Product Life Cycle Check

A *Guide* ©

Translation

Henrik Wenzel and Nina Caspersen, Institute for Product Development, Anders Schmidt, dk-TEKNIK Special edition adapted for course 42372, Tech.University of Denmark by dr. Michael Hauschild, September 2000.

Preface

This *Guide* has been written in connection with the project with the Danish title *Stimulering af mindre virksomheders interesse for arbejdet med renere produkter (Stimulating small companies' incentive for producing environmentally cleaner products)* sponsored by the Danish Environmental Protection Agency. The project was managed by TIC (Technological Information Centres). The *Guide* can be used as course material but can also be used as a supporting tool for the preliminary assessment of a product's environmental *properties*.

The guide was subsequently translated and further elaborated by Mrs. Christine Molin, Institute for Product Development, Denmark and reviewed and commented by Dr. Michael Hauschild, IPT, Technical University of Denmark, Dr. Per Nielsen, Asian Institute of Technology, Bangkok, Thailand, Prof. Chris Buckley, University of Natal, Durban, South Africa, and Dr. Stig Irving Olsen and Dr. Niels Frees, Institute for Product Development, Denmark and finally by the authors.

Content

Appendices:

1. Introduction

Product Oriented Environmental Strategies (POMS) in Denmark

In 1996, the Danish Environmental Protection Agency published a proposal for an intensified product oriented environmental initiative [1]. The purpose was to support and contribute to the development and marketing of cleaner products in order to reduce the impacts associated with production, use and disposal of products.

The proposal also outlines the framework needed to promote the availability and sales of environmentally improved products on a market, which increasingly puts environmental issues on the agenda. However, it is crucial that an improved environmental effort does not jeopardise the competitiveness of the companies, this would neither be beneficial to the environment nor the economy.

Many companies are aware of the increasing demand for information on products' *environmental properties*. In Denmark, for instance, all public purchase must include environmental considerations, and for many product areas, environmental *Guidelines* for this are being drafted. Also companies, which have adopted the product oriented environmental strategy, set environmental demands to their subcontractors.

Life Cycle Assessment (LCA)

Since the late eighties, intensive work has been undertaken in Denmark to develop methods and tools for the environmental assessment of products and services. Many industrial companies have adopted the concept of LCA. During 1998, a survey of Danish industry's experience with LCA was made, showing that more than 70 % of companies having worked with LCA were positive towards it and wished to continue to use LCA in the course of product development [4].

However, all companies agree that there is a need to simplify the work with LCA, and the Danish Environmental Protection Agency has initiated activities concerning simplification of LCA to meet this need. One of the initiatives was the work and project behind this *Guide* on how to do a quick *Life Cycle Check* of a product or service.

Aim of the Life Cycle Check

The aim of the *Life Cycle Check (LCC)* is to illustrate the life cycle thinking and to give the company a tool to perform a preliminary LCA. The *Life Cycle Check* shall be an "*eye opener*" which can guide the planning and optimising of the further work of assessing environmental impacts from the company's products.

Moreover, the *LCC* shall provide a short-cut to the discipline of LCA to any newcomer, and a short-cut to performing an LCA to any LCA practitioner by serving as the initial screening thus allowing for focusing the work and saving a lot of time.

Aim of the Guide

The aim of this *Guide* is to support and guide the work of performing a Life Cycle Check, and it is especially targeted towards SMEs. The *Guide* also serves as educational material for introductory courses on LCA.

The user of the *Guide* must have a technical or chemical background or knowledge corresponding to an engineer or equal education. Some knowledge of environmental issues is recommendable, but detailed knowledge on LCA or environmental assessment in general is not necessary. However, it will facilitate the use of the *Guide*, if the user participates in a short-course on *LCC*, where the guide and its exercises are used as educational material.

The person performing the Life Cycle Check can be a company employee, a consultant or anyone else wanting a short-cut and an easy start on the rocky path of LCA.

Motivation helps

Before you or your colleagues introduce the *Life Cycle Check*, it is necessary to find out if your company has the incentive and motivation for these product oriented environmental initiatives. One way of doing this is described in [3]. This *Guide* assumes that your company already has acknowledged the need for undertaking a preliminary LCA, and that your company has allocated the resources necessary to obtain the data needed for this task.

1.1 User guide

Scope and
time consumption

When you have read this *Guide* and have participated in a two-day hands-on course, you are equipped to make a *Life Cycle Check* in approximately 2 days. You do not need a PC-tool, only paper, pencil and pocket calculator. Your company, or the company you are addressing, must also accept a commitment of 1-2 working days from others to obtain the necessary information and data. You will document the result of the *LCC* in a 5 to10 page report incl. figures and tables. This *Guide* also provides advice on reporting the *Life Cycle Check* together with templates and examples of figures and tables in which your data can be presented.

Procedure

- preparation and kick-off

Before commencing the *Life Cycle Check*, your company has to choose which product shall undergo the check. Then you and your co-workers or company contacts – if you are an external consultant – can have a kick-off meeting. This kick-off meeting should follow the agenda stipulated in appendices of this *Guide*.

The first task in the Life Cycle Check is to describe the service provided by the product in question. *The second task* is to describe the product's life cycle – from cradle to grave. These tasks are initiated at the kick-off meeting, where the relevant people from product development, production, sales and marketing or environmental department are present. The specific attendance to the meeting depends on which departments have the relevant information.

The third task described in this *Guide* is how to do the preliminary LCA and the fourth task is how to evaluate and report the results to the company. This work is purely desk work and you can use this *Guide* and enclosed templates for the final reporting.

- dialogue

Before you submit the final report, it is a good idea to give your contacts/customers in the company or one of your colleagues (if you are an internal employee) a draft of the report for their comments. The very first time you have to report a *Life Cycle Check*, it is reassuring to get a more experienced colleague to go through the report.

In Appendix 4, the procedure is outlined systematically as the *10 steps of LCC*.

Examples as templates

This *Guide* provides examples of all aspects to be covered in the final report, and you can use these examples as templates.

The base case throughout the Guide

The base case studied throughout this *Guide* is that of a Life Cycle Check of a domestic electric coffee maker but other examples will also be considered.

The base case of the Guide: a domestic coffee maker

2. Choice of product

Criteria for choice of product

The company must choose a product for the *Life Cycle Check*. Various considerations can lie behind the choice of product, but typically, the following criteria are essential:

- The product is representative for the company's product range
- The market for the product is receptive to environmental considerations, e.g. that environmental labelling exists or is on the way for this type of product
- The product is easy for the company to manage as the necessary data for an *LCC* is readily available
- The company is about to develop the next generation of the product, and is interested in integrating environmental considerations in the product development.

Products can be chosen based on other criteria, but the above are the most usual.

Prior to the kick-off meeting, discuss the choice of product and the criteria for it.

3. The service provided by the product

The first step in the *Life Cycle Check*, is to define and describe the service provided by the product. The *product service* can be defined as the benefit the product provides to the user, or the service the product gives the user, when covering the demand of the user. Why is this particular product purchased? What are the functions it provides? In short, what does this product do for the user?

Environmental assessment is a comparison

The reason why it is crucial to define the product's service, is that LCAs will always address comparisons. First of all, there is no such thing as an environmentally friendly product. There are only environmentally *friendlier* products. All products are brought about with the use of materials and/or energy, which imply the use of resources and which give rise to impacts on the environment. Some products will contain less materials and consume less energy than others, and they are therefore *better* for the environment. Thus, an environmental assessment or an LCA is per definition always a comparison.

When two products are compared, or if improvement potentials for a new product are measured against an existing product, it is vital that the compared *services* be identical. You cannot compare A to B, and conclude that A is better from an environmental point of view, if A does not deliver the same *service* as B. If A's *service* to the user is not as good as B's, the customer would never buy A in preference to B.

Example of a product's service: Hospital staff' uniforms

Taken an example: Hospitals buy uniforms for their staff. Some uniforms are laundered daily. This amounts to approximately 100 washes prior to disposal. The example used here is a nurse's uniform or so-called white coat. The uniforms can be 100 % cotton or they can be a blend of polyester and cotton. In the mixed fabric uniforms, however, the cotton fibre will slowly wash out. After 20 washes, the mixed fabric white coats will consist mainly of polyester and become statically electric, the ability to absorb moisture will decrease, and it will become slightly transparent. A nurse will then often choose to wear a cotton T-shirt under her white coat. Not because the patients complain about the transparency, some may even like that, but because the uniform is no longer as comfortable as the 100 % cotton uniform.

Nurses' uniforms as shown on Beslin's

home page at http://www.beslin.co.za/hospitals.htm

The *service* of the uniform is therefore not only 1 piece of hygienic and reasonably insulating uniform, it also contains functions like comfortable feeling against the skin, moisture absorption and protection against curious eyes. If all these different elements of the *service* provided by the uniform are not identified, one will believe that a mixed polyester-cotton uniform can be compared to the 100 % cotton one. But no, what should be compared is one cotton uniform to one mixed polyester-cotton uniform plus x % T-shirt. Moreover, a condition for making this comparison is that the life span of the uniforms are the same, but this might not be the case. More aspects of this hypothetical example will be provided later.

Example of a product's service: paints

Another example concerns paints. We buy paints to decorate and protect surfaces. Paints can be based on water or turpentine as solvents. Most of us have experienced that these two types of paint do not have the same ability to cover the painted surface. Let us assume that we need 1.3 litres turpentine based paint for every 1 litre water based paint. But the surface we are painting is an outdoor surface, and let us further assume that the water-based paint will not last as long as the turpentine based paint. We therefore need to paint our outdoor surface twice as often to achieve the same standard of maintenance and appearance. The service we have to consider is thus not decoration and protection of x m^2, but decoration and protection of x m^2 surface for y years. The durability of the paint is an integral part of the service. So what we need to compare here is not 1.3 litres turpentine based paint to 1 litre water based paint, but 1.3 litres turpentine based paint to 2 litres water based paint.

As this example illustrates, it is extremely important to achieve a precise definition of the product's service. If the service is not correctly defined, the product assessment will not be valid.

Talk to the sales and marketing staff

When defining the product's *service*, it is recommended to talk to the company's sales- and marketing employees. The bottom line is that it is the customer who decides what the product service is, no-one else, not even the people who developed the product, although they are an important source of information. In the example of the nurse's uniform, it is the nurse who decides to wear the T-shirt in order to get satisfactory comfort when wearing the polyester-cotton uniform.

A customer can in this context both be the buyer in the retail shop, but can also be an internal company customer or another purchaser somewhere along the chain of buyers right up to the end user.

Sales- and marketing personnel will typically possess information about customer demands, because of their influence on marketing efforts and subsequent sales.

Obligatory and positioning properties

When describing the service of the product, it is thus imperative to identify the most important product *properties*. These are the *properties* the customer considers as decisive. Some product *properties* are called *obligatory. Obligatory properties* are the ones which a product most have to be marketable and to be considered for selection by the customer. If the *obligatory properties* are not present, the product will not be an option to the customer. *Obligatory properties* can be decided by law, i.e. a car must have brakes. They can also be determined by customer demands: a hospital white coat must be white. At least in some countries, a TV must have a remote control. Almost all products in the market will fulfil the *obligatory* customer demands, and the ones that do not, will soon vanish.

