environmental documentation of their products – e.g. environmental declarations – as elements of an environmental management system or as a tool for assigning priorities to internal environmental initiatives.

Use the lessons learnt. Look at the suggestions for use of environmental assessments listed in part A, chapter 3. If you and your company wish to be cutting-edge in environmental terms, it is important that you adopt a life-cycle perspective – in more ways than one.

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Other relevant references:

LCA-nyt: The Danish newsletter for LCA is the Danish Environmental Protection Agency’s newsletter about methods for life-cycle assessment. LCA-nyt is available on the Danish EPA website under the heading “livscyklusvurderinger”.

The leaflet Standarder for miljøledelse - et overblik over ISO 14000-serien describes the environmental standards published by ISO.

Standards for life-cycle assessment can be found in the 14040 series.

SETAC's LCA Newsletter: a newsletter from SETAC (Society of Environmental Toxicology and Chemistry) which includes a section about the latest news on life-cycle assessment in Europe and the USA. The newsletter is available at the organisation website: http://www.setac.org/lca.html

Schmidt K., Øllgaard H., Nielsen C. B., Christensen F. M., Juul L.: Håndbog i produktorienteret miljøarbejde, Miljøstyrelsen, 2000.

The Danish Environmental Protection Agency: http://www.mst.dk
This website includes information about environmental legislation in Denmark, the current state of affairs within a number of environmental fields, links to relevant websites, subsidy schemes, etc.
For life-cycle assessments, see: http://www.mst.dk/fagomr/30000000.htm

The EEA – European Environment Agency: http://www.eea.eu.int/
This website contains information about the European environment.
The EEA has published the report :"Life-cycle Assessment (LCA) – A guide to approaches, experiences and information sources". This report is available at: http://themes.eea.eu.int/toc.php?toc=39297

Green Network: www.Greennetwork.dk
A website for the environmental collaboration between the business community and public authorities in the County of Vejle and Middelfart. Includes many links.

Databases:

http://esc_plaza.syrres.com/interkow/kowdemo.htm
Chemfinder: http://www.chemfinder.com/
HSDB (Hazardous Substances DataBank): http://sis.nlm.nih.gov/cgibin/sis/htm

Glossary of acronyms

APME	Association of Plastics Manufacturers in Europe
CAS no.	CAS = Chemical Abstract Service. A CAS no. is a unique number identifying a given chemical substance
CFC	Chlorofluorocarbon (i.e. hydrocarbons with chlorine and fluorine)
CO2	Carbon dioxide
DIN	Deutsches Institut für Normung (DIN – the German Institute for Standardization)
DS	Dansk Standard (DS – The Danish Standards Association)
EDIP	Environmental Design of Industrial Products
EN	European Standard
ISO	International Organisation for Standardisation
LCA	Life Cycle Assessment
MECO	Materials, Energy, Chemicals, and Other
mPEM	milli-Person Equivalent – targeted
mPR	milli-Person Reserves
MUP	*Det Materialeteknologiske UdviklingsProgram* – a programme for development of materials/technology
R phrase	Risk phrase

Swan label	A Nordic eco-label signifying that the product labelled is among the top 33 per cent of the relevant product group as regards environmental issues
UPH	A Danish system used to describe chemicals consumption at enterprises. The letters stand for *Uacceptabelt-Problematisk-HŒndterbart*, which can be translated as „Unacceptable-Problematic-Acceptable (literally, „possible to handle“)
VA approval	An approval in accordance with the machine directive

Appendix A Formulae

Formula Page

{1} Material consumption
no. of kg of material [A] x mPR/kg for [A] = mPR for material [A]

{2} Primary energy consumption
Amount of material [kg] x primary energy for the material [Mj/kg] = primary energy consumption [Mj]

{3} Conversion of energy
Electricity consumption [MJ] x 2.5 = primary energy consumption [MJ]

{4} Conversion of energy
Electricity consumption [kWh] x 9 = primary energy consumption [MJ]

{5} Energy contents in energy resources
Energy resource [kg] x calorific value [MJ/kg] = primary energy consumption [MJ]

{6} Energy contents on incineration
Material [kg] x calorific value [MJ/kg] = heat generation [MJ]

