DANISH MINISTRY
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Environmental
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The working environment in LCA
A new approach

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Introduction to the series

Life cycle thinking and life cycle assessment are key elements in an integrated product policy. There is a need for thorough and scientific well-founded methods for life cycle assessment. Parallel to this, there is a need for simple, easy-understandable methods, which reflect life cycle thinking. Which method to use must depend on the goal and scope in each case, inclusive target group, publication strategy etc.

It is common for all life cycle assessments that they have to give a solid and reliable result. A result, that is a good foundation for the decisions subsequently to be made.

During the last 10 years a number of projects concerning life cycle assessment and life cycle thinking has received financial support.

The main results of projects on life cycle assessments will from 2000 and in the next couple of years be published as a mini-series under the Danish EPA's series Environmental News (Miljønyt).

As the projects are being finalised they will supplement the results of the EDIP-project from 1996. The tools, experience, advice, help and guidance altogether form a good platform for most applications of life cycle assessments.

Life cycle assessments is a field so comprehensive, that it is not likely to be possible to write one book, that will cover all situations and applications of life cycle assessments. The Danish EPA hopes, that the LCA-publications together will present the knowledge available to companies, institutions, authorities and others, who wish to use the life cycle approach.

The Danish Environmental Protection Agency,
October 2000

Preface

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

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

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

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

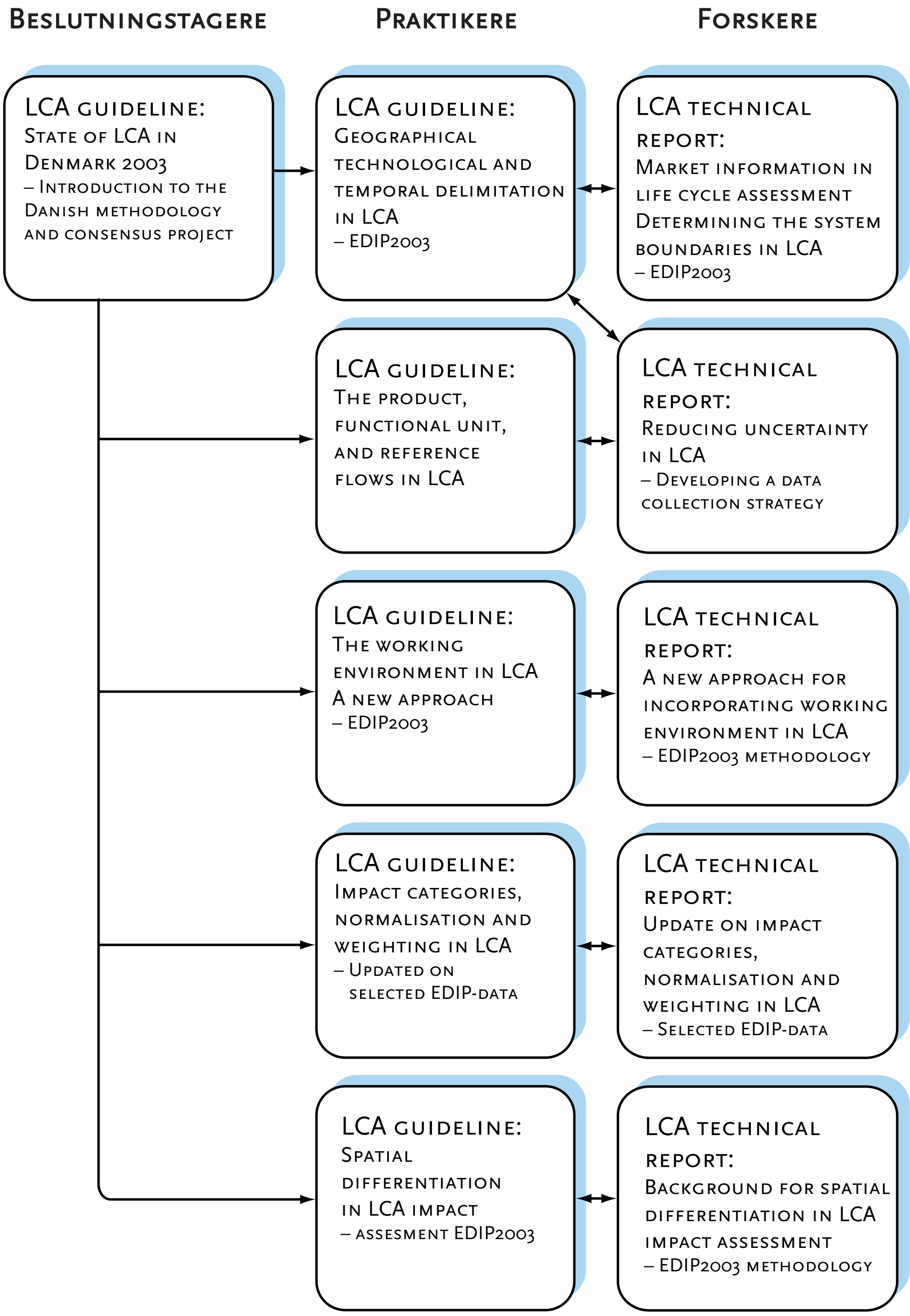
The guidelines are supported by a number of technical reports, which present the scientific discussions and documentation for recommendations offered by the guidelines. These reports are also planned to be published during 2004. The guidelines and the technical reports are presented in the overview figure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

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

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

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

Guidelines and technical reports prepared within the Danish LCA-methodology and consensusproject



Summary and conclusions

The present guidelines describe a new methodology for inclusion of the working environment in life cycle assessments. The guidelines also include a database with many of the data that are necessary in order to perform an assessment.

The new methodology is suggested as an operational alternative to the original EDIP-methodology (EDIP97) that never has become a natural part of the overall method, probably because of the requirements in data collection and handling.

The new methodology is based on two types of Danish statistical information regarding economic sectors, i.e. information on the amounts being produced (in weight units) in a number of sectors, and information on the number of reported work-related diseases and damages in the same sectors. By combing the statistics it is possible to establish a figure for working environmental impacts per produced unit that can be used together with information on the impacts in the external environment.

The following impact categories are included in the assessment of the working environment:

- Fatal accidents
- Total number of accidents
- CNS function disorder
- Hearing damages
- Cancer
- Muscolo-sceletal disorders
- Airway diseases (allergic)
- Airway diseases (non-allergic)
- Skin diseases
- Psycho-social diseases

The main advantage of the new methodology is that it is much easier to collect and process the necessary information for a working environmental LCA. Another advantage is that the uncertainty in combining information from very different sources is avoided. Finally, it is possible to establish the same type of information for other countries, thereby facilitating thedevelopment of an even more extensive database.

The main limitation when using a sector assessment is that the level of detail cannot be increased beyond the level allowed by the basic statistical information. Assessment of specific processes is outside the scope of the methodology, and only larger companies can be expected to possess a set of statistics that can replace the average information from the whole sector. The method can thus not be used to assess the effect on the overall results following changes in the choice of specific processes or materials in a single company.

The established database covers about 80 economic sectors that are divided into four groups, i.e. raw material production (e.g. energy resources, metals, paper, etc.), production of intermediates and components (e.g. wood products, plastics, ceramics, metal products, etc.), production of final products (e.g. furniture and different electro-mechanic products) and transportation. The database is at present not integrated in the EDIP PC-tool, but is available in form of a spreadsheet.

The guidelines also describe how comparable information can be derived from companies whose activities are not included in the database. This type of information is most often significantly less detailed, but can be used to indicate the relative importance of a given activity.

It is concluded that the new methodology and the associated database can be used to make life cycle assessments of the working environment. This is demonstrated in a case study of an office chair, in which the magnitude of the actual impacts is examined along with the relative importance of the single activities. It is also possible to get an overview of which activities that are most important for each of the impact categories included in the methodology.

1 Introduction

The primary purpose of the present guidelines is to make LCA-practitioners able to include the working environment (WE) in LCA along with other types of impacts. The secondary purpose is to give the decision-makers, i.e. the persons who at the end of the day shall use the results, an impression of the possibilities and limitations of the method.

The main reason for including the working environment in LCA is to give a possibility to examine whether environmental product improvements are implemented on the expense of a deteriorated working environment.

The method has therefore been developed in order to make it possible to perform a general assessment of the changes in working environmental impacts that are induced by changes in the choice of materials and processes. This knowledge can subsequently be combined with more specific knowledge about potential hazards in relevant sectors and form the basis for a dialogue between the actors in a product chain. WE-LCA can thus be seen as a natural component in the efforts for development of products with less impacts on the environment and human health.

It is, however, not possible to examine or protect against deterioration as a consequence of company-specific changes, e.g. an increased tempo or efficiency, by using the developed LCA-methodology. For this purpose, work place assessments for each employee is a better suited tool that cannot be replaced by WE-LCA.

Including the working environment in LCA is basically a question of being able to calculate the potential WE-impacts per functional unit by adding the impacts from a number of processes and other activities. The present guidelines show a way to do this and contain at the same time a database that covers a large number of processes.

Until now, the lack of a broad database has been an important barrier against inclusion of the working environment in LCA. It is therefore expected that the working environment will be included more often in LCA in the future. It is, however, mentioned here that the database developed in the current project has some inherent uncertainties. As an example, the database figures will present an underestimation of the actual impacts if the processes take place in less developed countries.

Toady's lack of a broad database can partly be explained by a missing international interest in including the working environment in LCA. The method development in international LCA has so far been marked by a high degree of exchange of experiences, leading to consensus on procedures for making inventories and impact assessment and – subsequently – data exchange.

Method development in WE-LCA has mainly been a Scandinavian issue, but the co-operation between the countries has been limited. The historical dimension is presented briefly at the end of the guidelines, and a more detailed description of other available methods for WE-LCA can be found in the technical report that forms the basis for the present guidelines.

1.1 Overview of the content

The essential elements in the method are presented in chapter 2 together with an assessment of the sensitivity, limitations and uncertainties of the method. The purpose of chapter 2 is to give both LCA-practitioners and decision-makers a broad knowledge of the method in order to create a common understanding of the principles.