Other product *properties* are called *positioning properties*. These are the *properties* the customer will consider nice to have, and which will make the product attractive compared to other products with the same *obligatory properties*. Over time, some positioning properties will become obligatory as ever more products in the market become them. An example of this is the safety equipment of cars where seat belts and later ABS brakes used to be positioning properties but today are nearly obligatory. Recently, airbags are undergoing the same development.

Exercise

Try to consider and identify which *properties* are *obligatory* and which are *positioning* for the hospital overall and the paint for outdoor surfaces. Arrange the *properties* in a table, just as we have done in the example below for a electric coffee maker (**Table 1**)

Example
- a coffee maker

Obligatory properties	*Positioning properties*
• *Brew coffee* • *Keep coffee hot* • *Fire precaution*	• *Brewing time* • *Brewing volume* • *Temperature* • *Stand-by temperature* • *Stand-by time/automatic turn off function* • *Easy to clean* • *Design* • *Rotating filter holder* • *Transparent jug* • *Coffee aroma* • *Volume marks on jug* • *Volume marks on coffee maker* • *Price* • *Durability* • *Can be pre-programmed*

Table 1. Description of the service provided by the coffee maker with both obligatory properties and comprehensive positioning properties.

Make a table like this at the kick off meeting

Market segments and -niches

The obligatory *properties* will be known to the company. These are either stated by law or are *properties* so essential, that it would be unthinkable to produce the product without them. The positioning *properties* are more fluctuating and are variable in strength. Some can be key elements in marketing and sales, others can be more marginal.

The market can be divided into market segments and market niches. A niche is just a further sub-category of a market segment. Each segment or niche will target different *properties*. For one market niche, sales parameters for the coffee maker can be price, brewing time, and ease of cleaning. Such parameters might be the decisive for use in public offices or factory canteens. In other niches, design and taste could be a more important parameter, for instance in private homes.

Identify the most important positioning properties for the product

Start by making a gross list on the product's positioning *properties* in collaboration with other product stakeholders inside and if possible outside the company. Then discuss which *properties* are the most significant for the markets in which the product is sold. The most important *properties* must be maintained, also in new developments of the product. Less important *properties* are expendable or can be replaced by others. Additional functionality usually leads to higher costs and further environmental impacts. A product possessing more functionality than the customers demand, is usually not an economically or environmentally good solution.

Which product properties can be left out?

If only 5 % of the market demands a rotating coffee filter arm, it is permissible to seek environmental improvements in avoiding this swinging device. However, you cannot seek environmental improvements by lowering the water temperature to 80 °C, because this will have a negative effect on the flavour of the coffee, which certainly will narrow the market share for the coffee maker. In the example of the nurse's uniform, environmental improvements cannot be obtained in using a fabric with a lower cotton content, even though this fabric compared to cotton has lower environmental impacts when washed and tumble dried, because some vital positioning *properties* are lost in the mixed polyester-cotton garment, thereby leading to a surplus flow of other products (the T-shirts).

Remember, that environmental improvements are only achieved, if the product substitutes for another less environmentally friendly product in the market.

The conclusion is, that some positioning *properties* stated in the comprehensive list can be disregarded, while others cannot.

3.1 The functional unit

It is not sufficient to qualitatively describe the product service as it is done in Table 1. Of course, the kind of service must be the same, but also the amount or extent of the service should be equal, as shown in the example with the outdoor paint. A quantitative description is also necessary.

When the product service is quantified with respect to volume and time it is called defining the *functional unit*. The *functional unit* is made up by:

1. Quantity
2. Durability

because all products in comparisons are normalised to same quantity and durability, and

3. Quality (services/functions, which by the customer are interpreted as equal and which in this context enable us to compare the products environmentally. This is where obligatory and essential positioning *properties* enter)

Example
- nurse uniforms

In the hospital uniform example, we have up till now forgotten to include the durability of the service, that is the life time of the overall. For a poor fabrics quality (which is not rare) the life time of the polyester-cotton garment is shorter than the garment of pure cotton. The polyester-cotton fabric garments are disposed earlier. Where as a poor quality cotton garment can be washed 60 times before disposal, a poor quality polyester-cotton garment can only be washed 40 times before disposal. If you want the same durability of the service here, you need to use 50 % more polyester-cotton fabric garments plus the use of T-shirts under the garment, as illustrated in the example earlier on (again this a hypothetical example).

Exercise

Try to define the *functional unit* for both the hospital uniforms and the paints. Use the table as shown here for the coffee maker.

Example
- a coffee maker

	Obligatory properties	Positioning properties
Qualities/ Properties	Brew coffee Keep coffee hot - Temperature ≥ 82 °C Fire precaution	Brewing temperature ≥ 94 °C Keep flavour in coffee Brewing time ≤ 8 minutes Price ≈ 500 – 600 DKK Smart design Long durability
Quantity	Brewing 1 litre coffee twice a day	
Time in use	7 days a week during 5 years	

Table 2. The functional unit of a domestic coffee maker marketed for middle class families

Positioning properties in a coffee maker for middle class homes

In the example of the coffee maker, we have assumed that the market for the product in question is private homes and the market niche is wealthy private homes. We have identified that the essential positioning *properties* in this market niche are design and the quality of the brewed coffee, which mean *properties* such as water temperature, coffee temperature and the ability to keep the flavour (closed pot). The customer also expects the coffee maker to be durable. Price is not an issue, so the product can be relatively expensive. Perhaps it is even necessary for the product to be expensive, as this signals quality.

The service according to market demands for this particular coffee maker is now identified. New and more environmentally friendly products must deliver the same service, otherwise the product cannot compete. If the product is not sold, the new environmental improvements are of no consequence. As stated earlier, a more environmentally friendly product only delivers environmentally improvements if it substitutes another less environmentally sound product. In this case improvements cannot be achieved by lowering the water temperature to below 94 ^{o}C when brewing coffee unless another solution ensures the same flavour of the coffee. Perhaps it is possible to save energy if the coffee maker is designed in a way which allows the coffee to be brewed directly into a thermos jug without comprising the overall design of the coffee maker. Remember, in this case design was one of the positioning *properties* for the market niche.

During the kick off meeting, make a table stating the product's *functional unit*

3.2 Secondary services

Example
- house hold products

At this stage we have defined the service that our product must deliver and therefore know what our company can optimise when integrating environmental improvements for the product. The service is described in the *functional unit*, which is exactly what the company produces and sells. However, a product most often also delivers other services or has additional functions to the ones profiling the product. Those services are *secondary services* and are market irrelevant

A *secondary service* can be waste heat from energy consuming household appliances like a refrigerator, a TV or a PC. The waste heat can be a significant contribution to heating a house. It actually substitutes oil or gas for the central heating system. So in practice there is an actual utilisation of the waste heat unless the product is sold in a geographical market segment (subtropical or tropical countries) where the waste heat will cause an increased need for room cooling (air conditioning).

Example
- the coffee maker's secondary properties and consequent secondary services

When a coffee maker is produced, it is not only the coffee maker which is produced but in reality also a small heating appliance. If the glass jug of the coffee maker is recycled, it is in fact a "*raw material*" for beer bottles. If the plastic materials in the coffee maker are incinerated after disposal (i.e. at a Danish waste incineration plant) the plastic is a "*raw material*" for energy production (electricity and heating).
As can be seen here, most of the *secondary services* are not intended services and these product *properties* are market irrelevant.

Foresee and plan secondary properties when designing the product

However, there is an increasing focus on *secondary properties* because society is increasingly seeking to maximise the utilisation of resources and energy. Knowing that an increasing amount of materials will be recycled, companies have started to pay attention to this fact. When planning the development of a new product, why not take these issues into consideration and plan all the product *properties*, also the *secondary* ones? Society has so great an interest in this that future developments will be in this direction. Solely from an environmental point of view, the *secondary services* will be important. The environmental impacts from a product must be allocated among all the *services* of the product. If material is recycled, the raw materials in question will only be extracted once, which means that all the products in which these materials are used must share the responsibility for the environmental impacts from raw material extraction and production.

4. The product life cycle

When you have a good grip on the product's service to the user and of the secondary services as well, you shall identify, where the environmental impacts lie. Start off by getting an overview of the product's life cycle. This is an overview of all the processes from material extraction and production to the disposal of the product.

4.1 Overview of the product life

The product life cycle has 4 stages

The product life cycle has four main stages. These stages are called:

Materials
Manufacturing
Use
Disposal

Distribution and transportation are included in and between all the four stages. So is disposal, but a separate stage is usually devoted to the disposal of the product itself to allow specific attention tot the behaviour of the product in society's waste treatment systems.

Get an overview before you meet with the company

Before your meeting with/at the company start by making an overview on a piece of paper. Make your own estimates on what is significant and what is not significant in the product life cycle:

- Make an estimate of the product's weight and the type of materials. Consider whether manufacturing will involve problematic processes or chemicals.
- Consider the product's life time. For most products the *use stage* will make up the major part of the total life time (except for food products and fire works…..) With today's technology, the total time for the manufacturing a coffee maker is less than one hour, while the duration of the *use stage* very well can be 5 years or more.
- Try and estimate the relative part of the total lifetime spent in the *use stage*.
- Consider which routes of disposal are the most likely.
- Consider which materials are likely to be recycled and which will be disposed of through other processes, e.g. incinerated with recovery of energy.
- Consider where the product will be sold: what is the geographic market segment for this product?
- What are the disposal routes of this market segment?

Before the kick-off meeting make an overview like the one in Table 3

Stage	Description	Data source
Material Stage	Total weight: a couple of kilograms Material: mostly plastics, glass, steel, copper in wires Packing: mostly cardboard, most likely recycled	Parts list. Manufacturing dept.
Manufacturing stage	Moulding/casting of materials. Special processes/chemicals: no information available - must be checked	Parts list. Manufacturing dept Data on chemical from environmental dept.
Use stage	Duration 5 years Sold in (>80 %): Denmark, Sweden, Norway and Germany Use Total no. of brews are 2 x 7 x 52 x 5= 3640. Time consumption for one brew is 12 minutes. The coffee is kept hot (80 °C?) for 30 minutes (average estimate) Energy consumption: 3640 kilograms coffee is heated from ca. 10 °C until boiling. Heat loss from 1 kilogram very hot water during 1820 hours. Material consumption: 3640 filters and coffee beans Maintenance Removal of lime with acetic acid, cleaning with detergent. Energy consumption when descaling which implies heating 2 litres of water once a month.	Sales and marketing dept. Manufacturing dept.
Disposal	Mostly sold in Scandinavia. Disposal via recycling plants or via household waste. Will under all circumstances be incinerated. Energy recovery. X% of glass jug will be recycled.	Manufacturing or sales dept. Research centres Local authorities

Table 3. The preliminary overview of the life cycle of a coffee maker

Some products are active, which means they ”come alive” in the *use stage*. This is the case for all energy consuming products, like vacuum cleaners, computers, TV’s or pumps. Some products are based on chemicals like paint or detergents, and other products require frequent maintenance during the *use stage*, e.g. products as textiles, dinner sets and pots and pans. For the products mentioned here, the *use stage* is usually always the most dominant from an environmental perspective.

Other products are passive, which means that they do not give the same degree of environmental impacts during the *use stage*. These could be products like furniture, newspapers, packaging and disposable plates and beverage containers. But even for passive products, the *use stage* will result in some environmental impacts. Furniture have to been cleaned, and some pieces of furniture might even evaporate chemicals to the indoor climate, other products might need washing and cleaning, some might need heating, others cooling. Even passive products can, during the *use stage*, cause environmental impacts because they enter or interact with other systems. Packaging of food will cause energy consumption when put into a refrigerator.