{7} Energy consumption during transport
The sum of: {transported material [kg] x distance [km] x nergy consumption [MJ/(kg x km)]} = total energy consumption[MJ]

{8} Consumption of energy resources
Energy consumption [MJ] / 1,025 [MJ/mPR oil] = consumption of oil resources [mPR]

Appendix B Reference tables

Calculating resource consumption

Table B.1 comprises a number of specially selected, frequently used materials. For each material, the resources used to make it are listed. The resource consumption values are converted into mPR/kg. This means that account has been taken of the availability of the relevant resource worldwide, as well of the annual average consumption per person.

The column entitled "Comments" lists special discharged or emissions associated with production or reprocessing of the relevant resources. The remarks listed under "Comments" should not, however, be regarded as exhaustive.

Table B.1 Conversion of materials consumption into resource consumption

Raw materials	Resource consumption (kg/kg)	mPR/kg	Comments
Aluminium, Al - rolling alloy - casting alloy	Al: 1.00 Al: 0.88 Silicon: 0.12	 1.5 1.3	Fluorides1,2
Lead, Pb	Pb: 1.00	Pb: 80.00	Heavy metals
Bronze	Sn: 0.10 Cu: 0.90	Sn: 90 Cu: 15	
Cadmium, Cd	Cd: 1.00	Cd: 4,300	Heavy metals[2]
Calcium carbonate	$CaCO_3$: 1.0	-	
Glass	-	0	Plentiful resources
Gold, Au	Au: 1.00	Au: 90,000	
Iron, Fe	Fe: 1.00	Fe: 0.08	
Cobalt, Co	Co: 1.00	Co: 1,000	
Copper, Cu	Cu: 1.00	Cu: 16.5	Heavy metals2
Quartz sand	-	0	Plentiful resources
Mercury, Hg	Hg: 1.00	Hg: 9,100	
Manganese, Mn	Mn: 1.00	Mn: 10.00	
Brass - rolling alloy - casting alloy	 Zn: 0.37 Cu: 0.63 Zn: 0.33 Pb: 0.02 Cu: 0.65	 Zn: 12.2 Cu: 10.4 Pb: 1.6 Cu: 10.7	
Molybdenum, Mo	Mo: 1.00	Mo: 250	
Sodium chloride, NaCl	-	0	