Chapter 3 contains an overview and discussion of the method in relation to the steps specified in the ISO 14040-series: Inventory, Impacts assessment and Interpretation. The discussion focuses on the new method, but parallels to other methods for working environmental LCA are drawn. The chapter ends with an example on how the method can be applied on a specific case.

Chapter 4 contains a short description of the historical development of working environmental LCA. This description is included in order to give the background for the development process in the current project. The chapter ends with suggestions for the future developments in working environmental LCA.

In the Appendix to the guidelines the database that was developed in the project can be found. The database contains information on about 80 unit processes.

The frames for the present guidelines do not give the possibility for a detailed discussion of the elements in the method, including the advantages and limitations. The reader is referred to the technical report from the project, where these discussions are more detailed.

It is the hope of the project group that the working environment with the new method will find a natural position in LCA. It is our judgement that the method will be able to give essential information with a relatively modest consumption of time and resources. At the same time the method is open for improvement and extension of the database through international co-operation. Hopefully, this will help create international consensus about a method for working environmental LCA within a relatively short period of time, using the basic procedure described in the current project.

2 The new method

The new sector assessment method that is presented in the following chapters is seen as a good alternative to the combined sector- and process assessment method described in EDIP97[1]. The new method has as its main consequence that it is easier and operational to include the working environment in LCA. It also has the consequence that the level of detail is decreased in comparison with a full assessment made with the combined EDIP97 method. The level of detail is however sufficient to fulfil the basic requirements, i.e. to create an overview of the changes in the working environmental impacts following changes in the life cycle of a product or a product system.

As for the sector assessment in EDIP97, the new method is based on statistical information. The main difference between the two sector assessment methods is that the new method uses the goods statistics to calculate production amounts in the sectors, whereas the EDIP97 method uses the supply statistics, both from Statistics Denmark.

2.1 The data format

In the goods statistics, information on produced amounts (in pieces, tons, m^2, etc.) can be found along with information on the value of the products. The information has been collected in a way that allows them to be related to specific sectors, as is the case for information on work-related accidents and injuries. The two types of information can then be combined, producing key figures on e.g. "accidents per produced tons" for a number of sectors. The unit for the key figures is basically the same as that for other effect categories in LCA, where e.g. "tons CO^2-equivalents per produced tons product" is an expression of the contribution to global warming.

The use of the goods statistics gives the possibility of establishing a homogenous and transparent database for a large number of sectors in Denmark. It is also possible to update the database when new information is available from Statistics Denmark. Furthermore, it will be possible to establish similar information from other countries, as the goods statistics are prepared in the same way in most countries. The main difference from one country to another will then be caused by the differences in the statistical information on work-related accidents and injuries.

[1] "EDIP97" is in the present report a common denominator for the methodology descriptions that can be found in Hauschild (ed.): Bag-grund for Miljøvurdering af produkter, Miljøstyrelsen/Dansk Industri 1996, (English version: Hauschild and Wenzel: Environmental As-sessment of products. Volume 2: Scientific background. Chapman & Hall, 1997), Wenzel, Hauschild and Rasmussen: Miljøvurdering af produkter, Miljøstyrelsen/Dansk Industri 1996, and in Broberg og Rasmussen: Arbejdsmiljø fra vugge til grav, Arbejdsmiljøfondet 1996.

2.2 A short description of the method

The main content of the new method is that it is able to calculate the number of reported accidents and injuries per produced weight unit on the sector level. The procedure for the calculations can be described in five steps that are exemplified in section 2.6.2.

The first step is selecting sectors and sub-sectors with a significant number of work-related accidents and diseases. By choosing sectors with a significant impact on the working environment the statistical uncertainty regarding the number of impacts is reduced.

An important criterion is that the sector can be characterised by one or more unit processes that are of interest in relation to LCA. The sector "Production of plastics packaging" (NACE-code 252200) will thus comprise processing of almost all types of plastics using extrusion, injection moulding etc., but it is not possible to achieve a higher level of detail. Another example is the sector "Production and first processing of lead, zinc and tin" (NACE-code 274300) which - as the title indicates - comprise both production and processing of all three materials.

The second step is to identify in the goods statistics the products that are being produced in the selected sectors. The products are identified by an 8-digit code that is unequivocally related to an economic sector. As an example, products made in the sector "Production and first processing of lead, zinc and tin" (NACE-code 274300) all start with the numbers 78 (lead), 79 (zinc) and 80 (tin), respectively.

It is strongly suggested that a professional statistician from a governmental statistical agency perform this step - and the subsequent calculations - with access to the basic statistics given by the companies.

The third step is to produce an aggregate of the produced amount (in tons) for all goods in the chosen sectors. In some cases, when information on the weight of the products is not available, additional information from the foreign trade statistics can be used to calculate the weight of the production. Information from the companies to be used in the foreign trade statistics must contain information on the weight and the value of exported products. The average value per weight unit of the export was therefore used to calculate the (missing) weight of the total production in the goods statistics of a given product by the following equation:

$$\text{Total production of product (in kg)} = \frac{\text{Value (in kr)}}{\text{Average value per weight unit (kr/kg)}}$$

With the additional information from the foreign trade statistics the weight of the produced amount in a sector can be calculated by simple addition.
The resulting figure (in tons) is the best estimate of the total amount of

products being produced in a given economic sector.

The fourth step is not a calculation, but simply accounting for the work-related injuries and damages for the activities in the same sector as the produced volume was calculated for. As described earlier, the Danish Labour Inspectorate kindly provided this information which can be found at a lower level of detail at their homepage, www.at.dk.

The fifth and final step is to calculate the working environmental impacts per functional unit by dividing the information from step 4 with he information from step 3. The result of this calculation is a figure for the number of work-related accidents and injuries per produced tons. This figure can be used along with figures for other impact categories in the LCA-calculations.

2.3 The impact categories

2.3.1 The statistical background

In Denmark, all notified occupational accidents and occupational diseases are recorded by the Registry of Occupational Injuries, which is a part of the Danish National Labour Inspection Service. The information is treated statistically and is published annually on a 2- or 3-digit DB93/NACE-code level. The Danish National Labour Inspection Service is however able to specify the statistics in more detail upon request, and this detailed information was used in the above procedure.

2.3.2 The content of the statistics

Even though the accidents and diseases are sorted and registered into respectively 15 and 18 different categories only the result of 10 categories are published. The published ones are:

Accidents:

- Fatal accidents
- Other damages from accidents. This effect category is in the statistics subdivided into nine types of damages, e.g. amputations, concussions, wounds and poisonings. The nine types of damages have been aggregated into one category, the main purpose of which is to create an overview of the potential for unwanted and acute incidents.

Diseases:

- CNS function disorder
- Hearing damages
- Cancer
- Muscolo-sceletal disorders
- Airway diseases (allergic)
- Airway diseases (non-allergic)
- Skin diseases
- Psycho-social diseases

In order to minimise the statistical uncertainties, an average for the years 1995-1997 is used for both the produced amounts and the accidents/ damages in a sector.

2.4 Advantages and disadvantages of the method

2.4.1 The advantages

The main advantage of the method is that it is able to create an overview of the working environmental impacts of a product in a short time. Inventory data have been established for a large number of unit processes and can be used for calculations in a spreadsheet or a dedicated LCA PC-programme. In comparison with EDIP97 it is not necessary to supplement the data with company specific information, a procedure that is very resource demanding.

By exclusively using a sector assessment it is secured that the database for the assessment is as homogenous as the basic statistical material allows for. At the same time, the potential problems in combining information derived in two different ways in a sector and a process assessment are avoided.

2.4.2 The disadvantages

The main disadvantage of the method is that the level of detail cannot be increased beyond the level allowed by the basic statistical information. This may in practice limit the possibilities for interpretation of the results. This is discussed in the following sections.

2.5 The limitations of the method

The new method has been developed so it can handle all types of unit processes at the same level of detail. There are no formal limitations of the method as seen in relation to the ISO 14040-series, but there are some practical limitations that the LCA-practitioner should be aware of.

2.5.1 Danish statistics

The method is based on Danish statistics on production of goods as well as work-related accidents and injuries. The collection of statistical background material has with a few exceptions been limited to Denmark and the developed database therefore reflect Danish conditions almost exclusively.

A main consequence of this is that the results of a working environmental LCA show the anticipated impacts as if the whole life cycle takes place in Denmark. This is very rarely the case, especially because many raw materials are being produced outside of Denmark. The following general and specific aspects must therefore be considered when interpreting the results.

2.5.1.1 General aspects

The number of reported diseases and accidents is assumably somewhat lower than the actual number. This is a general finding in all sectors and is probably also the case in other countries.

The Danish working environmental conditions are presumably better than in many other countries. The use of Danish statistics to account for impacts in other countries will therefore underestimate the impacts. This to some extent counterbalanced by an assumed lower reporting frequency in other countries.

2.5.1.2 Specific aspects

The impacts from production of raw materials have been calculated using statistics on the relatively modest Danish production. This is for example the case for aluminium and steel, where the Danish production is based on secondary aluminium and steel as the basic raw materials. In other countries, primary as well as secondary raw materials are used in the production of the two materials. For plastics, Denmark has a very limited production, and none of the bulk plastics like PP, PE, PS or PVC are produced in Denmark. It should, however, be remarked that plastic production in all countries takes place in the same sector (NACE-code 241600), irrespective of the plastic type being produced.

The main implication of this difference between Danish and foreign production of raw materials is that the representativity of the data used to describe these processes is unknown and therefore an uncertainty is introduced.

This limitation of the method can maybe be reduced if other countries establish corresponding figures using the same procedure. The goods statistics are made following internationally accepted guidelines and are therefore comparable from one country to another. Statistics on work-related accidents and injuries however vary significantly, both with respect to the types of injuries that are reported and with respect to the frequency of reporting. Using foreign trade statistics will thus introduce other types of uncertainties; e.g. it will be difficult to aggregate all effect categories over the whole life cycle.

2.5.2 Supplementary data

During the establishment of the database it was tried to create a broad overview by finding the outlined information for about 75 economic activities in different sectors. The activities have been selected on the basis of their relevance for LCA in general ("the most common processes") as well as the statistical background material. The latter means in practice that some sectors have been omitted because the number of reported diseases/accidents is very small, leading to a large statistical uncertainty.