You have to imagine all the scenarios of the product life cycle and all the processes it encounters and the potential environmental impacts which will result. An overview of the product life cycle will help you to get the right proportions. Where are the large volumes, how long are the time intervals and where will the important impacts be?

Example
- sports wear

A couple of years ago company manufacturing sportswear gave a presentation at a seminar on environmental management. As a consequence of their work with product oriented environmental strategies, the company had introduced a new textile fibre which only required half the amount of energy for manufacture compared to the old fibre. This was presented as a substantial environmental improvement in their product. The company was subsequently asked to produce information on how many times the sports garment was washed and tumble-dried during the garment’s life time. There were also questions on the new fibre’s ability to retain water during spinning in the washing machine. The amount of rinsing water the fibre retains will influence the drying time in the tumble drier. The company had not considered any of these issues at all.

Exercise

Try to make an estimate of the energy consumption for 100 washes, spinning and tumbling drying. Make an estimate of the significance that a 10 % reduction in water retention in a textile garment after spinning has in relation to a 50 % decrease in energy consumption during the manufacture of the fibre. In *Appendix 3* you will find information about the life cycle of different textile fibres.

How do you get data?
- parts list
- sale & marketing
- product development

You now need to get specific data about the product and its life cycle. Data on raw materials and manufacturing will often be available from the company's production department. Many companies have one or more of a unit process list, a bill of materials, a parts list or a list of components for each product. From a unit process list you can get the data needed. Data on where the product is sold will most likely be available in the marketing and sales department. Data on the *use stage* can usually be supplied by the sales and marketing department or by the product development department. Data on disposal is not often available in the company, and must be sought elsewhere. Information about disposal can be obtained by the municipality, or by the retailers, who might get the used and outdated product back when a new product is purchased. Also information centres and research institutes may be able to provide information on disposal. If the product contains several materials and sub components, you can get an overview by presenting the data in a structure similar to the unit process list. In Table 4 you will find a unit process list for the coffee maker.

Material stage and production stage

The parts list and the manufacturing processes including the ancillary materials needed in the processes, are given in Table 4 for the coffee maker. This table repeats the information obtained from the parts lists and it follows the structure used for most parts lists.

Use stage

Give data for the *use stage* in the same way as presented in the parts list, see Table 4. Remember that the *use stage* also includes operation and maintenance. You can often get data about the *use stage* from the company, but you can also make your own calculations with information from specifications and product labels. The coffee maker's heating element has a power consumption of 600 W. It takes 12 minutes to brew 1 litre of coffee, so the energy consumption is 0,600 x 0,2 hours x 3640 brews which results in an power consumption of 440 kWh if 3640 brews are done in the life time of the coffee maker. The hot plate, which keeps the coffee hot after brewing has a power consumption of 55 W. Each brew is estimated to be kept hot on the hot plate for 30 minutes, this results in a power consumption of 0,5 hours x 0,055 kW x 3640 brews = 100 kWh, assuming that the hot plate operates continuously. The total energy consumption in the *use stage* is 100 + 440 = 540 kWh.

Remember that the coffee beans and filters also are part of the *use stage*. You can of course ask if these items are necessary to include when doing a Life Cycle Check for the company manufacturing the coffee maker. But choice of product concept and the design of the coffee maker can influence both consumption of coffee beans and filters. It is necessary to consider if any design changes will affect the consumption of coffee beans and filters, and if so, what are the resulting changes in environmental impacts. If you have any doubts on what to include in the Life Cycle Check, the rule is to include anything which could have an impact on the choices the company will make.

The disposal stage

The *disposal stage* can be listed as shown in Table 4 as well. In this example the product is disposed of through ordinary household waste collection system. In Denmark, this implies that the product will go to incineration except for the glass jug, where we estimate a recycling of 50 %. The distribution among different disposal routes is shown in the second column of the table, which shows the share of material or component to follow the particular disposal route. It is assumed that during incineration 50 % of the steel is retained on the magnetic sorting conveyer and thus recycled, the balance is assumed to be incinerated. In the Table the notation crediting is used for processes where secondary services of the coffee maker benefit other systems. This will be further explained later in Paragraph 4.2.

Transportation

Include a conservative estimate of all *transportation* processes in the product life cycle. This will show if *transportation* contributes significantly to the overall picture. If it does, a more realistic estimate of the transportation processes must be made but in most cases transportation is not important. In this context, optimisation of transport can most often be left in the hands of the logistics department, which is responsible for the total optimisation of *transport processes* within the company. Also *Transportation* for the coffee maker is shown in Table 4.

Table 4a Composition of coffee maker with associated manufacturing processes. Parts list structure.

Components	Quantity	Material	Weight (kg)	Manufacturing processes	Ancillary substances for the process

Table 4. Parts list model of the life of the coffee maker

Materials and manufacture

Component	No.	Material	Weight/fu (kg)	Manufacturing processes	Ancillary substances
Cabinet	1	Plastic, polystyrene	1,1	Injection moulding	Release agent
	1	Aluminium	0,1	Die casting?	Lubricant
	1	Steel	0,3	Pressing, Punching	?
Cord	1	Copper	0,02	Wire extrusion	
	1	Softened PVC	0,02	Coating	
Glass jug	1	Glass	0,34	Glass moulding	
Handle	1	Plastic, polystyrene	0,02	Injection moulding	Release agent
Strap	1	Aluminium	0,01	Rolling	?
Packaging	1	Cardboard	0,39	-	?

Use

Material/ Component	Process			Ancillary substances
	Name	Unit	Amount/f.u.	Name
The whole product	Coffee brewing - electricity - coffee filters - coffee beans (ground) - water	kWh	540	
		kg	7,3	Bleaching agents for coffee filters?
		kg	290	Pesticides, fertilisers
		kg	3640	
	Cleaning (brewer and jug)	kg	50	Water (hot/warm)
		ml	25	Detergent
	Descaling (lime removal)	kg	15	Acetic acid
	Crediting indoor heating	kWh	÷360	

Disposal

Material/ Component	Process				Ancillary subst.
	Share	Name	Unit	Amount/f.u.	Name
Aluminium	1	Waste incineration, aluminium	kg	0,1	?
Polystyrene	1	Waste incineration, polystyrene	kg	1,1	?
	1	*Crediting heat and power from waste incineration*	MJ	÷33	?
Glass	0,5	Waste incineration, glass	kg	0,17	?
	0,5	Re-melting, glass	kg	0,17	?
	0,5	*Crediting of glass*	kg	÷0,17	?
Steel	1	Waste incineration, steel	kg	0,3	?
	0,5	Re-melting of steel	kg	0,15	?
	0,5	*Crediting of steel*	kg	÷0,15	?
Copper	1	Waste incineration, copper	kg	0,02	?
Coffee filters	1	Waste incineration, coffee filters	kg	7,3	?
	1	*Crediting heat and power from waste incineration*	MJ	÷110	?
Coffee grounds	1	Waste incineration, organic matter	kg	290	?

	1	*Crediting heat and power from waste incineration*	MJ	÷3000-÷4300	?
Packaging	1	Waste incineration, cardboard	kg	0,39	?
	1	*Crediting heat and power from waste incineration*	MJ	÷5,8	?
Total transport					
Material/ Component	Process				Ancillary materials
	Share	Name	Unit	Quantity/f.u.	Name
	1	Transport of raw materials, ship	kgkm	40 * 10^5	Fuel oil
	1	Transport of raw materials, lorry	kgkm	1,2 * 10^5	Diesel
	1	Transport to consumer, van	kgkm	0,03 * 10^5	Gasoline
	1	Transport to refuse dump , car	km	5	Gasoline

An overall view

A table such as Table 4 for the coffee maker is the core of your *Life Cycle Check*. The table specifies all the information you need about the product and its life cycle, and this one table gives you an overall view. Quite often there will be a lack of data, especially concerning processes and auxiliaries. In the first round, you have to just leave this as it is but include further data collection in the planning of additional activities. See also Paragraph 4.2

Proportions of mass and energy flows in the life cycle

We now have figures on the most significant mass and energy flows in the life cycle of the coffee maker. The sizeable consumption of power, water, coffee beans, acetic acid and detergents in relation to the other life cycle stages speaks for itself. The table confirms the assumption that the *use stage* is the most important in the life cycle of the coffee maker. If many hazardous chemicals were used in manufacturing, this stage would perhaps be of equal importance. But already we realise that this is not likely with common material manufacturing processes such as the case is here. The disposal stage could, however, be significant. The incineration of coffee grounds, shown in Table 4, could be an important consideration – a consideration we did not realise at first. In Table 4, processes labelled *crediting* are shown. The relevance of this will be explained later in Paragraph 4.2

Parts list- or flow diagram?
Example:
- hospital white coats

The part list is an excellent tool to get an overview of the life cycle if the product under study is a complex product. A complex product is a product containing components and subassemblies and several raw materials. When the product under study is simpler a flow diagram can be used instead providing a more convenient overview. It is up to you to describe what is the simplest way to proceed. An example showing a flow diagram model for a hospital white coat is presented in Figure 1.