Table B.1
Continued

Raw materials	Resource consumption (kg/kg)	mPR/kg	Comments
Sodium hydroxide, NaOH, 100%	-	0	Plentiful resources
Natural gas	Natural gas: 1.0	Natural gas: 0.06	
Natural rubber	-	0	Renewable resources
Nickel, Ni	Ni: 1.00	Ni: 106	
Oil products, refined	Crude oil: 1.00	Crude oil: 0.04	
Paper and cardboard	Wood: 1.00	0	Renewable resources
Plastic, ABS acrylonitrile styrene-butadiene	Crude oil: 0.50 Natural gas: 0.50	Crude oil: 0.02 Natural gas: 0.02	Styrene[1]
Plastic, EPS, Expanded polystyrene	Crude oil: 0.60 Natural gas: 0.40	Crude oil: 0.02 Natural gas: 0.02	Styrene[2]
Plastic, PA Polyamide	Crude oil: 0.50 Natural gas: 0.50	Crude oil: 0.02 Natural gas: 0.02	
Plastic, PC Polycarbonate	Crude oil: 0.50 Natural gas: 0.50	Crude oil: 0.02 Natural gas: 0.02	
Plastic, PE Polyethylene - HDPE - Linear LDPE - LDPE	Crude oil: 0.57 Natural gas: 0.43 Crude oil: 0.35 Natural gas: 0.65 Crude oil: 0.55 Natural gas: 0.45	Crude oil: 0.02 Natural gas: 0.02 Crude oil: 0.01 Natural gas: 0.03 Crude oil: 0.02 Natural gas: 0.02	
Plastic, PET Polyethylene terephtalate	Crude oil: 0.80 Natural gas: 0.20	Crude oil: 0.03 Natural gas: 0.01	
Plastic, POM Polyoximethylene	Crude oil: 0.50 Natural gas: 0.50	Crude oil: 0.02 Natural gas: 0.02	
Plastic, PP Polypropylene	Crude oil: 0.80 Natural gas: 0.20	Crude oil: 0.02 Natural gas: 0.02	
Plastic, PS Polystyrene	Crude oil: 0.50 Natural gas: 0.50	Crude oil: 0.02 Natural gas: 0.02	Styrene[2]
Plastic, PUR Polyurethane	Crude oil: 0.34 Natural gas: 0.32	Crude oil: 0.01 Natural gas: 0.02	
Plastic, PVC Polyvinylchloride	Crude oil: 0.40 Natural gas: 0.20	Crude oil: 0.01 Natural gas: 0.01	Vinylchloride monomers[2]
Plastic, SAN styrene acrylonitrile	Crude oil: 0.52 Natural gas: 0.48	Crude oil: 0.02 Natural gas: 0.02	Styrene[2]
Plastic, PB Polybutadiene Synthetic rubber	Crude oil: 0.62 Natural gas: 0.41	Crude oil: 0.02 Natural gas: 0.02	Styrene[2]
Platinum, Pt	Pt: 1.00	Pt: 125,000	
Silicon, Si	Si: 1.00	0	Plentiful resources
Steel - machine steel - casting iron - stainless steel	Fe: 0.99 Mn: 0.01 Fe: 0.99 Mn: 0.01 Fe: 0.73 Cr: 0.18 Ni: 0.09	Fe: 0.08 Mn: 0.05 Fe: 0.08 Mn: 0.05 Fe: 0.06 Cr: 2.3 Ni: 9.9	Heavy metals[1]
Silver, Ag	Ag: 1.00	Ag: 19,000	
Pewter, Sn	Sn: 1.00	Sn: 900	Renewable resource
Wood	Wood: 1.00	0	Renewable resource
Tap water, Danish	Water: 1.00	0	Heavy metals[1,2]
Zinc, Zn	Zn: 1.00	Zn. 33	

1 EDIP PC tool (the database)
2 EMEP/CORINAIR, 2000 Atmospheric Emission Inventory Guidebook (Second edition)
3 Climate Change, 1997

Calculating energy

Table B.2 illustrates the energy consumption involved in production of materials. The amounts of energy have been calculated as primary process energy and include the amount of energy used to manufacture and reprocess the material. Their energy contents, measured as the lowest calorific value, are also stated. Energy is measured in MJ per kg of the relevant material.

Table B.3 shows the energy consumed to reprocess selected materials.

Table B.4 provides information on the energy consumption associated with selected processes, while table B.5 includes information on the energy content of energy resources.

Table B.2 Energy consumption for production and energy contents for selected materials

Materials	Primary energy, production (MJ/kg)	Energy contents, calorific value (MJ/kg)
Aluminium, Alv	170	0
Ammonia, liquid[2]	60	25
Argon, Ar[2]	7	0
Pesticides[2]	80	20
Bitumen[2]	50	40
Calcium carbonate, CaCO31	0.14	0
Glass[1]	10	0
Copper, Cu[1]	90	0
Preservatives[2]	80	20
Carbon dioxide, liquid[2]	12	0
Quartz sand[1]	0.4	0
Glue, solvent-based[2]	12	40
Magnesium, Mg3	150	0
Paint and varnish, water-based[2]	24	5
Paint and varnish, solvent-based[2]	14	30
Brass[1]	80	0
Sodium chloride, NaCl[1]	1.2	0
Sodium hydroxide, NaOH, 100%1	38	0
Natural gas[1]	3.4	49
Nickel, Ni[1]	190	0
Nitrogen, $N_2$1	7	0
Oil products, refined, liquid[2]	50	45
Oil products, refined, gaseous[2]	45	40
Solvents with oxygen (e.g. ethanol)[2]	80	25
Solvents, chlorinated[2]	60	3
Oxygen, O_2[2]	7	0
Paper/cardboard[1]	40	20
Plastic, ABS, acrylonitrile-butidiene styrene[1]	95	40
Plastic, EPS, expanded polystyrene[1]	79	48
Plastic, PA, polyamide[1]	140	30