There are, however, still a number of activities or unit processes that is not covered in the database. If data are missing on processes that are assumed to be important, it is recommended that the LCA-practitioner establish his own information on these key processes, for example with help from Statistics Denmark. This could for example be the case for economic activities, where the practitioner judges that the actual impacts differ significantly from the average values given in the database.

Another area where an alternative procedure is necessary is in the sectors where the basic method cannot be applied. This is for example the case for the sectors "Surface treatment of metal" (DB93/NACE-code 285100) and "Textile finishing" (DB93/NACE-code 173000) where the calculation of produced amounts and their value follows guidelines that are different from those for other sectors. It has not been possible to describe a procedure for such sectors within the current project.

For some activities like production of basic raw materials it is possible to extract the requested information from the annual report from Danish or foreign companies. An example is given in the next section.

The example shows that key information is relatively easy to obtain through public available information sources. The example also shows that the level of detail is relatively low. The company does not publish the number of reported diseases and in order to include this information in a LCA, collection of supplementary information is required.

It has not been possible to specify a procedure for such collection. It is suggested that the first step is to search for key institutions and persons on the home page of the Finnish Institute of Occupational Health and Safety (http://www.occuphealth.fi/e/eu/haste/index.htm) that contains an overview of statistical sources for a number of countries. Due to differences in reporting requirements and formats it will, however, often be difficult to obtain a level of detail that matches the present database.

The LCA-practitioner must also be aware of another problem when using the foreign data in the database, namely the representativity. In the case outlined in the present section, information from one year only has been used to establish the information. This means that variations from one year to another are not reflected in the figures for the activity. It can be seen in the technical report that the variation is about 25% for accidents, while it is 100% for fatal accidents (the number of fatal accidents vary between zero and four for three consecutive years).

The representativity of the figures for nickel production on the global scale is also unknown. The producer in the example, WMC, has implemented a number of safety measures, but still has a relatively high accident frequency. Other countries (especially developing countries) and specific companies may have a less effective safety policy that can lead to a significantly higher accident frequency. However, the opposite may also be the case.

2.5.3 Nickel production as an example of calculations on the company level

As an example of using company specific information, the magnitude of the working environmental impacts can be derived from the annual reports from WMC, an Australian producer of metals, fertilisers and other products.

The combined "Lost time and Medically treated injury frequency rate" (LMI) was in average for all WMC operations 30.7 per million hours worked in 1996-1997. For the nickel operations, the average figure was 34.7 with a range from 6.1 to 54.0 in different operations.

The production in 1996-1997 was 47.600 tonnes and the labour productivity was stated to be 37 tonnes of nickel metal produced per employee in the same year. Assuming that each employee works 2000 hours per year, the LMI per tons nickel can then be calculated to

$((34.7 * 10^{-6}) * (2000/37) \approx 1.9 * 10^{-3}$ injuries per tons nickel.

There were two fatal accidents in the nickel operations in 1997 in WMC. With a production volume of 48.000 tonnes the number of fatal accidents per kg nickel can be calculated to 2/48.000 kg $\approx 4*10^{-5}$ fatality per kg nickel.

2.6 The uncertainties of the method

As indicated in the previous sections, the described method is associated with some uncertainties. Two of the most important issues in this context are addressed in the following sections.

2.6.1 The level of detail for certain sectors

One of the starting points for choosing the sectors to be included in the database was the EDIP PC-tool, simply because a main goal was to find statistical information on the working environment for the same processes that are contained in the database. Neither the statistics on work-related accidents nor the goods statistics do however give the possibility of matching the level of detail in the EDIP PC-tool. It should be noted in this context that a satisfying level of detail is required for both types of information in order to reach the desired result.

The consequence of this is that most sectors will be assessed by using average figures for the sector as whole, and not by using figures for specific processes. As an example, the working environmental impacts are the same for extrusion of one kilo of PE-sheets as for injection moulding of one kilo of ABS-crates. The reason for this is that both activities takes place in the same sector, "Production of plastic packaging" (DB93/NACE-code 252200). Likewise, it is not possible to distinguish between the impacts from production of lead and production of zinc, and a subsequent processing of the materials. In this case, the statistics on work-related accidents and injuries is the limiting factor, because the goods statistics has the possibility of distinguishing between the two materials.

2.6.2 Produced amounts in the sectors

The procedure for calculating the produced amounts in the single sectors may also introduce some uncertainties.

The total amount produced in a sector – measured in a weight unit – is one of the two parts of the equation used for calculating the impacts per tons. For some sectors, information on the weight of the products is available in the goods statistics for all products, whereas for other sectors, the produced amount is stated in m2, rolls, etc. In these cases, the weight must be estimated using foreign trade statistics. This procedure can best be illustrated by an example where a number of goods being produced are used for the calculations. As can be seen in Table 1, there is information on both the amount and the value for some products, while for others only information on the value is available.

Table 1. Example of basic statistical information used in the calculation of produced amounts in a sector

Product	Amount in tons	Value in 1000 DKR
Rigid PVC-tubes, seamless	?	150.000
Rigid PVC-tubes, with seam	22.400	287.400
Flexible PCV-tubes, with seam	5.902	103.494
Flexible PE-tubes, seamless	1.904	24.473
Rigid PE-tubes, seamless	10.533	210.291
Rigid tubes condensation plastic	?	17.296
Sum	40.739 + ?	

The total production can be calculated by the following procedure:

(1) For the products with the missing information in tons, the average value per weight unit (kr/tons) is calculated from the foreign trade statistics, where both information on value and weight is available.
(2) The total production (in tons) for the product is calculated by dividing the value of the product (from the goods statistics) with the average value per weight (calculated from the foreign trade statistics in (1)).
(3) The total production for that sector is calculated by simple addition of the production for each product.

The uncertainty that is introduced in this calculation is that the average value per weight unit used in the foreign trade statistics (export/import) may not be the same value as used in the goods statistics. Even though it is exactly the same products, the price may differ from the home market to the export market. The average value per weight unit from the foreign trade statistics may therefore be over- or underestimated, causing some uncertainty regarding the produced amount. However, the results from all sectors are based on a comprehensive statistical basis, i.e. many products are used in the calculations, and the potential uncertainty is therefore in general regarded as low.

An example is the steel producing sector where the calculated and measured (Jernkontoret, 1999) amounts in the steel producing sector for two years are compared in the table below. As can be seen from the table, the difference between the two values is at most about 5%.

Table 2. Comparison of calculated and actual production in the steel sector

Steel Production		
Year	Calculated production	Actual production
1996	703 kton	739 kton
1997	777 kton	786 kton

In other sectors, the number of products where information on both price and weight is available is smaller. This is most pronounced in sectors with a high degree of wage work, e.g. in textile processing. For this sector, use of foreign trade statistics has been essential, giving a rather high uncertainty, and the results from these two sectors should be used with great caution. For surface treatment, another sector with a high degree of wage work, the amount of available data was so small that the results most probably would be misleading. This sector is therefore omitted from the database.

In very few sectors the goods statistics could not be used for the calculations because of confidentiality restrictions. This is the case for "Production of rock wool" (DB93/NACE-code 268220) where the number of companies in the sector in Denmark is so small that Statistics Denmark is obliged to keep the production figures confidential.

The actual magnitude of the uncertainties caused by the statistical limitations cannot be assessed precisely. The uncertainty may amount to a factor 10 or more in extreme cases, but the uncertainty will generally be comparable to that found in effect categories like human toxicity and ecotoxicity.

2.7 The sensitivity of the method

The results achieved by using the method are sensitive for variations in the basic statistical data and the applied calculations. This can to some extent be compensated for in a specific LCA by choosing a set of data from the database that covers the actual activity in the best possible way. The following sections show some of the limitations and possibilities associated with the database.

2.7.1 Production of raw materials

Production of raw materials is – like other processes – described by using Danish information. This may cause some practical problems, as many basic raw materials are not produced in Denmark.

2.7.1.1 Data for secondary raw materials

In order to be able to include production of raw materials in the LCA, data for production of secondary raw materials in Denmark have been established. Both the production volume and the number of accidents and injuries in these sectors are small, and the calculations of accidents/injuries per produced unit are accordingly associated with a relatively large uncertainty.

2.7.1.2 An alternative calculation method
As an alternative, the impacts from production of a few metals from metal ore have been calculated. The calculations are documented in full in the technical report, and an example is shown in section 2.5.3. The examples show that it is possible to use annual reports from companies to derive the requested information, although the precision and representativity is not of the same quality.

2.7.1.3 Only accidents included
A major difference between company specific data and the Danish average data is that company specific information generally only concern accidents and fatal accidents. When the information from several activities in the life cycle of a product are aggregated this will give some black spots in the calculations, i.e. that the contribution to other effect categories will be underestimated. One example is that mining of metal ore has a large impact with respect to hearing damages and lung diseases, but this will not be included in the results.

2.7.2 Impacts in single companies and on individuals
2.7.2.1 Single companies
The basic statistics used in the method gives an average assessment of the impacts per produced unit of a material or product. It is obvious that in real life there will be a wide variation in the impacts in single companies because of differences in the product-, material- and process portfolio as well as the internal management of the working environment. Using the method cannot reflect this variation.

This also means that it is not possible to assess the changes in the working environmental impacts following changes in the choice of e.g. processes and materials. The best way to examine such changes is by performing work place assessments that specifically has the aim of mapping the impacts in a given process and to prioritise the efforts that are necessary to make the working conditions satisfactory. If a company has a certified working environmental management system it is ensured that the company fulfils all legal requirements and that the company is devoted to a continuous effort to prevent working place injuries on both the short and long term.

Another inherent issue (or problem) is using the algorithm of the method is the connection between impacts and produced amounts. It is obvious that with an unchanged number of accidents and injuries an increase in the produced amounts will lead to a smaller number of impacts per produced unit.

Individuals who are producing larger amounts because of an increase in the work intensity will however not experience this as an improvement of the working environmental conditions, rather on the contrary. The risk of accidents, an impaired psycho-social working environment and an increase in repeated monotonous work will often be the result of an increased working intensity, but this is not reflected in the method.