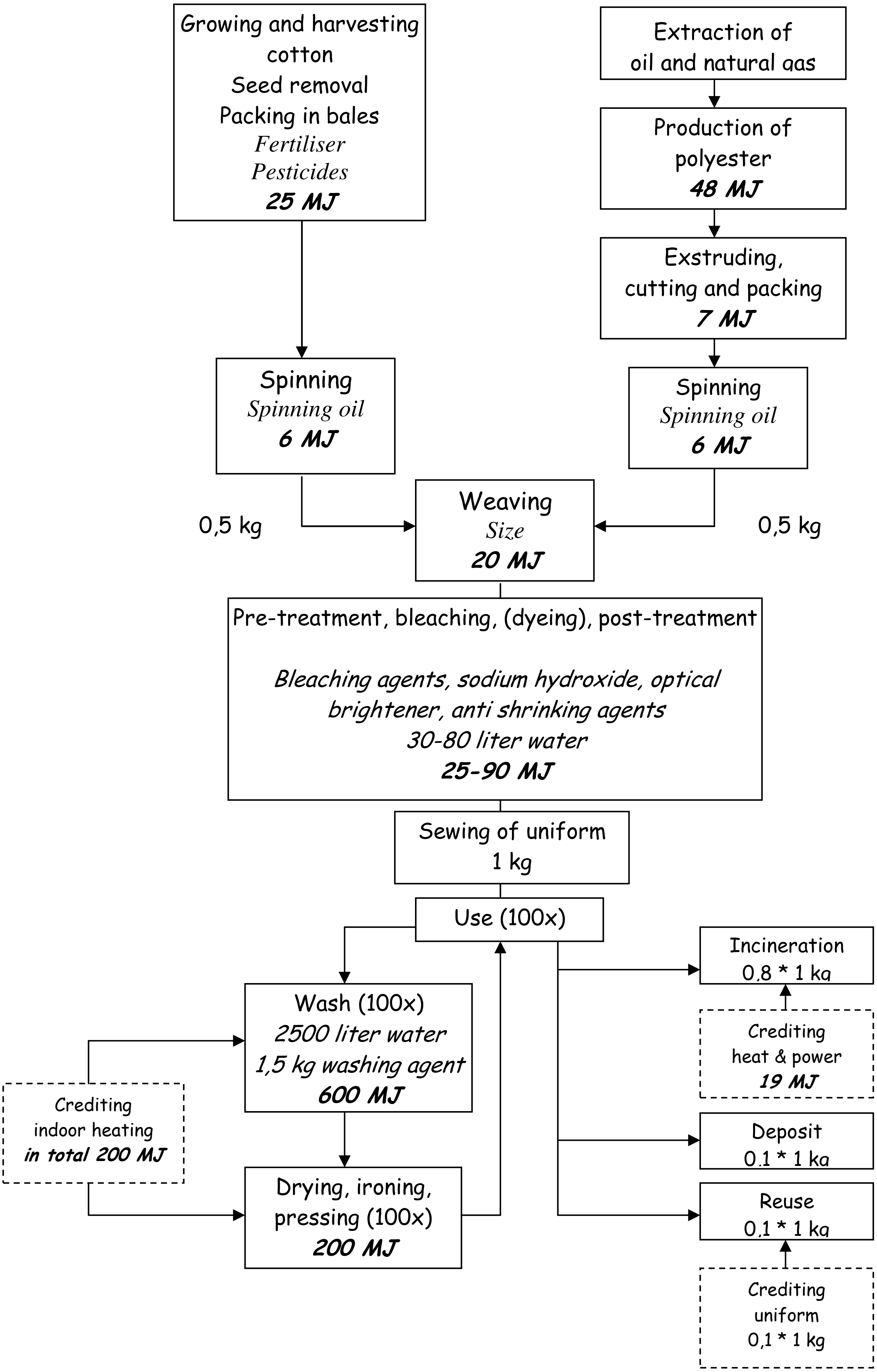

Figure 1. Flow sheet per kilogram overall for the life cycle of a hospital uniform of high quality 50/50 polyester-cotton. We assume that waste heat from the laundry is utilised for room heating.

4.2 Interaction with adjoining systems

As mentioned in the previous paragraph, the unintentional *secondary* services which occur in most product life cycles are often significant when seen in an environmental context. These unintentional *secondary* services occur where the system we are investigating interact with other systems, the system of investigation being our product's life cycle and the processes it contains. Where the *secondary* service occurs, savings on other ways of providing this *secondary* service are obtained. In all fairness it is necessary to credit the system for this different way of providing the service, i.e. if metals are recycled, it is fair to subtract the production of the equivalent amount of metal.

Due to their *secondary services* both the coffee maker and the hospital white coat have significant interactions with other systems. These interactions must be credited. This is shown in Table 4. The coffee maker's *secondary* services are 1) the heat loss during *use stage*: which substitutes room heating, 2) recycling of glass and steel: substitutes production of these materials, and last but not least 3) incineration of materials: which substitutes production of energy and heat at power and heating plants. Let us start with the latter, which under Danish conditions is the most significant

Table 4 shows the surprising recognition that coffee grounds are important for the disposal stage. This we did not realise at the preliminary quantitative overview. The significance of the coffee grounds are caused the *secondary* service it provides. This service occurs from electricity and district heating from the waste incineration plant when the coffee grounds are incinerated. Therefore, coffee beans provide two services. One service is as raw material for coffee and the other is as raw material for power production. And it is a sizeable mass of coffee beans that enters the life cycle of a coffee maker as almost 300 kg of coffee beans are processed. The calorific value of dry coffee ground is equal to wood and paper, namely 20MJ/kg. With a utility value of 80 % in the incineration plants, the 290 kg coffee grounds will produce approx. 4300 MJ power, if the coffee grounds are dry. However, the coffee ground may not be dry, and therefore an interval is given in the table. Notice that this power production is equal to the power consumption of the coffee maker when calculated as MJ primary energy. The details of this calculation are showed later.

Exercise
- identify the uncertainty of energy data

But there are shortcomings in the information on energy. Try to identify if there is any energy consumption, not shown in the table and where this energy consumption lies. Discuss this with a colleague or make your own reflections on this aspect while continuing reading. The subject will be further elaborated in the following text.
Reflect on the environmental considerations of making coffee without a paper filter as is done in manual pump coffee jugs. Energy for the

Exercise
- compare the coffee maker to a manual compressor coffee maker

hot plate is not used, but will you discharge the coffee grounds with the wastewater down the kitchen sink when rinsing coffee grounds from the coffee jug? What happens to the coffee grounds? How much of the coffee grounds can be discharged with wastewater before the energy you saved in not having a hot plate is lost? What will it do to the overall picture if the coffee was brewed directly into a thermos?

Recycling of materials
- substitute new materials

Coffee filters and the plastic parts of the coffee maker contributes in the same way to power generation, put together this is approximately 93 MJ. When materials are recycled, resources are salvaged and the environmental impacts are less than when manufacturing the new material. Both the environmental profile and the resource profile for a product is closely connected to the grade of recycling for each material. In the coffee maker example, the assumption is that 50 % of steel and glass is recycled. As can been seen in the table, these are relatively small amounts of energy in the relation to the total picture.

Heat loss during use
-substitutes room heating

The heat loss from the coffee maker during *use stage* substitutes for other heating if the rooms are heated by thermostat controlled heating in the room where the coffee maker is placed and where the hot coffee is consumed. If the season for room heating is estimated to last 8 months, it means that 2/3 of the heat loss substitutes other room heating. A coffee maker is not an efficient room heater, because the heating element is operated by electricity, which has lower thermal energy efficiency than other typical sources for room heating, i.e. natural gas or fuel.

Exercise
- crediting

In the example we assume that 2/3 of the coffee maker's electricity consumption is credited, because it is placed in a room, which is heated during the cold season. The crediting covers the electricity used for brewing keeping the coffee hot. Our assumption is based on the use of the coffee maker in countries with cold climates and the substitution of room heating, We also assume that the coffee is consumed. You should use a little time to reflect on these assumptions. How much of the brewed coffee is not consumed and therefore wasted?

The purpose of this exercise is not to create confusion, but only to reinforce the concept that many parameters have to be considered with regard to making a product more environmentally friendly. A coffee maker brewing small quantities, might be more environmentally sound than one brewing larger quantities. This conclusion is reached if less coffee is wasted when only brewing small quantities. So, did we earlier on make a mistake when identifying the *functional unit*? Should the *functional unit* rather be 2 x 1 litre of coffee *consumed* per day, and not *brewed* per day?

Before the meting with the company make an overview of the product life cycle in a parts list or a flow diagram

5. Preliminary environmental assessment

Limitation of the study and interpretation

You have now established an overview of the product life cycle. This gives you an impression of proportions; what is large and what is small. You have also an overview of the parameters of which you do not know anything. So, at this point you have defined the object of the study and you have defined the limitation of the study, Already at this point you and the company can make certain conclusions, as the coffee maker example has shown. You know the significance of the *use stage* i.e. the energy consumption for brewing the coffee in comparison with the energy consumption. You know the significance of utilising the energy contained in the coffee grounds. Now is the time to make a systematic overview and to ensure that all significant parameters are included. You should also state if there are important data deficiencies.

In a traditional life cycle assessment, you would now make an inventory of the inputs from and outputs to the environment from all the processes in the life cycle. You would also try and track all inputs back to their resource consumption from natural sources and you would track all outputs to their final emissions to the environment, which means emission to air, soil and water. However this task is rather time consuming and requires knowledge of many environmental impacts and knowledge of the potential contributions from the substances emitted to the environment. Finally, you would have to assess the uncertainties in the environmental assessment and make an interpretation. This procedure is described in the ISO standards [5] and in several of the methodology publications used at present [6], [7], [8] and [15].

Screening according to MECO

This Life Cycle Check *Guide* aims at introducing shortcuts and it bypasses the traditional procedure. However, it does not contradict the traditional procedure. But instead of making a detailed inventory followed by a detailed assessment, you will undertake a screening of the most significant environmental impacts. This is achieved by combining the inventory and assessment in the same procedure. The screening described here follows the MECO-principle (Materials, Energy, Chemicals, Other), which was developed as part of the EDIP-methodology [8], and uses a matrix as shown in Table 5.

	Material stage	Manufacturing stage	Use stage	Disposal stage
Materials				
Energy				
Chemicals				
Others				

Table 5. The MECO matrix used for the Life Cycle Check

The principle of the screening is to evaluate the agents causing environmental problems instead of focusing on the actual environmental impact categories. The agents causing environmental problems are grouped under the headings *Materials, Energy, Che*micals and *Others*. The latter covering special problems that cannot be listed under the three other. The strength of this structure lies in the fact that these cover all types of environmental problems with only a small degree of overlap in the type of problems categorised. *Material* consumption typically results in use of natural resources and consequent waste problems. *Energy* consumption means use of energy resources and consequent problems as global warming, nutrient enrichment and waste in the form of slag, ashes or radioactive waste. *Chemical* consumption typically results in impacts as toxicity to humans and the environment, stratospheric ozone depletion, and photochemical ozone formation. The *Other* category includes noise, radiation, microbiological problems, land use and physical impacts to nature.

How to get an overview

You must look at the MECO matrix as a tool to get a concise overview of the environmental problems. In the following you will be guided through the use of the MECO-matrix. But it is also recommended that you use the matrix to structure your own considerations: write keywords, names on scarce resources or toxic substances, or just add marks to indicate where the problems exist. The matrix is a tool to assist you – do not see it as a limitation. You can see a qualitative usage of the matrix in [14].

Start by making a MECO matrix with plus or minus signs or keywords. Perhaps you can make it during your meeting with the company

5.1 Materials

	Mat	Manu	Use	Disp
Materials				
Energy				
Chemicals				
Others				

State the content of scarce resources for each stage. Resources are considered scarce if they have a short supply horizon. A short supply horizon means that the known reserves only are sufficient for a short period of time given the present extraction rate. In this context a short supply horizon is defined as 50 to 100 years. In Table 6 some examples of scarce resources are listed. *Appendix 1* lists more examples.

Quantitative assessment of scarce resources

Table 6. Scarce resources

Resources	Supply horizon (years)	Resources	Supply horizon (years)
Copper	ca. 40	Tin	ca. 30
Nickel	ca. 50	Manganese	ca. 90
Lead	ca. 20	Natural gas	ca. 60
Zinc	ca. 20	Oil	ca. 40

Then calculate the consumption of the scarce resource quantitatively by dividing the known content in the product with the known reserve per person. The figure you reach will show this product's share (in % or 0/00) of the resource in relation to what is the reserve per person through time. This figure or unit is in the EDIP-methodology call person-reserve or PR. Appendix 1 shows data for the supply horizon and known reserves for certain non-renewable resources, Appendix 2 contains data on the resource content in certain materials.

Waste from materials

Now tabulate, where possible, the amounts of hazardous waste, slag ashes and bulk waste (not hazardous waste) derived from the consumption of materials. State the quantities in kilograms.