Table B.2 Continued

Materials	Primary energy, production (MJ/kg)	Energy contents, calorific value (MJ/kg)
Plastic, PC, polycarbonate[1]	115	30
Plastic, PE, polyethylene1	75	40
Plastic, PET, polyethylene1 terephtalate	80	30
Plastic, PMMA, polymethylmethacrylate[1]	110	40
Plastic, POM, polyoxymethylene (acetal plastic)[1]	84	45
Plastic, PP, polypropylene[1]	80	40
Plastic, PS, polystyrene[1]	90	40
Plastic, PUR, polyurethane[1]	110	30
Plastic, PVC, polyvinylchloride[1]	65	20
Plastic, SAN, styrene acrylo-nittrile[1]	90	40
Plastic, polybutadiene, Synthetic rubber[1]	35	46
Stainless steel[1]	46	0
Silicon, Si[1]	220	0
Cast iron[1]	30	0
Steel[1]	40	0
Tensides[2]	60	30
Wood[1]	0.2	18
Tap water, Danish1	0.001	0
Vegetable oil[2]	80	40
Wax2	70	45
Zinc, Zn[1]	70	0

1 EDIP PC tool (the database)
2 The Danish Environmental Protection Agency, environmental project no. 281, 1995
3 Institute for Product Development

Table B.3 Energy consumption associated with reprocessing of selected materials. The energy consumption values have been estimated on the basis of the EDIP database.

Material	Primary energy, reprocessing MJ/kg
Aluminium, melting	30
Glass, melting	7
Copper, melting	50
Cardboard/paper, reprocessing	10
Steel, melting	20
Stainless steel, melting	40
Plastic, separation and granulation	6[1]

1 Simapro database

Table B.4
Energy consumption for processes

Unit process	Comment	Process energy	Unit
Bending metal sheet	Energy measured per meter of sheet bent at 90oC.	0.02-0.2	MJ/m
Lathing or milling of aluminium	Unit is kg of material removed	30	MJ/kg
Electrolytic surface treatment of metal	Great variations	10	MJ/m2
Cold extrusion, medium deformation.	Weak mordanting Cold flow, incl. cold work with metal, here steel or stainless steel.	30	MJ/kg
Sheet pressing Low deformation	Pressing of steel sheets	5-15	MJ/kg
Die casting of plastic	Small objects typically require greater energy consumption than large ones	4-60	MJ/kg
Punching, sheet	Energy per metre	1	MJ/m
Welding	Energy per welded meter in thin sheet (<2mm). Standard distance . Normal distance between weld spots 3-4 cm.	0.7	MJ/m
Pressure die casting	-	20-50	MJ/kg

Table B.5
Energy content of energy resources

Energi	kg	m3	MJ
Solid fuels			
Coal[2]	1	-	29.5
Wood (hard), TS[2]	1	-	18.3
Liquid fuels			
Gasoline1	1	0.0014	42.7
Diesel oil1	1	0.0011	41.9
Fuel gas oil1	1	0.0012	42.3
Gaseous fuels			
Butane[1]	0.39	1	118.5
Bottled gas1	0.46	1	100.5
Natural gas[2]	1	0.833	48.5
Propane1	0.51	1	90.7

1 Andersen, E. S., et. al., 1981
2 The Danish Environmental Protection life-cycle-assessment System, 1998
3 The density of natural gas is regarded as equal to the density of North Sea gas

Danger categories

Dangerous and hazardous substances are classified according to the threat they represent. This classification is based on the inherent properties of the substances and comprises three main groups:

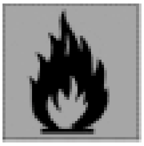
- Explosive and flammable
- Harmful to health
- Dangerous to the environment

If a substance is only classified as flammable or explosive, it will not be relevant to carry out an environmental assessment.

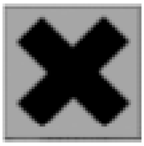
The symbols used for these substances are shown below. The commonly used indication of danger and the abbreviations are included.


Explosive [E]

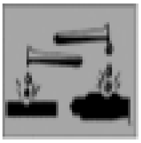

Oxidizing [O]


Extremely flammable [Fx]
Highly flammable [F]

If a substance is classified as being harmful to health, it will be relevant to carry out a more detailed assessment. The symbols used for such substances are shown below.