3 Application of the method

The method has been developed with the purpose of including the working environment in LCA. One of the main goals of LCA is generally to give an overview of the main impacts in the life cycle of a product, for example in product development. A LCA of the working environment that is based on sector assessments can meet this general goal because it gives an indication of where in the life cycle the main impacts can be expected and how big they are.

The process of making an LCA with inclusion of the working environment does not differ from a ”normal” LCA. The main difference is that important indicators for working environmental impacts are included, giving the possibility for an assessment of whether the results of changes in material composition and applied processes also causes significant changes in the overall impacts.

3.1 Inventory

The method has been developed with the aim of being integrated in the overall EDIP-method and eventually also being a part of the EDIP PC-tool. The PC-tool can however not handle the changes in data format and impact assessment that are the consequence of the new method. It is recommended that the changes be implemented when revising the current version of the PC-tool. This will cause the working environment to be a naturally integrated part of the overall assessment.

Until a PC-tool can handle the database it is recommended that a working environmental LCA should be performed separately, using a spreadsheet. A spreadsheet in EXCEL-format containing the database can be downloaded from the web-site of LCA Center (www.lca-center.dk/cms/site.asp?p=2217). A procedure for use of this spreadsheet is outlined in the following paragraphs and exemplified in section 3.4. It should be noticed that the outlined procedure is only a suggestion and that other practitioners may choose to handle the data by another procedure. This will not be detrimental to the precision and reliability as long as the procedure and the limitations of the database is described in a transparent way.

3.1.1 Inventory procedure

1. The first step is to calculate the materials flows for the product. The most precise calculations are obtained by using the EDIP PC-tool or another LCA-program and use the results directly for further calculations of the working environmental impacts. The advantage of using a dedicated PC-program is that material flows from previous and unseen activities in the life cycle will be automatically included.

   Another, but less precise procedure is to use the component list for the product for calculation of in-going material flows (see e.g. Table 4). If this procedure is used, the practitioner will have to make special considerations regarding the activities earlier in the life cycle. As an example, the material input for production of one kilo of primary plastics - generally speaking - is one kilo of crude oil and one kilo of natural gas. These inputs must be accounted for. The primary plastic is subsequently processed, and here there are several processes to choose from in the database – see step 2. The material loss in these processes is however relatively small and can often be neglected. In the case described in section 3.4 the component list is used for the calculations together with a supplementary calculation of the amount of energy resources that enters the life cycle.

2. The materials flows calculated in the first step are now distributed (aggregated) on relevant processes in the developed database (see the example in Table 7, section 3.4). Before this can be done it is therefore necessary to establish a good overview of all the processes in the database. As an example, the weight of all iron- and steel components are added in order to calculate the impacts from production of the basic raw materials ("Danish iron- and steelworks" in the database). In order to calculate the impacts from the following manufacturing processes, the weight of the components is distributed on relevant processes. In the case described in section 3.4, the basic iron and steel is processed in two different sectors, i.e. "Production of screws, springs, etc." and "Productions of other metal products". Another example is that the database contains information on nine different types of plastic processing, two of which are relevant in the case. The results of the second step is that a more operational overview is established, i.e. the number of material and process combinations has been reduced significantly.

3. The aggregated material flows from step 2 are now entered into a spreadsheet. This can for example be done by entering information on each process regarding material, process name, NACE-code and weight in four columns.

4. For each process the weight is multiplied with the impacts per weight unit for each of the effect categories. In practice this can be done in many ways, e.g. by adding ten columns with the same headings as in the developed database. In each of the cells in the ten columns, a formula of the type "= A*B" is entered, where "A" refers to the address of the cell containing information on the weight of the material and "B" refers to the address of the cell in the database that contains information on the impact per weight unit for the relevant effect category and process.

5. When the formulas have been entered the spreadsheet automatically per forms the calculations. The resulting figures can subsequently be added in order to calculate the total impacts in each effect category. It is also possible to make further groupings/aggregations of the processes and thereby create other and perhaps more operational overviews. In the case in section 3.4 it was chosen to add the life cycle impacts relating to

components made from different materials (plastic, steel, paper/cardboard, etc.) in order to compare these to each other and to other activities like assembling, transportation and production of energy resources. It is also possible to add the impacts from processes in different phases in the life cycle, e.g. by adding the impacts from different types of raw material production, material processing, assembly and transportation, respectively.

6. It is not possible to give a more precise description of the options that are available, simply because each case has its own characteristics with respect to goal and scope of the LCA as well as the material composition and the life cycle of the product(s) under examination. The case in section 3.4 can be used for inspiration, but the database is in principle open for all types of calculations and associated interpretations.

3.1.2 Matching the inventory and the database

When developing the database the aim was to find information for as many typical ”LCA-activities” as possible. However, one of the largest uncertainties in the calculation procedure is probably to find data sets in the database that matches the actual activities.

This problem is caused by the fact that many thousand product groups have to be related to a relatively small number of sectors, less than 300. In the project, Statistics Denmark who has the copyright to the information did this. In practice, the procedure implies that many processes are described by the same set of data although they are significantly different. One example is that the sector ”Production of plastic packaging” uses thermoforming, injection moulding, blow moulding, extrusion, foaming, etc. of all types of plastic.

For other types of processes a single set of data is used to describe a complicated process sequence. An example is ”Production of household appliances” which generally is done in an assembly line and involves a number of persons. The data format for such processes is the same as for other processes; i.e. the impacts are given per produced unit of weight .This means that for a household appliance weighing 5 kilo, the impacts in the database must be multiplied with 0.005 (the database figures are per ton) in order to calculate the impacts per appliance for the assembly process.

Another uncertainty is that it is not possible to take the impacts from previous processes into consideration unless they are specified. This is for example the case for production of energy resources; e.g. the impacts from production of household appliances only include the production itself and not the production of the energy used in the production. When using a spreadsheet for the calculations, it is not possible to make the iterations that are an integrated part of the EDIP PC-tool. Both types of uncertainties are judged to be of minor importance, but may be avoided if the database is integrated in the PC-tool.

3.2 Impact assessment

When the inventory data have been calculated it is not necessary to process them further in order to make an impact assessment. The reason for this is that the inventory is measured in category endpoint in the cause-effect chain. The potential effects are in other words measured directly in the inventory.

The working environmental impacts differ in this respect from most other impact categories, where the potential impacts are measured much earlier in the cause-effect chain. As an example, the category endpoint for global warming is regional changes in temperature and their associated socio-economic effects following desertification or increased water levels. These effects cannot be measured directly, and instead the impact assessment is performed in two steps. Firstly, emissions are classified as contributing to global warming (e.g. CO^2 and CH^4) and secondly their contribution is calculated by multiplying with their potential for causing the effect, e.g. by taking their specific ability to absorb IR-light and their residence time in the atmosphere.

3.2.1 Normalisation

The aim of the normalisation step in EDIP is to give an overview of the relative importance of the single effect categories. This is done by relating the actual (calculated) impact to the average impact caused by a person in the relevant geographic area. Hereby, the normalisation step becomes similar to that used in other impact categories in EDIP.

In the present methodology, the basis for the normalisation is easily identified as the total number of reported working environmental accidents and damages in Denmark, distributed evenly on the number of Danes in the same period of time. As for the other calculations, the normalisation factors in Table 3 have been calculated as a three-year average for 1995-1997.

The procedure is thus simple, using the total number of accidents and work-related diseases as reported to the Danish Labour Inspectorate and dividing with the number of inhabitants in Denmark.

The normalisation reference or person equivalent can be interpreted in the way that if every Dane was working, one out of a hundred persons would experience an accident at work every year.

Table 3. Normalisation factors for working environmental impacts

Basis for normalisation / Effect category	Person equivalents, PE Danish population	Worker equivalents Danish work force
Fatal accidents	$1.54 * 10^{-5}$	$3.06 * 10^{-5}$
Accidents	$9.69 * 10^{-3}$	$1{,}92 * 10^{-2}$
Cancer	$3.54 * 10^{-5}$	$7.02 * 10^{-5}$
Psycho-social damages	$1.40 * 10^{-4}$	$2{,}77 * 10^{-4}$
CNS-function disorders	$6.37 * 10^{-5}$	$1{,}26 * 10^{-4}$
Hearing damages	$4.56 * 10^{-4}$	$9.06 * 10^{-4}$
Airway diseases, non-allergic	$1.00 * 10^{-4}$	$1{,}99 * 10^{-4}$
Airway diseases, allergic	$7.93 * 10^{-5}$	$1{,}57 * 10^{-4}$
Skin diseases	$3.12 * 10^{-4}$	$6{,}19 * 10^{-4}$
Muscolo-sceletal disorders	$1.44 * 10^{-3}$	$2{,}85 * 10^{-3}$

The normalisation reference for the working environment is comparable to the normalisation reference for other environmental impacts, e.g. the contribution of an average Dane to acidification is calculated by dividing the total Danish contribution to acidification with the number of inhabitants in Denmark.

When performing the normalisation step, i.e. using the person equivalent, it is possible to examine both how the working environment differs between products and how important the working environment is in comparison with the impacts in the natural environment.

In Table 3, another set of normalisation factors, "The worker equivalents", is found. This set of figures show the probability for an average worker of experiencing an accident or report a work-related disease in a year. The only difference between the two sets of factors is that the worker equivalent is calculated using the number of employed persons in Denmark. The worker equivalent is suggested for use in specific working environmental LCAs, where absolute figures may give more suitable information than when using the Danish population as the normalisation reference. It should however be stressed that when the worker equivalent is used in normalisation, comparisons with other effect categories can not be made.

3.2.2 Weighting

The normalisation procedure for the working environment gives information on which effects that will be most frequently observed in the life cycle of a product. However, the most frequently observed effects are not necessarily the most problematic, e.g. fatal accidents must be regarded as more serious than hearing damages.

To account for this, the general EDIP methodology introduces an optional impact assessment step, namely weighting. The weighting of the impacts in the natural environment is done by using political targets for reduction in emissions.