The coffee maker example - assessment of resources

In the material stage, the coffee maker consumes scarce resources as copper, crude oil, natural gas (in polystyrene) and manganese (which is an alloying element in steel). In the *manufacturing stage* there is only a minor consumption of resources. In the *use stage* the resource consumption is mostly related to energy resources, but some mineral resources made be used in growing coffee beans (phosphorus may be a scarce resource in the future though not listed in Appendix 1). In the disposal stage both iron and manganese are reclaimed in the steel sent for recycling (both iron and manganese are reused in the production of recycled steel. Also crude oil and natural gas is saved through the recovery of the energy in the coffee grounds and other combustible materials. An example of calculation of the person reserve is:
1,1 kg crude oil (if all plastics in the coffee maker are calculated as oil) divided by 25.600 kg per person = 0,043 mPR (millipersonreserve). For copper: 0,02 kg/60kg per person = 0,33 mPR. In the unlikely case where you purchase 3000 coffee makers for yourself, you have thus used up all the known amount of copper available for you and all your descendants. So buy only one coffee maker!

In *Paragraph 5.5* we have filled in a matrix for the coffee maker

Remember that there is also resource consumption hidden in energy consumption. State this in the next column on energy. A product which mainly contains renewable resources may not be the product with the lowest consumption of non-renewable resource in the life cycle. Take the example of cotton:

Example
- cotton; a renewable resource?

In principle, cotton is a renewable resource. But before the manufactured cotton fabric reaches the *use stage*, non-renewable resources have entered the life cycle. In fact, the consumption of non-renewable resources consumed in the process outweighs the finished cotton fabric. Approximately 1 litre of crude oil or fuel is consumed per kilogram cotton. The fuel is used in farming, in spinning and weaving cotton and in production of chemicals. Also mineral resources enter the life cycle as fertilisers on cotton fields (up to 1 kg/kg cotton) and as pest control. Look in Appendix 3 for further details.

5.2 Energy

	Mat	Manu	Use	Disp
Materials				
Energy				
Chemicals				
Others				

Through the overview of the product life cycle, you have some knowledge of energy consumption in the life cycle stages. Now it is time to ensure that the listed energy consumption is comparable and that all significant energy consumption is included. To compare energy consumption in the various processes and stages, you have to convert the figures to primary energy. *Primary energy* is defined as the amount of energy contained in the energy resource when extracted from nature. As a rule of thumb for Danish power plants, 2 MJ primary energy is on average consumed when producing 1 MJ (thermal energy or electricity) to the consumer. This 1 MJ which reaches the consumer is called *secondary* energy or direct energy.

In general: convert to primary energy

Material stage

List the primary energy consumption for materials. In Appendix 2 you will find primary energy and calorific value for some common materials. Some of the energy content of materials will be recovered in the disposal stage (see Paragraph 4.2).

Manufacturing stage
- estimates

It is not always possible to make an inventory of the energy consumption for the individual material. In most cases, a company will know its total energy consumption possibly divided on departments. This total will then have to be allocated to the manufactured products. If there is no other way you can for instance allocate the energy consumption weighted according to product volume multiplied by sales price. With this procedure you will include both the specific process energy and the overhead energy. Overhead energy is what is used for heating, lighting and ventilation of buildings. Depending on production facilities, the overhead energy can often be greater than the process energy.

For companies engaging in common material manufacturing processes, the overhead energy consumption is typically 2 to 3 times larger than the process energy. The total consumption of primary energy for manufacturing the product (including overhead energy) typically amounts to a maximum of 30 % of the primary energy required in the material stage. So if you have no data, estimate the manufacturing stage as 30 % of the material stage. For companies engaging in very energy intensive processes, like paper and pulp manufacturing, which evaporate large quantities of water, the process energy can be the more significant.

As a first estimate, the energy consumption for a process can be calculated from the power consumption given at the machinery name plate multiplied by production time for this particular component or product. This provides a conservative estimate of the process energy. In addition overhead energy must be estimated and allocated to the manufactured product volume multiplied by product price. Usually, it is not necessary with a more precise estimation energy consumption at process level because energy consumption in manufacturing is negligible compared to the energy consumption in the other life cycle stages.

Include product operation and maintenance throughout the life cycle. Operation can be consumption of energy, resources and auxiliaries. Energy consumption must be calculated as primary energy. Materials and auxiliaries must – if possible – be taken back to their primary extraction of energy resources. Remember to credit recovery of energy from any *secondary* services in the *use stage*.

Include energy consumption in the disposal stage, i.e. remelting if the material is recycled. Remember to credit the recovery of energy (see *Paragraph 4.2*). If materials are recycled, both the process energy to produce the material and the calorific value (for combustible materials) must be credited. Disposal of materials by incineration in incineration plants with utilisation of energy, the calorific value is credited, and you can calculate an energy utilisation efficiency of 80 %.

Transport
- a conservative estimate

You may include the total transportation as a separate ”stage” to evaluate the size of energy consumption for transportation. Make a rough estimate on various types of transportation and calculate the energy consumption. Some data can be found in Appendix *2*.

Example: the coffee maker
-Material stage

Primary energy consumption for the materials in the coffee maker is shown in Table 7. For plastics and pulp, both process energy consumption and calorific value are included. For the metals only process energy is included because metals burn at a higher temperature than will occur in the incineration plant. Aluminium can be incinerated in ordinary incineration’s plants but the surface very quickly oxidises to aluminium oxide, which prevents further combustion. Only very thin aluminium products like aluminium foil will release their full calorific energy during incineration.

Material	MJ/kg	kg in product	MJ in product
Plastics, PS	90	1,075	97
Steel	40	0,3	12
Aluminium	170	0,1	17
Copper	90	0,02	1,8
Glass	10	0,335	3,4
Cardboard, packaging	40	0,39	16

Table 7. Primary energy in materials (the coffee maker). Energy value for plastics and cardboard included.

- Manufacturing stage

In this case we calculate the manufacturing stage to be 30 % of the primary energy consumption for materials.

- Use stage, operation

The coffee maker has an energy consumption in operation of 540 kWh. Calculated as primary energy in MJ: 540 kWh · 3,6 MJ/kWh · 2 ≈ 3900 MJ.

Energy consumption for heating water is estimated theoretically by using specific heat of the water which is 4,2 kJ/(kg · K). It is assumed that the water is heated from 10°C to 94°C, which is a temperature increase of 84K. The theoretical energy consumption is

$$3650 \text{ kg water} \cdot 84\text{K} \cdot 4{,}2 \text{ kJ/(kg} \cdot \text{K)} \cdot 0{,}001 \text{ MJ/kJ} = 1290 \text{ MJ}$$

The total energy loss for brewing coffee and keeping it hot is 3900 MJ – 1290 MJ=2510 MJ, allocated as loss of approximately 1300 MJ in production of electricity and an equal loss of 1300 MJas heat dissipated from the coffee maker.

The energy efficiency here compared to a 100 % effective thermodynamic solution is 1300/3900 or approximately 30 %

Operation also includes the consumption of coffee beans and use of filters, with an energy content as shown in Table 8.

Material	Mass flow (kg)	Primary energy (MJ/kg)	Energy value (MJ/kg)	Primary energy (MJ total)
Filters	7,3	40	20	290
Coffee	290	25	20	7250

Table 8. Primary energy in materials use for operating the coffee maker. Energy for processing coffee: growing, drying, packaging transport etc. is estimated at 5 MJ/kg

- Use stage, crediting

The coffee maker, as mentioned earlier, produces heat during operation and both the hot coffee and the heat loss from the coffee maker itself contribute to room heating. If thermostats regulate the temperature in the house, the heat from the coffee maker and hot coffee will replace the usual room heating, and thereby substitute oil and gas from the house central heating system. As discussed previously, this scenario is only valid for the cold season. In Scandinavia this is approximately 2/3 of the year. The energy utilisation effect in central heating systems is estimated at 85 % and derived savings in primary energy are credited the coffee maker: $540\ \text{kWh} \cdot 2/3 \cdot 3{,}6\ \text{MJ/kWh} \cdot 1/0{,}85 = -1520\ \text{MJ}$

- Use stage - maintenance

Maintenance includes descaling and cleaning the coffee maker. Descaling is estimated to be done 60 times in the lifetime of the coffee maker. At every descaling 2 litres of water is used during ”brewing”(descaling and rinsing out). The energy consumption is

$$600\text{W} \cdot 0{,}2\ \text{hours/litre} \cdot 120\ \text{litre} \cdot 3{,}6\ \text{MJ/kWh} \cdot 2 = 100\ \text{MJ}$$

We assume that the coffee maker is cleaned with a dishcloth that is rinsed out in lukewarm water from the tap (40 °C). This is likely to happen in connection with descaling, so 0,5 litre of water is used each time. Most of this water is discharged directly through the kitchen sink drain and the energy content is lost without giving any additional heating to the room. The glass jug is cleaned/rinsed out once a day in 0,2 litre of lukewarm water (40 °C), perhaps with addition of the small amount of detergent. Here too, the energy is lost in the kitchen drain. The outlet temperature of water is approx. 10 °C. The energy utilisation effect in heating system to the tap is estimated at 75 %. Approx. 15 % is lost in the burner and another 10 % in the pipes and boiler. The consumption of primary energy for cleaning is:

$$(0{,}5 \cdot 60 + 0{,}2 \cdot 365 \cdot 5)\text{kg} \cdot (40-10)\text{K} \cdot 1/0{,}75 \cdot 0{,}0042\ \text{MJ/(kg} \cdot \text{K)} = 66\ \text{MJ}$$

- Disposal

As mentioned earlier, we assume that the coffee maker is disposed at a Danish incineration plant with energy recovery. We also assume that 50 % of the steel is extracted magnetically and recycled. Also half of the glass jugs are recycled. The fate of the materials are tabulated in Table 4c. Applying the data in *Appendix 2* we can calculate the energy scenario for the disposal stage:

Materials	Volume (kg)	Recycling (MJ)	Crediting (recycling) (MJ)	Crediting (incineration) (MJ)
Steel	0,15	3	-6,0	0
Aluminium	0,10	-	-	0[1]

Plastics, PS	1,10	-	-	-33
Glass	0,17	1,2	-1,7	0
Cardboard	0,39	-	-	-5,8
Filters	7,30	-	-	-110
Coffee grounds	290	-	-	-(3000-4300)[2]

Table 9. Energy consumption and –crediting in the disposal stage (coffee maker). Note 1) Aluminium is assumed not to be incinerated 2) the interval states the uncertainty regarding retained water

Total transportation

We did not have to look at the energy consumption at the incineration plants, as this is small and insignificant for our scenario. Transportation energy consumption can been taken from the estimates shown in Table 4 d and *Appendix 2*. See also Table 10.

Means of transport	Volume	Energy consumption
Ship (bulk carrier)	$40 \cdot 10^5$ kgkm	170 MJ
Lorry > 16 tons	$1{,}2 \cdot 10^5$ kgkm	120 MJ
Van < 3,5 tons	$0{,}03 \cdot 10^5$ kgkm	15 MJ
Car	5 km	15 MJ

Table 10. Energy consumption for transport in the life cycle of the coffee maker

Energy consumption shown in the table derives from the life cycle of the coffee beans. We presume that all the coffee beans are from Brazil and are transported 10.000 to15.000 km in bulk carriers. We also presume that the coffee is transported 400 km in lorries. These estimates are probably a little too high.

Energy profile

You can now make an energy profile for your product. The energy profile, must as a minimum, illustrate each life cycle stage. It may also be a good idea to subcategorise the stages to see where the different contributions occur. See the example for the coffee maker in Figure 2.