Irritant [Xi]
Harmful [Xn]


Toxic [T]
Very toxic [Tx]


Corrosive [C]

If a substance is classified as dangerous for the environment, it will also be relevant to carry out a more detailed assessment. The symbol used for such substances looks like this:


Dangerous for the environment [N] 182

Definitions and more detailed information about each danger category is available in the Statutory Order on Classification, Packaging, Labelling, Sale and Storage of Chemical Substances and Products.

For each danger category, risk phrases (R phrases) and safety phrases (S phrases) are used.

- R phrases specify the hazards of the relevant substance in relation to their classification.
- S phrases provide directions on the safety precautions which must be taken for the relevant substance.

All R and S phrases are included in the Statutory Order.

The Statutory Order entitled "List of Dangerous Substances" includes a large number of classified substances. Here, each substance is listed with information on its CAS no., danger category, and R and S phrases.

Ozone-depleting substances

Table B.7
List of substances which degrade ozone in the stratosphere

Substance	Formula	Substance	Formula
CFCs		**Halons**	
(CFC-11)	$CFCl_3$	(halon-1211)	CF_2BrCl
(CFC-12)	CF_2Cl_2	(halon-1301)	CF_3Br
(CFC-113)	$C_2F_3Cl_3$	(halon-2402)	$C_2F_4Br_2$
(CFC-114)	$C_2F_4Cl_2$		
(CFC-115)	C_2F_5Cl	**Individual substances**	
(CFC-13)	CF_3Cl	carbon tetrachloride	CCl_4
(CFC-111)	C_2FCl_5		
(CFC-112)	$C_2F_2Cl_4$	1,1,1-trichloroethane	
(CFC-211)	C_3FCl_7	(methyl chloroform)	$C_2H_3Cl_3$
(CFC-212)	$C_3F_2Cl_6$		
(CFC-213)	$C_3F_3Cl_5$	bromochloromethane	CH_2BrCl
(CFC-214)	$C_3F_4Cl_4$		
(CFC-215)	$C_3F_5Cl_3$	methyl bromide	CH_3Br
(CFC-216)	$C_3F_6Cl_2$		
(CFC-217)	C_3F_7Cl		
HCFCs		**HBFCs**	
(HCFC-21)	$CHFCl_2$		$CHFBr_2$
(HCFC-22)	CHF_2Cl	(HBFC-22B1)	CHF_2Br
(HCFC-31)	CH_2FCl		CH_2FBr
(HCFC-121)	C_2HFCl_4		C_2HFBr_4
(HCFC-122)	$C_2HF_2Cl_3$		$C_2HF_2Br_3$
(HCFC-123)	$C_2HF_3Cl_2$		$C_2HF_3Br_2$
(HCFC-123)	$CHCl_2CF_3$		C_2HF_4Br
(HCFC-124)	C_2HF_4Cl		$C_2H_2FBr_3$
(HCFC-124)	$CHFClCF_3$		$C_2H_2F_2Br_2$
(HCFC-131)	$C_2H_2FCl_3$		$C_2H_2F_3Br$
(HCFC-132)	$C_2H_2F_2Cl_2$		$C_2H_3FBr_2$
(HCFC-133)	$C_2H_2F_3Cl$		$C_2H_3F_2Br$
(HCFC-141)	$C_2H_3FCl_2$		C_2H_4FBr
(HCFC-141b)	CH_3CFCl_2		C_3HFBr_6
(HCFC-142)	$C_2H_3F_2Cl$		$C_3HF_2Br_5$
(HCFC-142b)	CH_3CF_2Cl		$C_3HF_3Br_4$
(HCFC-151)	C_2H_4FCl		$C_3HF_4Br_3$
(HCFC-221)	C_3HFCl_6		$C_3HF_5Br_2$
(HCFC-222)	$C_3HF_2Cl_5$		C_3HF_6Br
(HCFC-223)	$C_3HF_3Cl_4$		$C_3H_2FBr_5$
(HCFC-224)	$C_3HF_4Cl_3$		$C_3H_2F_2Br_4$