This is however only possible to a limited degree for the working environment, as the only specified target is that the number of fatal accidents shall be reduced to zero before year 2005. In addition, the Danish minister of labour has identified a number of other impacts that are of special concern and therefore should be reduced or totally avoided by year 2005:

- Hearing damages
- Occupational exposure to carcinogenic substances and work-related damages to the central nervous system caused by exposure to solvents or heavy metals
- Injuries to children and adolescents at work
- Damages to health caused by psycho-social risk factors at work
- Sickness or serious annoyances caused by an unsatisfactory indoor climate
- Damages and injuries caused by lifting of heavy burdens or by monotonous repeated work

No specific goals have been specified for these impacts and it is also not possible to relate all the concerned impacts to the effect categories used in the methodology.

It is therefore suggested to exclude the weighting step from the assessment of working environmental impacts for the moment being. As a consequence, when comparing impacts in the natural environment to impacts in the working environment, this should be done following the normalisation step.

In the end, it is the judgement of the LCA-practitioner whether the results following normalisation are suitable for decision support or a supplementary interpretation of the results is necessary to compensate for the lack of weighting in the method. On the longer term, weighting methods using economic indicators can be developed and used to assess the relative seriousness of the single impacts. A possible database for this is information from the worker compensation board or workers experience insurance companies, where a price or value is attached to the many types of injuries and damages that may occur. It should be remarked that this type of weighting is not comparable to the general weighting method in EDIP.

3.3 Interpretation

The method has so far only been tested on a single case and it is therefore difficult to give precise guidelines as to how the results can be interpreted. The primary recommendation is to use information from both the basic inventory/impact assessment and the subsequent normalisation in the interpretation.

3.3.1 Interpretation following inventory

Following the inventory/impact assessment it is possible to establish an overview of how much each of the activities contributes to the single effect categories. This can for example be illustrated in a bar diagram, summing the activities up to 100%.

At the same level it can also be illustrated how many accidents and injuries a product causes, measured in absolute numbers. The unit for this information is accidents/injuries per functional unit. A three-dimensional matrix (combining the absolute number of accidents and injuries with each life cycle phase and each effect category) can create the full overview, but in practice, a two-dimensional illustration is more operational.

3.3.2 Interpretation after normalisation

Following the normalisation it can be assessed which effect categories that are the most important in the life cycle of a product. This can for example be evidenced by using a diagram depicting the normalised values, measured in person equivalents and summed up for the whole life cycle. In this way the fact that some types of accidents and injuries are reported more frequently than others can be taken into account.

The interpretation of this kind of results is independent of the choice of person equivalents or worker equivalents as the normalisation base. It is however recommended to use person equivalents if comparison with other impact categories is performed.

The normalised values can also be used for another type of interpretation. By dividing the worker equivalent with the impact from a product or a functional unit it is calculated, how many products can be produced (or functional units fulfilled) before the average impact of a worker is reached. In this case the worker equivalent is used for the calculations because it gives more meaningful numbers.

The recommendations outlined above are illustrated in a case in the following sections.

3.4 The method applied on a case

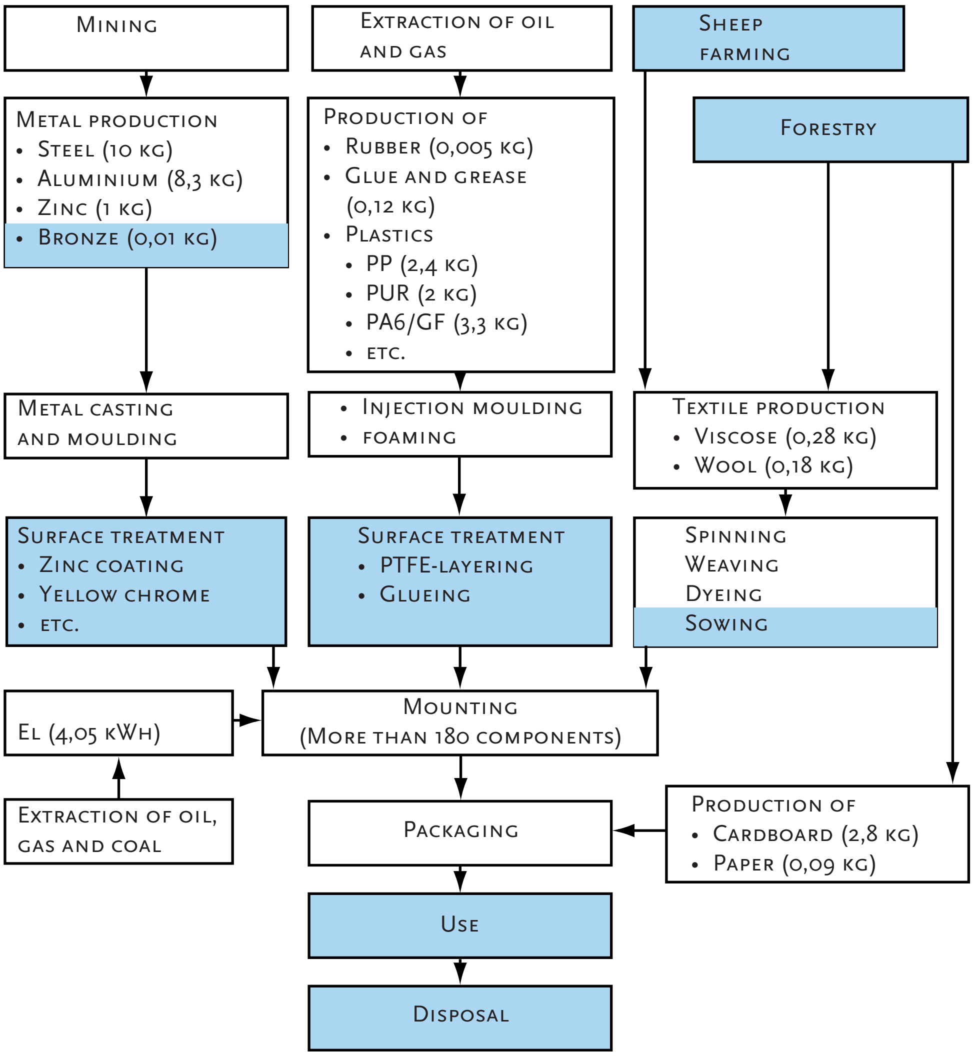
The chosen case – an office chair – has also been used in other parts of the LCA-method development and consensus project. One of the reasons for choosing this case is that large parts of a LCA has already been performed, e.g. much of the necessary information was available also for the working environmental part of the LCA. No further data collection was performed in the present project.

3.4.1 Making a flowchart

The starting point for the LCA is a component list for the product with information on material type, weight and applied processes (e.g. surface treated or injection moulded). In order to create a better overview of the comprehensive list of components, it is suggested as a first step that a flowchart for the generic material types (plastics, steel, metals, paper, etc.) is established.

The flowchart for the office chair is shown in Figure 1. The shaded boxes show the activities that could not be included in the calculations because of missing information. This is for example the case for forestry and surface treatment because the developed database does not contain data on these processes. Extraction of energy for transportation is also not included because the actual consumption was not calculated in the basic information for the study.

Figure 1.
Flow chart
for the ofice chair



3.4.2 Aggregation from the component list

The component list gives information on the amount of materials used in the product. Table 4 shows an excerpt from the component list for the office chair.

Number	Name	Material	Amount (in g)
1	Glider EGO f. back	Aluminium	450,0
1	Screw spec. 3 x 7	Steel	1,4
1	Catch EGO f. right	Steel	55,0
1	Spring EGO f. catch	Stainless steel	2,2
1	Screw, mach. M3x6	Steel	0,4
1	Trigger chip EGO	POM	2,6
1	Stop EGO f. back tilt.	Zinc	73,0
2	Brake block f. back tilt	Rubber	0,8
2	Bearing EGO upper	POM	0,6
1	Top cover	ABS	62,0
...	...	...	...

Table 4. Excerpt from the component list for the office chair

The office chair is made from more than 180 components that can be aggregated with respect to the basic material type and the weight (Table 5).

Material	Aggregated from	Weight
Steel	Steel, stainless steel, sintered steel	9830,7g
Aluminium		6413,0 g
Zinc		941,7 g
Bronze*		10,4 g
Rubber		4,4 g
Basic chemicals	Glue and grease	97,0 g
Plastics	POM, PA6, PA66, ABS, PP, polyester and PUR w. melamine	8205,9 g
Viscose/wool		462,4 g
Total		25965,5 g
Packaging		
Paper		18,3 g
Cardboard		2820,0 g
Plastics	PP and PA6	85,1 g
Total		2923,4 g

* Not included in the calculations

Table 5. Material content in the office chair

The data in Table 5 are used as input for the calculations of the impacts. The main aggregation is that different types of steel and plastics are found under two headings, steel and plastics, as it is not possible to make further discrimination in the database.

In the calculations it is assumed that the seat and back of the office chair will be replaced three times in the lifetime of the chair. The additional consumption of materials for this is included in the above figures.

3.4.3 Energy and transportation

The impacts from production of energy raw materials and transportation are also included in the assessment.

The overall consumption of oil, gas and coal for energy production and material feedstock has been used for the calculation, as no detailed information for the single materials was available. Production of electricity is only considered for the assembly process at the producers, as this was the only process for which this information was available.

For transportation, only national transportation in Denmark is considered and it is assumed that all transportation is performed by truck. Transportation between earlier parts of the supply chain is not considered, but the extra transportation associated with replacement of seats and backs of the chair is included in the calculations.

The aggregated figures for consumption of energy raw materials and transportation are shown in Table 6.

Table 6. Energy and transportation data

Energy raw material	Amount
- Coal	32,102 kg
- Oil	26,4 litres
- Natural gas	18,8 m3
- Electricity	4,05 kWh
Transportation	26038 kg-km

3.4.4 Matching the aggregated information with the database

An integrated part of aggregating the data in the component list is to find sectors in the database, for which the activities match those in the life cycle. Table 7 shows the sectors that were chosen to match the activities in the life cycle of the office chair.