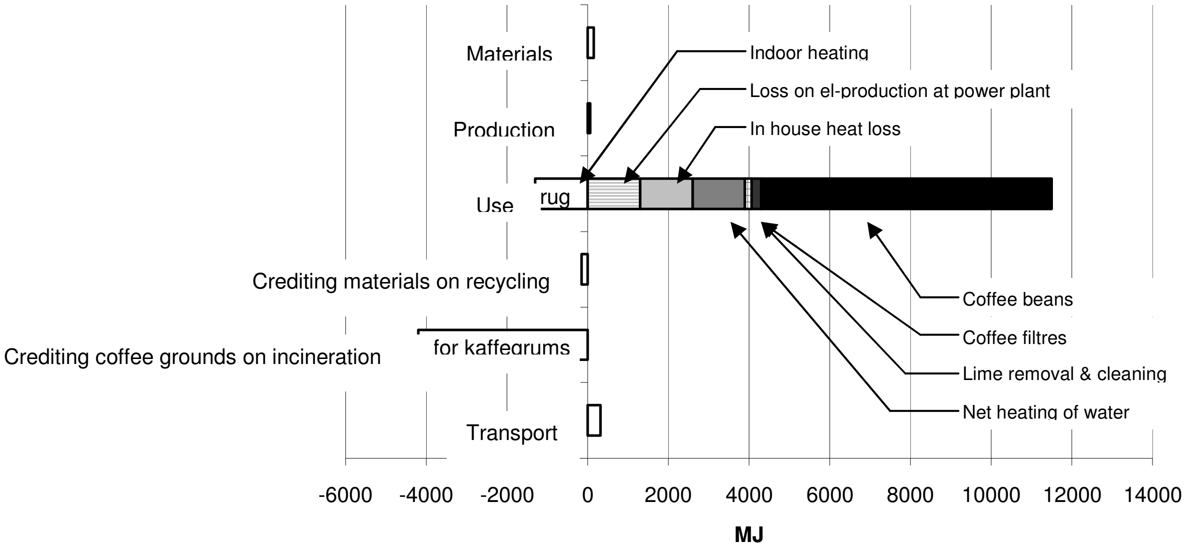

Figure 2. Energy profile of the coffee maker

Indirect energy consumption

Up till now we have only dealt with the energy consumption that product itself causes. We call this direct energy. In many cases, the product will also cause indirect energy consumption because it interacts with other systems. Remember the example with the wrapping of food in the refrigerator? What if the coffee maker was designed for use in a train’s buffet or trolley service? Then weight would cause energy consumption. More about this is explained in the following example

Example - car air-condition

It is well known that a car air-condition systems uses a lot of energy because it is operated by a petrol driven generator. What is not realised is that the car uses more energy because of the increased weight due to the air-condition system. A system, which weighs 20 kg, will cause an increased consumption of petrol around 150 litres in the lifetime of the car. So it actually costs twice as much to carry the system around in the car as it costs to manufacture the system. Therefore, it is recommendable to use lightweight materials, even if this leads to a higher consumption of energy during manufacturing.

5.3 Chemicals

	Mat	Manu	Use	Disp
Materials				
Energy				
Chemicals				
Other				

The chemical inventory and assessment is the most difficult part of the preliminary environmental assessment performed by the MECO analysis. You cannot count on getting all the data you need. Quite often the company does not have the data, and it can be difficult to get the information from the subcontractors. Therefore, the advice is to proceed as far as you can here, and leave the rest to the company.

In the parts list you have some information about the chemical consumption in manufacturing. It is also likely that you have data on chemicals entering into the operation/function of the product. Information on the latter is typically available in user manuals. However, in most cases you get information on trade names like ”MultiClean PX” etc., which is not very informative for the purpose here. You and your company will have to try to identify which chemical substances are used in these products.

Get data from the company

But remember that you only have a limited time to do the Life Cycle Check – two days. There is no time to trace data on substances in various chemicals. It is therefore of the utmost importance that you inform the right persons in the company in advance that you are going to need this information. Ask them to find as much data as possible before your meeting. Ask them to provide the so-called CAS numbers on substances. The CAS number is an unambiguous identification of the substance and it makes the Life Cycle Check procedure so much easier when you know it for most of the substances. You can tell your contact person that there must be a supplier manual for chemical products. A supplier manual should contain the necessary information for identifying the content.

- also chemical used by subcontractors

You may also try to find out which chemicals are used by suppliers and subcontractors. You can ask if the company makes demands with regard to use or content of certain substances or you can have the company ask the supplier to make a list of substances used for manufacture. Remember to ask for CAS-numbers.

It may be difficult to find CAS-numbers, but if you know the names of the chemicals the Internet can be of great help. Try and look on **http://chemfinder.camsoft.com/ or http://sis.nlm.nih.gov/sisl/**

The result of your efforts together with the company is a table where all the substance names and CAS-numbers are listed, as shown in Table 10.

Substance			Assessment		
Name	CAS-No.	Use	Danish List of Undesirable Substances	Danish Effect list	EU List of Hazardous Substances

Table 10. Table for information on chemicals

In the left-hand columns of the Table you write names and if possible CAS numbers of the substances you know are used in the product's life cycle (information from the company, subcontractors and from the *use stage*). You must also write what the substances are used for.

The right-hand columns are used for the assessment, which is very simple. The assessment consists in checking whether the substance is included on one of the official lists of hazardous substances published by the Danish EPA or the EU. The two Danish lists can be downloaded from the Internet at:

Undesirable substances: http://www.mst.dk/doclibrary/pdf/87-7944-117-3.pdf

Effect list: http://www.mst.dk/doclibrary/pdf/87-7944-100-9.pdf

Both of these lists are in Danish but the CAS numbers are international.

Danish Effect list and List of Undesirable Substances

The Effect List [10] comprises around 1400 substances which are in use in Denmark and have been identified as having a potential to cause harm to human health or the environment. The substances are ordered according to CAS number or alphabetically in the list. From the Effect list, substances which are used in large quantities or are considered problematic for other reasons are selected and supplemented by other substances which are considered unwanted by the Danish environmental authorities. The resulting List of Undesirable Substances [11] comprises around 100 substances of which the use should be reduced or discontinued in a foreseeable future. The list is structured alphabetically and it contains a brief statement of why the particular substance is included on the list and how it must be labelled and classified.

EU List of hazardous substances

In the Danish EPA's classification directive [9], the criteria for classification are described and there is an extensive list of examples of substances, which are classified. The List of Dangerous Substances is alphabetic in its structure, but it can be difficult to work your way round, so it is recommendable to have the CAS number to ensure that you are looking at the right substance.

The first assessment

As the first assessment of the chemicals, you simply check whether the substances you are investigating are found on these lists. If the investigated substances are found on the lists, you make a note of which characteristics are described, e.g. how the substance should be classified and labelled. Chapter 6 explains how you interpret the assessment you have made.

Example
- textiles

For textiles it is important to get in touch with the manufacturer. Quite a considerable amount of chemicals is used in textile manufacturing processes, i.e. weaving, bleaching, after treatment etc. Some of these chemicals can be hazardous to the environment and to human health. One example is the so-called alkyl-phenol-ethoxylates (APEOs), which are found on the List of Undesirable Substances, but none the less still used world wide in textile manufacturing. In the area of textile manufacturing it has proven possible to substitute less dangerous chemicals for hazardous chemicals

Example
- electronics

Other examples are printed circuit boards, cabinets containing electronics, and household appliances which may contain substances, which later in the lifecycle will be emitted to the environment. Investigations have shown that e.g. brominated flame retardants in computers are emitted to the working environment in offices. The same substances may contribute to formation of dioxins in incineration plants. There are alternatives to many of the hazardous substances, but often you have to ask for alternatives because many suppliers have not yet recognised that their products have hidden environmental hazards due to the content of chemicals.

Taking a closer look at the coffee maker, it appears that the manufacturer uses chloroparaffins as lubricants when casting the aluminium. Chloroparaffins are relatively hazardous chemicals with a potential to cause reproductive damage and carcinogenesis. They are found in the list of Undesirable Substances. Furthermore, it appears that the obligatory property of "flame retarding" is obtained using brominated flame retardants in the plastic.

5.4 Others

Under "Others" you make a note of other resource and environmental problems, i.e. problems with the working environment, which have not yet been covered. This can be noise, dust (causing lung problems) hygiene problems (microbiological), irradiation (as have mentioned as a possible problem with mobile phones), land use or physical impacts on humans and the environment.

Water in very large quantities is required for growing cotton, often as irrigation. This may cause water shortage in cotton growing areas, which can have serious consequences. The best known example of this is the areas surrounding the Aral Lake. Because of the lack of fresh water supply to the lake it has turned to salt and large areas have dried out. Vast areas are affected because the salt is spread by the wind to agricultural areas surrounding the lake.

"Other" in the coffee maker life cycle perhaps requires a bit of imagination. Perhaps scalding of the user can be one problem to be noted here

5.5 The MECO-matrix

	Material stage	Production stage	Use stage	Disposal stage
Materails	Oil[1] : 1,1 kg ≈ 0,04 mPR Cu: 0,02 kg ≈ 0,33 mPR Mn: 0,03 kg ≈ 0,20 mPR			Mn: - 0,015 kg ≈ -0,10 mPR Slag: 0,45 kg
Energy	Plastics: 100 MJ Other: 50 MJ **In total: 150 MJ** ≈ ca. 3,5 kg oil-eq.[2] ≈ ca. 0,1 mPR[1] oil	**In total: 45 MJ** ≈ ca. 1,5 kg oil-Ep. ≈ ca. 0,06 mPR oil	Operation, El: 3900 MJ (- hot water: 1300) (- loss El-prod: 1300) (- loss coffee m.: 1300) Crediting: -1520 MJ Coffee beans: 7200 MJ Filtres: 240 MJ Lime removal: 100 MJ Cleaning: 66 MJ **In total: ca. 10000 MJ** ≈ ca. 240 kg oil-Ep. ≈ ca. 9 mPR oil	Coffee grounds: -(3000-4300) MJ Filtres: -110 MJ Other: > -50 MJ **In total:-(3200-4500) MJ** ≈ ca. -(75-110) kg oil-Ep ≈ ca. -(3-4) mPR oil
Chemicals	The List of Undesirable Substances: Brominated flame retardants	The List of Undesirable Substances: Chloroparaffins	The List of Undesirable Substances: Brominated flame retardants, maybe some pesticides	Potential dioxin formation from brominated flame retardants
Other				

Table 11. Life Cycle Check of the coffee maker according to the MECO principle. Notes: 1) the plastic is calculated as 100 % crude oil, 2) the energy consumption is calculated in equivalent quantities of crude oil and resource consumption is calculated as crude oil for all energy consumption shown in the table

Make a MECO matrix for the product as shown here. You might also make an energy profile as shown in Figure 2.

Now you can compare the final MECO to the quantitative assessment you made initially. How is your environmental intuition?

6. Interpretation and further work

How far did the Life Cycle Check get us? Well, we have not made the final environmental assessment, because an environmental assessment is always a comparison as mentioned earlier. However, we have established an overview and a platform for ideas and the further work.

Did you notice how you hardly could avoid getting ideas for improvements during the process of establishing the overview of the life cycle and the overview of the different sources of environmental impacts. Where can the company influence the impacts of the products? How can the service defined in the beginning be delivered more environmentally soundly? It is not only the large numbers, which are interesting to the interpretation. Rather, it is the parameters, which the company can influence within the product and its life cycle. Very often the influence is greater than first assumed.