Substance	Formula	Substance	Formula
HCFCs		**HBFCs**	
(HCFC-225)	$C_3HF_5Cl_2$		$C_3H_2F_3Br_3$
(HCFC-225ca)	$CF_3CF_2CHCl_2$		$C_3H_2F_4Br_2$
(HCFC-225cb)	CF_2ClCF_2CHClF		$C_3H_2F_5Br$
(HCFC-226)	C_3HF_6Cl		$C_3H_3FBr_4$
(HCFC-231)	$C_3H_2FCl_5$		$C_3H_3F_2Br_3$
(HCFC-232)	$C_3H_2F_2Cl_4$		$C_3H_3F_3Br_2$
(HCFC-233)	$C_3H_2F_3Cl_3$		$C_3H_3F_4Br$
(HCFC-234)	$C_3H_2F_4Cl_2$		$C_3H_4FBr_3$
(HCFC-235)	$C_3H_2F_5Cl$		$C_3H_4F_2Br_2$
(HCFC-241)	$C_3H_3FCl_4$		$C_3H_4F_3Br$
(HCFC-242)	$C_3H_3F_2Cl_3$		$C_3H_5FBr_2$
(HCFC-243)	$C_3H_3F_3Cl_2$		$C_3H_5F_2Br$
(HCFC-244)	$C_3H_3F_4Cl$		C_3H_6FBr
(HCFC-251)	$C_3H_4FCl_3$		
(HCFC-252)	$C_3H_4F_2Cl_2$		
(HCFC-253)	$C_3H_4F_3Cl$		
(HCFC-261)	$C_3H_5FCl_2$		
(HCFC-262)	$C_3H_5F_2Cl$		
(HCFC-271)	C_3H_6FCl		

The substances in the table degrade the (stratospheric) ozone layer and are regulated worldwide by means of the Montreal Protocol. CFCs are banned, but it is still allowed to manufacture 2.8 per cent of the quantities manufactured in 1989. The use of HCFCs is gradually phased out to zero in the year 2030. Halons may be used in quantities corresponding to 15 per cent of 1989 levels, while HBFCs are banned entirely.

The individual substances are banned. However, bromochloroethane and methyl bromide may be used until 2002 and 2005, respectively.

Appendix C
Overview of publications in the "miniseries" about life-cycle perspectives and assessments

About the mini series

The "mini series" about life-cycle perspectives and life-cycle assessments is published as part of the Environmental Protection Agency series Miljønyt. Taken as a whole, the publications in the "mini series" will provide support for companies, organisations, authorities, and others who wish to address environmental issues from a life-cycle perspective.

Along with previous publications on methods and tools for life-cycle assessment – particularly the EDIP books from 1996 – the mini series forms a set of tools which will eventually provide guidelines and advice on life-cycle efforts on all levels and for all situations. As part of the concept, some of the simpler methods and tools will be based on the EDIP method. This simple approach makes it possible to carry out straightforward life-cycle-based work which can subsequently form part of more detailed LCA work if the need arises. If detailed statements and assessments have been made, such work can also form the basis for e.g. a series of simple assessments.

Publications in the series, January 2001

Environmental News No. 53/2000. Håndbog i produktorienteret miljøarbejde (Manual of product-oriented environmental work)

Environment News No. 58/2001 Håndbog i miljøvurdering af produkter – en enkel metode (Handbook on environmental assessment of products - an easy-to-use method)

Previous publications on methods for life-cycle assessment (selected titles)

Nordic Guidelines on Life-Cycle Assessment, Nord 1995:20, ISBN 92 9120 692 X

Miljødimensionen i produktet – en introduktion til virksomhedens ledelse, March 1996, Miljøstyrelsen (ISBN 87-7810-453-1) and Dansk Industri (ISBN 87-7353-189-9)

Miljøvurdering af produkter, March 1996, Miljøstyrelsen (ISBN 87-7810-542-0) and Dansk Industri (ISBN 87-7353-199-5)

Miljørigtig konstruktion, March 1996, Miljøstyrelsen (ISBN 87-7810-435-1) and Dansk Industri (ISBN 87-7353-198-7)