Table 7. Sectors included in the calculations

Material	Amount	NACE-code	Database process/activity
Steel	9830,7 g	271000	Danish iron- and steel works
	692,5 g	287400	Production of screws, springs
etc.	9138,2 g	287590	Production of other finished metal products
Aluminium	6413,0 g	274200	Production of aluminium
Zinc	941,7 g	274300	Production of lead, zinc and tin
Bronze*	10,4 g		
Rubber	4,4 g	251300	Production of rubber products
Glue/grease	97,0 g	241300/ 241400	Production of basic chemicals
Plastics	8291,0 g	241600	Production of basic plastics
	8201,7 g	252490	Production of other plastic products
	85,1 g	252200	Production of plastic packaging
Viscose/wool	462,4 g	171000	Spinning
	462,4 g	172000	Weaving
Office chair	25965,5 g	361110	Production of chairs and sitting furniture
Paper and cardboard	2838,3 g	212100	Production of paper and cardboard packaging
Coal	32,102 kg		Extraction of coal
Oil	26,4 litres		Extraction of oil
Natural gas	18,8 m3		Extraction of natural gas
Electricity	4,05 kWh	401000	Electricity production
Transportation	26038 kg-km		Road transportation

* Not included in the calculations

Production of bronze is not included in the calculations because no sector in the database matches this activity directly. The potential error in this omission is however very small as the amount of bronze in the office chair is almost negligible. If an increased level of detail is requested, bronze could be included by using other processes, e.g. a combination of production of copper and production of lead, zinc and tin.

For steel and plastics, a number of sectors have been used to describe the life cycle, thereby giving the possibility for a more detailed assessment. For plastics, the life cycle starts with extraction of oil and natural gas, followed by production of basic plastics and ending with production of plastic packaging and production of other plastic products. For steel, the life cycle starts with production of steel and subsequently a division into production of screws and production of other steel products.

3.4.5 The calculations

The next step in the procedure is to multiply the information in Table 7 with the impacts per ton material that can be found in the database. It is important to observe that the units must match each other, e.g. weight is stated in tons.

The calculations can most easily be performed in a spreadsheet. About 60 unit processes contribute to one or more impacts in the life cycle of an office chair. In the spreadsheet it is possible to see exactly how many accidents and damages each process causes and it is also simple to add the impacts to get an overview of the total impacts.

3.4.6 Creating a better overview

In order to create a better overview of the importance of each material or component it is suggested that the information is aggregated in the same way as was done with respect to the information is the component list, i.e. on the material level.

As an example all processes involved in the production of plastic components are aggregated, the exception being extraction of oil and natural gas that is aggregated under the heading energy production. The same can be done for other materials and process where appropriate, and the simplified overview can be presented in a new spreadsheet that gives better possibilities for a graphic presentation. This size of the new spreadsheet for the office chair is indicated in Table 8, where the number of processes has been reduced from about 50 to 14.

Table 8. An example of a spreadsheet with aggregated information

			Accidents and diseases per chair									
Material	Weight (gram)	Life cycle process	Fatal accidents	Accidents	Cancer	Psycho-social damages	CNS function disorder	Hearing damages	Air way diseases (non-allergic)	Air way disases (allergic)	Skin diseases	Muscolo-sceletal diseases
Steel	9830,7	Production of steel	0,0E+00	3,8E-05	1,6E-07	8,7E-08	3,2E-07	2,6E-06	4,4E-07	3,1E-07	9,8E-07	4,1E-06
Aluminium	6413	Production of aluminium	0,0E+00	4,8E-06	2,6E-08	2,6E-08	7,8E-08	2,9E-07	7,8E-08	5,2E-08	7,8E-08	9,4E-07
Zink	941,7	Production of zink	0,0E+00	1,3E-05	0,0E+00	6,9E-08	1,4E-07	2,1E-07	0,0E+00	6,9E-08	6,9E-08	4,1E-07
Plastics	8286,80	Production of plastics	0,0E+00	1,9E-05	1,0E-07	3,7E-07	8,4E-07	5,3E-07	5,8E-07	7,3E-07	1,7E-06	4,8E-06
Rubber	4,40	Production of rubber	0,0E+00	1,8E-08	1,0E-10	0,0E+00	1,6E-10	5,7E-10	1,6E-10	3,6E-10	6,2E-10	1,4E-09
Textiles	462,40	Production of textiles	0,0E+00	3,0E-06	2,0E-08	0,0E+00	0,0E+00	3,2E-07	1,8E-07	1,6E-08	1,2E-07	3,5E-07
Paper/cardboard	2838,30	Production of paper/cardboard	0,0E+00	1,4E-06	3,3E-09	3,3E-09	1,5E-08	5,4E-08	3,3E-09	5,0E-09	2,1E-08	1,8E-07
Glue/grease	97,00	Production of glue/grease	0,0E+00	9,5E-09	0,0E+00	8,8E-11	1,8E-10	2,7E-10	3,5E-10	0,0E+00	1,8E-10	6,2E-10
Chair	25965,50	Assembling	1,5E-07	5,6E-05	2,9E-07	7,3E-07	1,2E-06	4,1E-06	4,4E-07	5,8E-07	1,6E-06	1,5E-05
Transportation		Transport	8,8E-09	8,0E-07	2,4E-09	1,2E-09	4,0E-10	2,4E-08	7,2E-09	2,0E-09	2,0E-09	7,8E-08
Energy consumption		Energy total	1,5E-09	2,9E-07	2,7E-10	1,0E-10	6,8E-11	2,8E-09	6,8E-10	6,8E-11	2,9E-10	3,5E-09
		Coal	1,4E-09	2,5E-07	0,0E+00	0,0E+00	0,0E+00	0,0E+00	0,0E+00	0,0E+00	0,0E+00	0,0E+00
		Oil	3,1E-11	3,6E-09	0,0E+00	0,0E+00	0,0E+00	9,4E-11	0,0E+00	0,0E+00	3,1E-11	3,4E-10
		Natural gas	2,4E-11	2,8E-09	0,0E+00	0,0E+00	0,0E+00	7,2E-11	0,0E+00	0,0E+00	2,4E-11	2,6E-10
		Energy production	3,4E-11	3,5E-08	2,7E-10	1,0E-10	6,8E-11	2,7E-09	6,8E-10	6,8E-11	2,4E-10	2,9E-09

3.4.7 Creating the graphic overview

It is relatively simple to use the aggregated information in Table 8 for a graphic presentation of the results, provided the practitioner has some general experience with spreadsheet management. A number of possibilities are available and some of these are demonstrated in the following figures.

The first suggestion is to make a figure that illustrates the relative contribution from materials/processes to the total impacts from the product – the expected accidents and damages. This overview is presented for the office chair in Figure 2.

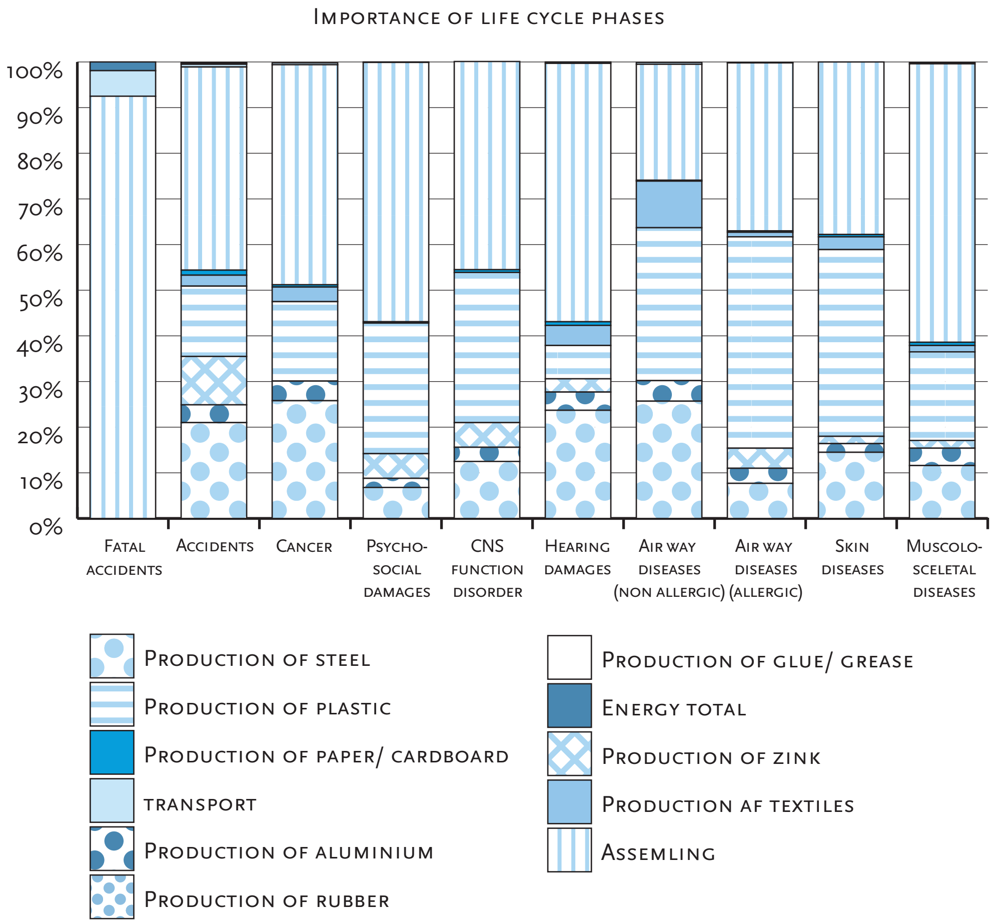


Figure 2.
The relative contribution of materials and processes to the overall impacts from the office chair