	Mat	Manu	Use	Disp
Materials				
Energy				
Chemicals				
Others				

Some examples for changes in the coffee maker are shown in the following. These examples illustrate how the Life Cycle Check can be a source of inspiration. Some of the examples are realistic, some are more speculative

- How effectively are the coffee beans actually used? Is the quantity of coffee beans used really necessary? Is it possible to optimise the interface between the hot water and the coffee beans when considered in relation to the conventional use of the filters?

- Is it possible to brew the coffee using the same concept as a manual pump coffee jug with an easy discharge of the grounds to dustbin (household waste and subsequent incineration and recovery of energy)?

  We know from the Life Cycle Check, that the most significant energy consumption is from the coffee beans. But do we know the potential for saving energy. Is it possible to save 20 % of the beans or only 2 %?

  How much coffee from each brew is not consumed but left in the coffee-pot and discharged to the kitchen sink? Is it 1/3? Can we manufacture a coffee maker designed to very rapidly brew only one or two cups of coffee. It is acceptable that the energy consumption for brewing increases if we can save a large amount of coffee beans – which is something we learnt from the Life Cycle Check. Perhaps our definition of our functional unit was too narrow? – perhaps the definition should not be 2 litres of coffee per day, but the experience of drinking coffee? And can this experience be given in an environmentally more elegant way and with less waste? Five millilitres of Turkish coffee, a nice aroma and a posh pointing little finger accompanied by a glass of water might give the coffee drinking consumer the same satisfaction as the traditional North European solution with 2 litres of coffee out of a coffee mug?

- Is there a way of separating the water from the coffee grounds, by spin-drying or pressuring? We now know that the calorific value of the coffee grounds is important for energy recovery. If the coffee grounds are too moist, energy will be used to evaporate the water.

- Can loss of energy associated with the production of electricity be avoided by using another source of energy? What about using natural gas or coffee grounds? We know from the Life Cycle Check that the coffee grounds contain enough energy to drive the brewing process. A combustion chamber, ignition by electricity, controlled combustion air and ventilation through the hole in the wall which already exists because of the cooking hood. This installation could be fully automatically, the only task the coffee consumer has is to dose the coffee beans. The installation will automatically separate the coffee grounds and use these as the energy source for the next brew. Ashes from the process provide a secondary service as fertiliser for the household plants.

- Can we save the heat for keeping the coffee hot by brewing directly into a thermos? Is there any other way of saving the heat loss from the hot plate? Can we combine the brewing into the thermos with saving in coffee beans the avoid of the use of filters?

- Can copper in electric wires be substituted by another material?

- Can brominated flame retardants be avoided? And chloroparaffins?

And so on and so on – try yourself to come up with more ideas. Note how the Life Cycle Check gives a good platform for you to relate to the potentials in the more or less realistic ideas. – For most of the ideas, it is now possible to make a reasonable assessment of the environmental improvements. Observe how the actual environmental assessment only is relevant after alternative solutions are drafted and these solutions must be compared to existing products. The comparison is part of the further work.

Significant uncertainties

Your starting point for the Life Cycle Check was the product's parts list, which means that you have information about the product's individual parts and qualitative information about consumption of additives. You have no information about waste of materials during the manufacturing process and you have no data on emissions. Due to the lack of this particular information a significant uncertainty must be assumed. Your data concerning energy consumption are relatively certain since you collected the relevant data for the use stage. Energy data concerning the material and disposal stage are also relatively certain, and manufacturing and transport stages are insignificant in the overall picture.

Typically, the largest uncertainty derives from the lack of knowledge about chemicals and their content of substances. You can assist the company with an interpretation according to the Guide given in the following, but typically the company will have to proceed further.

Take care when interpreting

Generally you must bear in mind, that you interpret, conclude and give recommendations based on only two days of work with the Life Cycle Check. Remember that the Life Cycle Check is an ”eye-opener”, a source for inspiration, a setting of proportions and perspectives. In the beginning we made some hearty suggestions for changes of the coffee maker. It is obvious that these suggestions are quite detached from any technically and economically considerations. It is also obvious that we focused on environmental arguments and possibilities, not conclusions. Take care not to make too strong conclusions on whether the changes in the product are improvements or not. Make your statements as suggestions and perspectives, not concrete conclusions.

Discuss the reporting

The first and second time you write a report on a Life Cycle Check, you should get help from somebody with more experience in environmental assessment. Maybe you can get somebody to review your report before it is handed over to the company. You should also write the report in close co-operation with your company contact person. Perhaps present a draft version before you submit the final report.

Interpretation

Assessing resource consumption is not the most difficult stage. The resource consumption is expressed in mPR, which is the most transparent method with respect to scarcity. However, scarcity is the only criterion contained in the figures given in mPR. The assessment does not contain any criteria for the value of the resource or if the consumption is irreversible (metals do not disappear when consumed, they are merely spread and diluted in the environment whereas consumption of fossil fuels means that they are gone for ever). The data we have on known reserves are uncertain because the inventories on known reserves are a function of economy for extractions and the knowledge of known occurrence. The magnitude of known reserves changes year by year and they tend to increase. But data on the resources regarded as having the shortest supply horizon, in relation to known reserves, is considered valid. Within reason, our assessment method can therefore be used to set priorities in relation to scarcity.

You cannot compare different types of waste in the MECO matrix we used here. A comparison would require normalisation and weighting as in the traditional life cycle assessment. But common sense is a useful tool when assessing the different types of waste.

Interpretation of energy consumption

All energy consumption is calculated as primary energy and can be compared. It might be of importance to note how the energy is produced. Mostly it is sufficient to look at MJ primary energy because the different sources of energy will, in the long run, substitute for each other. Even seen in a short-term perspective there is substitution. It does not matter if the product draws electricity from Norwegian hydroelectric power plants or Danish plants based on fossil fuel. Norwegian and Danish electricity substitutes for each other. The cheaper Norwegian electricity will of course be used in full, if not in Norway, then in Denmark.

Interpretation of the assessment of chemicals

If substances are found on the List of Undesirable Substances, it is a signal suggesting that alternatives should be found. Authorities will focus on some of the substances on the list, and these substances can be expected to be forbidden or phased out.

The situation is slightly different for substances appearing in the Effect List. You know that these substances have one or more unwanted properties and indeed, they may be as problematic as the substances in the List of Undesirable Substances. The only difference may be that the quantity marketed annually in Denmark is smaller. You should therefore avoid substituting a substance from the List of Undesirable Substances by a substance appearing in the Effect List. In general, it will be preferable to substitute by substances without known environmental or health effects, i.e. substances not appearing in any of these lists.

Even though a substance does not appear in the final list, the List of Hazardous Substances, it may still have unwanted properties. The List of Hazardous Substances is not exhaustive. Even if a substance in not found on the List of Dangerous Substances, it can still have undesirable properties. Therefore, the list also contains the criteria for labelling and classification of substances. If there is uncertainty about a specific substance, the company can have a consultant make an assessment of the environmental and health properties to determine the substance should be labelled and classified. In this way a reasonable basis is laid out for a comparison of alternatives.

However, a comparison can not be based exclusively on the mentioned lists. You should therefore support the company in getting in touch with a specialist who can assist with both a technical and an environmental assessment.

In the following paragraph you and the company will get suggestions on methods for the comparison of alternatives.

6.1 The further work

The Life Cycle Check has enabled us to establish priorities between resource consumption and energy consumption. However, the Life Cycle Check has not enabled us to make priorities between chemicals reciprocally. We are not able to make priorities between environmental impacts from chemicals and impacts from energy consumption. You may, however, recommend avoiding brominated flame retardants or to reduce heat loss. You can recommend that hazardous substances should be avoided unless doing so increases energy consumption and vice versa. In many cases these recommendations are sufficient.

A quatitative Life Cycle Assessment

If the company wants a complete environmental assessment and a better foundation for making priorities, it is necessary to undertake a quantitative environmental assessment. In this case it is recommended to use a software tool with a built in unit process database (EDIP PC-tool [12]), which will considerably reduce the time required for this task. Sometimes not all data on chemicals are available in the software tools and databases and it may be necessary to collect and input additional data in the database.

The need for company to proceed in further investigations is often caused by the lack of assessment of chemical consumption. The next step for the company could be to perform a chemical screening before moving on to the use of software tools and a full quantitative LCA.

Environmental screening of chemical substances

The procedure described for assessment of chemicals can only be used as a preliminary classification of the substances entering the lifecycle. If the company wants to proceed, further steps must be taken.

Substances not found on the List of Undesirable Substances or the Effect List may still have undesirable impacts on environment and health. The third list mentioned in this Guide, the List of Hazardous Substances, provides examples on the labelling and classification of substances and products. If a substance is found in this list (or fulfils the criteria to be labelled or classified), the company or hired external consultants can make a crosscheck in a system for chemical assessment. In the EDIP publication [8] simple screening methods are given.

Write a one-page interpretation of the Life Cycle Check.

Report the interpretation

The interpretation should contain the following elements:

- Where in the product life cycle do the most significant resource consumption and environmental impacts seem to be?

- Where are the most significant data shortcomings and uncertainties?

- Which possible changes could be environmentally attractive?

- What should be done before conclusions are drawn and before actions based on the environmental assessment are taken?

Use of the environmental assessment in marketing

If the company wants to proceed with the environmental assessment and, for instance, make comparisons to competing products, there are specific requirements in the ISO standards which must be met, e.g. the environmental assessment must be subjected to a critical review by a panel of independents experts.

You must inform the company hereof.

References

[1] Miljøstyrelsen (1996): En styrket produktorienteret miljøindsats. Oplæg fra Miljøstyrelsen. Miljø- og Energiministeriet, Miljøstyrelsen, København, november 1996.

[2] Miljøstyrelsen (1998): Miljøstyrelsens redegørelse om den produktorienterede miljøindsats. Miljø- og Energiministeriet, Miljøstyrelsen, februar 1998.

[3] TIC (1999): Afklaring af behovet for en produktorienteret miljøindsats hos virksomheden. TIC, 1999.

[4] Broberg, O. & Christensen, P.: LCA Experiences in Danish Industry. Int. J. of LCA 4, 257-262, 1999

[5] DS/EN ISO 14040: 1997. Miljøledelse. Livscyklusvurdering. Principper og struktur. Dansk Standard, Kollegievej 6, 2920 Charlottenlund, tlf. 39 96 61 01

[6] Heijungs R (final editor, 1992): Environmental life cycle assessment of products. Volume 1: Guide, volume 2: Backgrounds. CML, Leiden, Holland, 1992.

[7] Schmidt A, K Christiansen og K Pommer (red., 1994): Det Materialeteknologiske Udviklingsprogram. Rammeprogrammet for integrerede miljø- og arbejdsmiljøvurderinger. Livscyklusmodel til vurdering af nye materialer. Metoder, vurderingsgrundlag og fremgangsmåde. dk-TEKNIK, København, 1994.

[8] Wenzel H, M Hauschild og E Rasmussen (1996): Miljøvurdering af produkter, UMIP - Udvikling af miljøvenlige industriprodukter, Miljø- og Energiministeriet - Miljøstyrelsen, Dansk Industri, marts 1996.

[9] Miljø- og Energiministeriet (1997): Bekendtgørelse af listen over farlige stoffer. Miljø- og Energiministeriets bekendtgørelse nr. 829 af 6. november 1997.