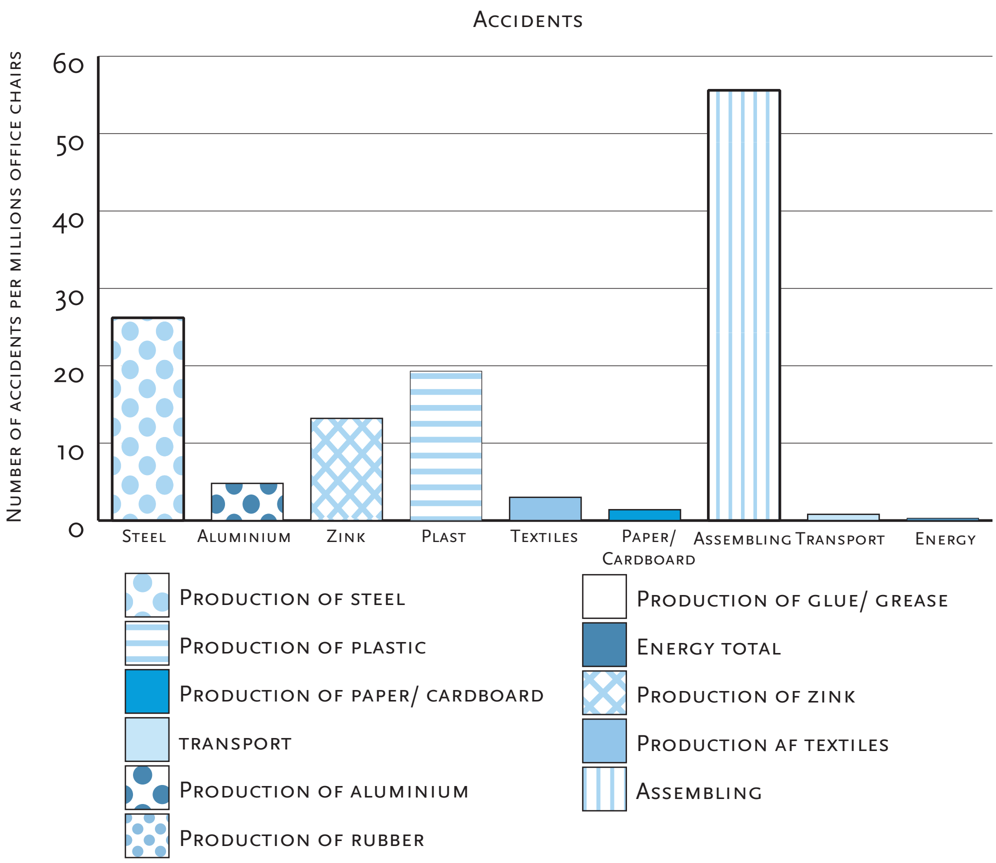
As can be seen from Figure 2, the assembly process is the most important process for many of the impact categories considered by the method. However, both plastics and steel also have a large impact in some categories, e.g. plastics as a whole causes more airways diseases than the assembly process and steel production together.

It can also be seen from the figure that transportation only has a significant contribution to one impact category, accounting for about 10% of the expected fatal accidents. For all other impact categories, transportation contributes only with an insignificant part. For energy production, the contribution cannot be observed in the illustration. It should, however, be remembered that the database for production of electricity, especially extraction of coal, is of a poor quality.

Looking at the absolute contribution to the single impacts from each of the materials and processes can create another type of overview. An example is shown in Figure 3, where the number of expected accidents per million office chairs is allocated to each of the materials and processes. This overview is often valuable, as the database for accidents is the most complete, i.e. this information has been collected for all processes.

It can be seen from the figure that the assembly process is the most important process with respect to the risk of accidents. It can also be seen that steel is more important than plastics. This is not the case for other impact categories as indicated in Figure 2.

Figure 3.
The contribution of single materials to the overall number of accidents in the life cycle of an office chair



The materials rubber, glue and grease only account for a minor contribution, primarily because of their low weight. Energy production and transportation is also of minor importance.

3.4.8 Normalisation

The results from the impact assessment can subsequently be normalised in order to gain knowledge on which effects that is most affected by the activities in the life cycle of a product. The normalisation is done by relating the expected number of accidents and damages to the average reporting frequency for an average Danish citizen. In practice, this is done by dividing the number of accidents and damages from the product with the normalisation references given in Table 3. With this calculation, the impacts can be stated in person equivalents, i.e. the same unit that is used for other impact categories in the EDIP method (1 person equivalent = 1 PE = 1000 milli person equivalents = 1000 mPE).

Figure 4 shows the normalised impacts from the office chair. It can be seen that the life cycle activities has the most significant effect on CNS-function damage, with an impact that amounts to about twice as much as the other impact categories.

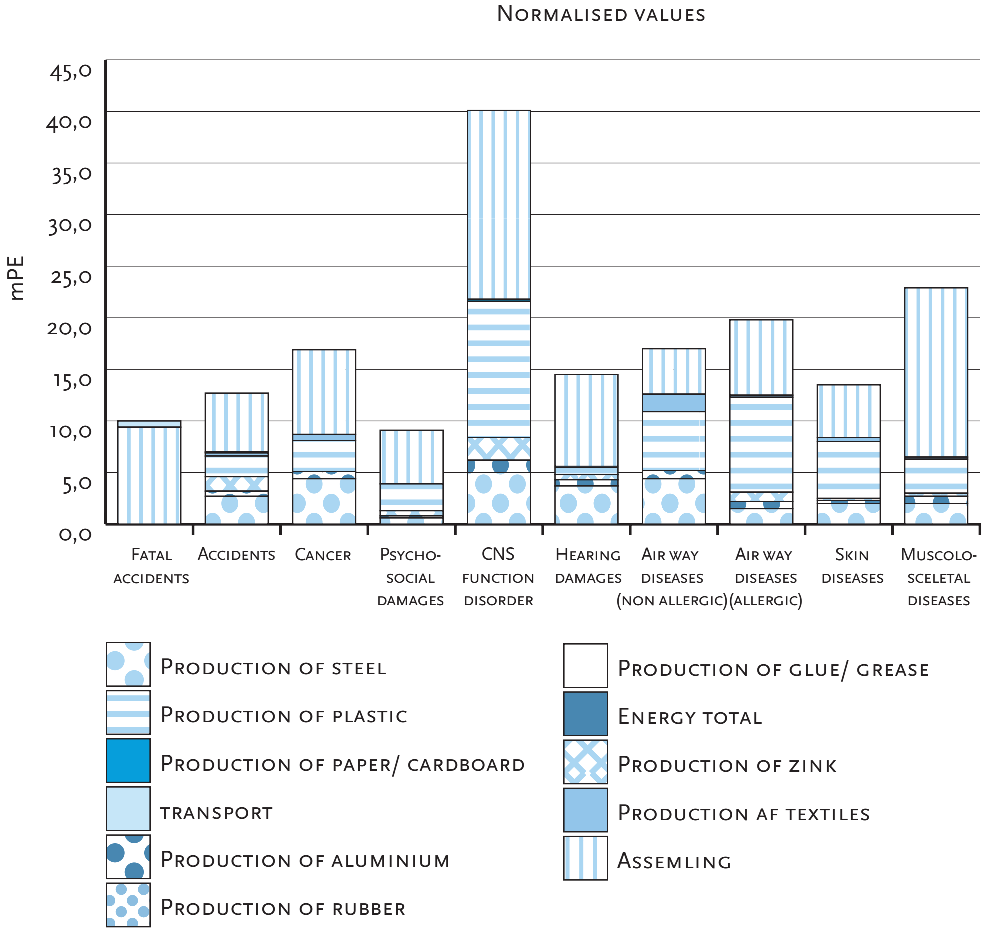
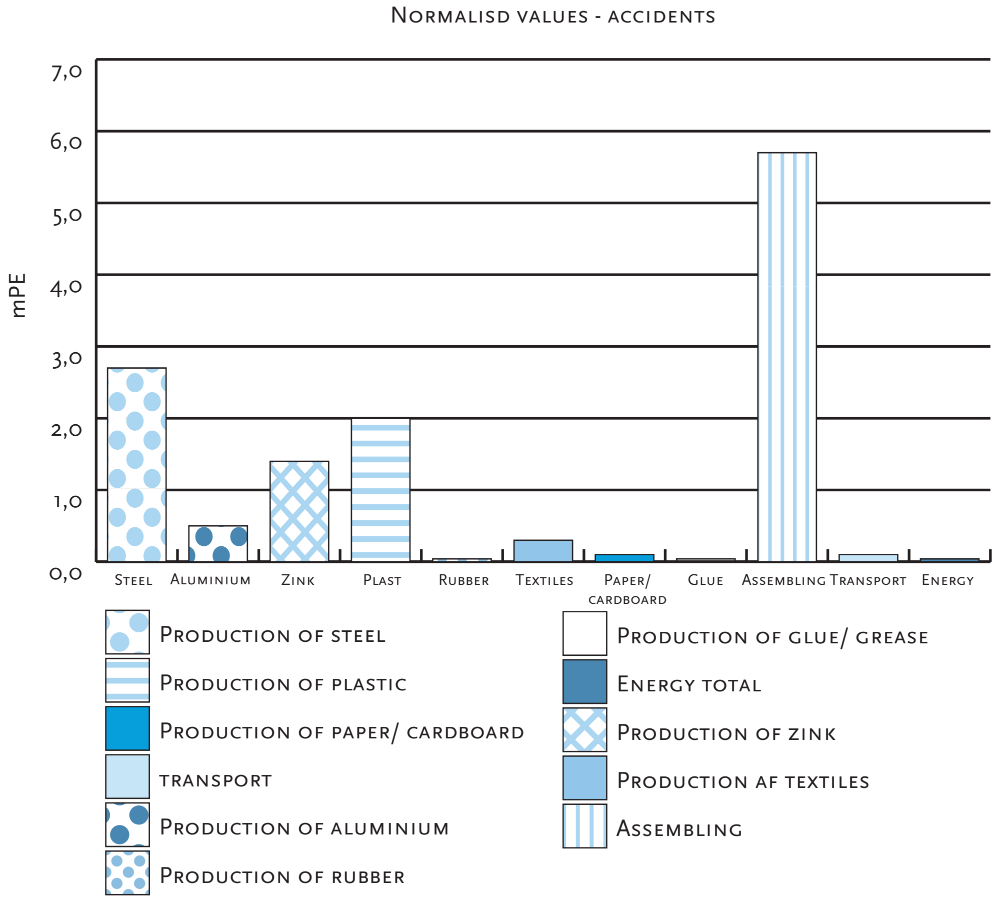


Figure 4. Normalised effects potential for the office chair

The effect potential measured in milli-person equivalents is an expression of how large a part of the annual impact on an average citizen that is caused by the production of an office chair. With respect to CNS-function damage only 25 chairs can be produced before the average impact is reached, while for skin diseases, 77 chairs can be produced.