[10] Miljøstyrelsen (1997): Effektlisten 1997. Arbejdsrapport fra Miljøstyrelsen nr. 1, 1997.

[11] Miljøstyrelsen (1998): Listen over uønskede stoffer. Orientering fra Miljøstyrelsen Nr. 1, 1998.

[12] Pedersen M A, H Wenzel, N Frees, J Siegumfeldt, P Berggren og P R Hansen (1998): UMIP PC-værktøj, version 2.10 Beta. Miljøstyrelsen, 1998.

[13] Frees N og M A Pedersen (1996): Enhedsprocesdatabase. UMIP. Miljøstyrelsen, 1996.

[14] Christiansen K, A Grove, L E Hansen, L Hoffman, A A Jensen, K Pommer og A Schmidt (1990): Miljøvurdering af PVC og udvalgte alternative materialer. Miljøprojekt nr. 131, Miljøministeriet, Miljøstyrelsen, 1990.

[15] Goedkoop, M. and Spriensma, R.: The Eco-indicator 99 – a damage oriented method for life cycle impact assessment. Pré consultants, Amersfoort, the Netherlands, 1999.

Appendix 1

Known supply horizons and global reserves per person [8]

Resource	Supply horizon year	Known global reserves per person kg/person
Oil	43	25.600
Anthracite coal	170	98.570
Brown coal	390	98.130
Natural gas (m^3/pers.)	60	23.440
Aluminium	200	660
Iron	120	12.200
Lead	20	13
Copper	36	60
Manganese	86	150
Nickel	50	9
Tin	27	1,1
Zinc	20	30
Silver	-	0,15
Gold	-	0,011
Palladium	-	0,008
Tantalum	-	0,047
Antimony	-	1
Cobalt	-	1
Molybdenum	-	4
Cadmium	-	0,23
Lanthanum	-	3,2
Cerium	-	5,9
Beryllium	-	0,038
Mercury	-	0,11
Platinum	-	0,008

Appendix 2

Energy properties for different materials

Material	Σ Primary energy (MJ/kg)	Calorific value (MJ/kg)	Crediting for reuse[1] (MJ/kg)	Crediting for incineration[2] (MJ/kg)
Steel	40	0	-40	0
Steel remelting	20			
Magnesium	150	0	-150	0
Aluminium	170	0/27[3]	-170	-0/22[3]
Alum. remelting	30			
Copper	90	0	-90	0
Copper remelting	50			
Stainless steel	40	0	-40	0
Stainl. steel remelting	40			
Zinc	70	0	-70	0
Plastic, Polypropylene (PP)	80	40	-80	-30
Plastic, Styrene acrylo nitril (SAN)	90	40	-90	-30
Plastic, Polyethylene terephtalate (PET or PETP)	80	30	-80	-25
Plastic , Polyurethane – soft or hard (PUR)	110	30	-110	-25
Plastic, Acrylo butadiene styrene (ABS)	95	40	-95	-30
Plastic, Polyamide (PA), Nylon	140	30	-140	-25
Plastic, Polycarbonate, (PC)	115	30	-115	-25
Plastic, Polyethylene (PE)	75	40	-75	-30
Plastic, Polyvinylchloride (PVC)	65	20	-65	-15
Plastic, Polystyrene (PS)	90	40	-90	-30
Plastic, Polystyrene, Expandable (EPS)	80	40	-80	-30
Plastic, Polymethyl metacrylate (PMMA)	110	40	-110	-30
Cardboard/paper	40	20	-40	-15
Cardboard/paper recycling	10			
Glass	10	0	-10	0
Glass remelting	7			

Notes:
1) Crediting if the recycled material can replace new material. Remember to include the energy consumption of the recycling process
2) For incineration 80 % of the material calorific value is credited
3) The calorific value of aluminium is 27 MJ/kg for foils and 0 MJ/kg for other types of material

Energy consumption for certain forms of transportation [13]

Transport means	Unit	Energy consumption
Ship (bulk carrier)	MJ/kgkm	0,00004
Lorry > 16 tons	MJ/kgkm	0,001
Van < 3,5 tons	MJ/kgkm	0,005
Private car	MJ/km	3

Resource content for certain materials

Material	**Resource**
Steel machine steel cast iron stainless steel	 Manganese 1 % the rest iron Manganese 1 % the rest iron Chromium 18 %, nickel 9 %, the rest iron
Magnesium	Magnesium
Aluminium rolling alloy casting alloy	 Aluminium Silicon 12 %, the rest aluminium
Copper	Copper
Brass rolling alloy casting alloy	 Zinc 37 %, the rest copper Zinc 33 %, lead 2 %, the rest copper
Bronze	Tin 10 %, the rest copper
Zinc rolling alloy casting alloy	 Zinc Aluminium 4 %, copper 0,5 %, the rest zinc
Plastic, PE el. EPS	Natural gas 40 %, oil 60 %
Plastic, ABS, PA, PC, PS	Natural gas 50 %, oil 50 %
Plastic, PET, PP	Natural gas 20 %, oil 80 %
Plastic, PUR	Natural gas 40 %, oil 40 %, the rest other
Plastic, PVC	Natural gas 20 %, oil 40 %, the rest including NaCl

Appendix 3

Environmental impacts from natural fibres and synthetic fibres

Most of the textiles we wear or use in our every day life are produced from natural fibres (cotton, viscose, wool) or synthetic fibres (polyester, nylon, polypropylene). It is often assumed that the natural fibres have the least environmental impact, but seen in a life cycle perspective the picture is more complex.

Materials
The main sources of raw materials needed to produce synthetic fibres are oil and natural gas; these raw materials have a limited supply horizon, 35 to 56 years. The main sources of raw material for cotton and viscose are cotton plants and wood, which are renewable resources.

Energy consumption
If you look at the energy consumption for production of synthectic fibres it is in the area of 100 MJ/kg. Almost all this energy is based on fossil fuel (oil and natural gas). Approx. 25% of the energy is recovered if the fabrics are disposed of through incineration with utilisation of waste heat.

If you look at the energy consumption for production of cotton fibres the energy consumption is less, almost down to 50MJ/kg, but also here, the main fuels are of fossil origin. Viscose is produced from regenerated wood. It requires considerable more energy, up to 150 MJ/kg. A part of this energy derives from renewable resources, mainly waste wood, but almost up to 100 MJ/kg comes from fossil fuels. Approx. 12MJ/kg of the energy is utilised if the cotton and viscose is incinerated.

Some of the difference in energy consumption is equalised again when you calculate energy consumption in relation to the functional unit. Polyester and viscose fabrics are lighter than cotton fabrics, and the synthetic fabrics will often have a longer lifetime.

When washing of fabrics is included in the overall picture, it will often appear that the light fabrics are less energy consuming in the long run. Light fabrics absorbs less water during washing and you can therefor wash larger quantities in one washing and there is also less water to dry during tumble drying. During the entire life cycle, where a piece of fabric is washed 50-100 times or more, the collected energy consumption will usually be less for light fabrics. This is especially the case if the fabrics are washed in an industrial laundry, because an industrial laundry can control fabric quantities and dosage of detergents and other chemicals very precisely.

Chemical consumption
Synthetic fibres are made of chemicals, which are refined through a number of processes. Many of the intermediate products occurring during refinement can cause serious environmental and human health impacts. However, in general emissions to the environment are minor because the production systems are closed.

Cropping cotton usually demands quite a few chemicals during The growth period. To crop well it is necessary to use fertilisers, insecticides, defoliants etc. in most cotton growing areas. The consumption of chemicals is so large that it often causes a visible impact on the environment and human health.

Wet treatment of fabrics also demands a large chemical consumption, especially during the dyeing processes. For all types of fabrics there is a vast environmental difference between best available technology and worst case technology.

Other
Water consumption is large in the life cycle of most fabrics. In cotton cropping irrigation is demanded in many areas. In some areas the amount of water used for irrigation is so huge that it compromises living conditions for the local population. Also the natural environment has in certain regions been degraded due to irrigation.

The water consumption for laundering textiles is also large, but the difference in water consumption between the various fabrics is not significant. Both in industrial and domestic laundering it is possible to reduce water consumption by introducing water saving technologies and optimising of washing machines' capacity.

Interpretation
Seen in a life cycle perspective conventionally farmed cotton fabrics will often cause heavier environmental impacts than synthetic fabrics. Fabrics made from ecologically farmed cotton will as a whole have the same environmental impacts as synthetic fabrics.

The aspects of quality is not included in the assessment, but looking at the comfort of fabrics (with regard to hospital uniforms) cotton fabrics seems to have the advantage. If cotton is chosen as the fabric for a certain garment, it is recommendable to choose ecological cotton or a cotton fabric with an environmental label. If none of these two choices are possible, it is recommended to buy a good quality of fabrics, which in an environmental context means fabrics which both in material and design ensure a long life time of the product.

Appendix 4: The 10 steps of LCC

Table for preparing and executing the Life Cycle Check

What to do	How to do it	Where to get information
Step 1: Clarify the need and motivation	Use appendix 5 (TIC's værktøj til behovsafklaring)or do a more informal need analysis together with the company	This guideline or appendix 5
Step 2: Choose a product	Get in touch (phone, e-mail or fax) your company contact person	This guideline
Step 3: Schedule a meeting	Get in touch with your company contact person. State the need for data and clarify/identify who needs to attend the meeting.	This guideline and appendix 4
Step 4: Get prepared for the meeting	Make your own assessment of the product before the meeting • Product's service (Table 1-2) • Life Cycle (Table 3) • Environmental impacts (Table 5) Fill in these tables preliminary to serve as checklists during the meeting	This guideline and your company contact person
Step 5: Have the meeting with the company	Meet for approx. 3 hours with your company contact person and other relevant persons from the company	Look below to see who has the various types of information
Step 6: Define the *product's service* and the *functional unit*	During the meeting. Fill in the two tables (table 1 and table 2)	Sales & marketing And possibly product developers, the environmental responsible, dealers and customers
Step 7: Make an overview of the product's life cycle	During the meeting. Discuss the preliminary table 3. Get the parts list from the company. Get information about the product's lifetime. Get information about where the product is marketed and sold . Get data on the use stage and maintenance and if possible information about disposal. Get information enough to fill in the overview in table 4 or figure 1.	Partslist: production Lifetime: marketing & sales plus retailers Use and maintenance: marketing & sales, product development, retailers and customers Disposal: ask your contact person if the company has any information about this. Perhaps the municipality has information , or recycling plants or scrap dealers or incineration plants or the national EPA

Step 8: Make a qualitative MECO assessment.	During the meeting: Wind up the meeting by discussing and filling in the MECO matrix (table 5) qualitatively. Guide the company through the relevant considerations concerning the life cycle assessment.	
Step 9: Make a semiquantitative MECO assessment	At your home base: Fil in a tagble as shown in *Table 11.* During the work process, fill in a table as shown in *Table 10* as you get data from the company. Make an energy profile as shown in *Figure 2.*	This guideline and appendix 1 and 2. See also page 36 of this guideline for websites
Step 10: Give the company guidelines for further interpretation and further actions	At you home base: Write an explanatory and discussing text to figures and tables. Give instructions on how to interpret the results of overview now established. Include the MECO matrix. Provide the company with suggestions and ideas for further actions. Make a first draft for the reporting, and let the company and a colleague comment on the draft.	This guideline