The normalised results can be further detailed in the same way as was done in the impact assessment. In Figure 5 is shown how the single activities contribute to the expected accidents. It can be seen that the average annual impact from accidents in the assembly process is reached when each worker has assembled about 170 chairs. With respect to the steel used in the chair, the average annual impact is reached when steel for 370 chairs has been produced and processed into components.

Figure 5.
Normalised values for accidents in the life cycle of the office chair



3.4.9 Further interpretation

The results emerging from each step in the impact assessment are open for a more detailed assessment and interpretation. For each of the materials used in the product it is thus possible to distribute the impacts on the processes in the life cycle, normally 2-4 processes for each material. In doing so, a more precise assessment of where the largest impacts can be found is obtained. This increase in the level of detail can easily be achieved with the established inventory and may be a better basis for a dialogue between suppliers and producers about how to improve the working environment. In the case of the office chair an obvious choice will be to emphasise the need to avoid organic solvents, as these are a well-known cause of the dominating effect, CNS-function disorder.

Another possibility is to compare the results from an assessment of two different products, e.g. two office chairs. This type of comparison has not been performed in the current project, as only information on one office chair was available.

A third possibility is to compare the results from the working environmental LCA with the results from the other impact categories. With such a comparison the most obvious goal of including the working environment can be reached, i.e. that it is possible to see whether changes in choice of materials, components or manufacturing processes lead to an (unwanted) change in the working environmental impacts. This comparison with several types of effect categories has not been performed in the present study, as the results from the assessment of the impacts on the natural environment or resource consumption are not known.

The method provides new possibilities to integrate the working environment into LCA. It is, however, emphasized that it is often the conditions at and prioritisations of the single companies that is determining for the prevalence og working-related injuries. A company that has a certified management system for the working environment (e.g. OHSAS 18001) is able to document efforts that go beyond regulatory demands. By choosing such a supplier it is ensured that their working environment is the best possible within the given sector and that there is a possibility for improvement through dialogue.

4 Historical background and the future for working environmental LCA

This chapter gives a short description of the historical development of working environmental LCA. The description is chronological, the main focus being on the methods with a possibility of aggregating the impacts over the whole life cycle in line with the recommendations in the ISO 14040-series. A more detailed description of the methods can be found in the technical report from subproject 3.

4.1 Early Danish screening methods

The wish to integrate the working environment in LCA has primarily been voiced by the Scandinavian countries. Accordingly, the largest part of method development in the area has taken place in the same region.

In Denmark, the first method for integration of the working environment was developed in the project "Environmental assessment of PVC and selected alternative materials" (Christiansen et al, 1990). The suggested method is an expert-based screening of the chemical impacts, but without precisely defined criteria for the scoring of parameters. Such criteria were suggested in the pilot project to the Danish Material Development Programme (MUP) (Schmidt et al, 1991), and further refined in a Nordic report on Product Life Cycle Assessment (Schmidt et al, 1992) and in the main reports from the Material Development Programme (Schmidt et al, 1994).

The suggested criteria are all based on Danish or Nordic guidelines for classification and labelling of chemicals. This ensures that there is a good relation between current regulations and the decision support that emerges with an LCA of this type. It is however only possible to aggregate the information over the life cycle by using scoring systems with an unknown precision and prediction power.

4.2 EDIP

The first effort in the EDIP-project was a pilot project, the aim of which was to elucidate the possibility of developing a method for assessment of environmental, working environmental and resource aspects of the choice of materials (Jensen, Broberg and Winge, 1992). The main content of this pilot project is a screening method that to a large extent also builds on guidelines for classification and labelling of chemicals.

In the further development of the method in the main EDIP-project (EDIP97), it was a main concern that the results of the method could be aggregated over the life cycle of a product. The results of this development process are documented in the original reports from EDIP. The suggestion in the reports is that a combination of a sector assessment method and a process assessment method is used. The idea behind using a combined method is that this procedure is more operational because of a reduced need for data collection.

Neither in EDIP97 nor in the development of the PC-tool to be used with the method is performed a data collection that makes it possible to integrate the working environment with the other impact categories at the same level. Information on a few processes have been collected, e.g. production of steel and electricity, but the limited amount of data is not sufficient for a full integration, unless they are supplemented with large amounts of data collected specifically for the purpose.

In the initial proposal for the project ”LCA- method development, method improvement and consensus creation”, a need for adjustment and/or improvement of the method for better integration was identified. The present guidelines are one of the visible results of subproject 3, ”Integration of working environment in LCA”. In the following sections the development process in the project is described in some detail.

4.3 The first phase of the subproject

In the first phase of the subproject the existing tools for working environmental LCA were assessed. A very general conclusion from this work was that a process assessment method can give more precise results than a sector assessment. This precision is however achieved at the expense of the number of included effect categories and a significant increased data collection. It was not possible to give an assessment of the interaction of the method types because of the modest database and the lack of experience in form of cases.

A Swedish process assessment method from IVF (Bengtsson, 1995, 1996, 1997) was judged to give a more detailed result in form of many effect categories, but the data collection procedure is similar to EDIPs with respect to the necessary time. Furthermore, integration of the results achieved with the IVF-method with other impact categories requires that the principles for impact assessment are totally different from those used in EDIP. Use of elements from the IVF-method in EDIP is therefore associated with a large amount of work.

A Swedish sector assessment from IVL (Antonsson, 1996) was assessed to be very similar to the sector assessment in EDIP with respect to the level of detail and the demand of resources. The statistical basis is somewhat different in the two methods, but it is obvious that there are possibilities for co-ordination of the two methods when more experience has been gained.

As the examination of the existing methods could not point to obvious possibilities for improvement of the EDIP97-method it was decided to continue with the original project plan, i.e. testing of the method on a case. The expected result of this work was an extended and improved database of working environmental impacts in unit processes.

4.4 The second phase of the subproject

The first task in the second phase was to extend the database used in the sector assessment by following he guidelines in EDIP97, the first sector in the test being the plastic processing sector. The procedure for this is not described in detail, but the basic idea is that it shall be possible to calculate the impacts per functional unit, e.g. “the number of impacts per ton plastic tube.

The data for the sector assessment can be expressed in a simple formula:

$$\text{Impacts per functional "unit"} = \frac{\text{Number of injuries/damages in sector}}{\text{Amount produced in sector}}$$

As an example, the impacts from producing one kWh in Denmark can be calculated by dividing the total number of impacts in the electricity-producing sector with the total amount of electricity being produced.

Supply statistics in combination with information on work-related accidents and damages was seen to be a main element in the development of the few sector-related data in the original database. It was also stated in the reports that the sector assessment methodology was best suited for large and homogenous productions.

The database for reported accidents and injuries in relatively easy to establish. The Danish Labour Inspectorate publishes annually an overview of accidents and injuries in 49 sectors (two-digit DB93/NACE-code level), and this overview was detailed with kind help of the Inspectorate, i.e. the information was distributed on a larger number of sectors that could be identified by their 3-, 4- or 5-digit DB93/NACE-code. It should be remarked that the Danish DB93 sector code system is identical to the EU NACE-code system with respect to the first four digits, whereas the 5th and 6th digits are nationally specific.

The problem in using supply statistics was experienced by the project team already during the first efforts towards extending the database. Here, Statistics Denmark were asked to provide supply statistics for the plastic processing sectors, i.e. the sectors with the following NACE-codes:

Table 9. NACE-codes for plastic processing sectors in Danish statistics

Activity	NACE-code
Production of plastic products	252
Production of sheets, films, tubes, hoses and other profiles	2521
Production of sheets, films and other flat plastics	252110
Production of plastic tubes and hoses	252120
Production of plastic bars and profiles	252130
Production of plastic packaging	252200
Production of building articles	2523
Production of plastic sanitary articles	252310
Production of plastic building components	252390
Production of other plastic products	2524
Production of plastic office- and school products	252410
Production of table service and kitchen equipment	252420
Production of other plastic products	252490

A given company is in the statistics identified by the NACE-code that covers the main economic activity. This means that companies in other sectors also can be processing plastics, e.g. the chemical industry, toy producers, insulation companies, automotive and electronics industry etc. On the other hand the sectors in Table 9 may also have other activities than processing of plastics.

The information from Statistics Denmark showed that it was only possible to establish supply statistics on the four-digit NACE-code level, i.e. NACE-codes 2521, 2522, 2523 and 2524. In comparison, the statistics from the Danish Labour Inspectorate can be established on a five-digit NACE-code level, giving a possibility for an increased level of detail.

Furthermore, it turned out that the imported amounts in the supply statistics are allocated to both companies making their own imports and wholesale dealers, e.g. regional offices of multinational plastic producers, that subsequently sell the imported plastics to companies in all sectors. As about half of the amount of plastic raw material is imported by wholesale dealers, the actual amounts being processed in each of the four four-digit NACE-codes can only be calculated with a high degree of uncertainty.

In conclusion, the sector method described in EDIP97 is not well suited for handling sectors with a wide variety of products being produced, the main problems being achieving a sufficient level of detail as well as precision. It should be mentioned in this context that the above mentioned problems probably will be even more pronounced in sectors where there is both a Danish production and an import of raw materials, e.g. the steel industry.

It was therefore decided at the second phase of the project to develop an alternative method for sector assessments in the third phase of the project. This work has resulted in the revised method described earlier in the guidelines and the database that can be found in the appendix to the guidelines.

4.5 Future developments in WE-LCA

4.5.1 The short perspective

The described method gives the possibility of including the working environment along with the other effect types in LCA. A relatively extensive database has been developed and with this one of the most important barriers has been overcome.

As indicated previously there are however some limitations in using the method:

- The calculations must for the moment being be performed in a separate spreadsheet.
- Weighting following the principles in EDIP cannot be performed
- Only the Danish working environmental conditions are used as the basis for the assessment.

None of these three limitations are so serious that they in advance exclude the use of the method or a further development.

The two first limitations can thus be solved fairly simple in a further development of the EDIP-method and the associated PC-tool.

4.5.2 The longer perspective

The third limitation – that the assessment is based on Danish working environmental conditions alone – must be solved by international co-operation. This naturally requires a longer period of time to be solved. The framework of the method is however of such nature that other countries can produce a similar database, although there will be differences from country to country in the way the statistical information on working environmental impacts is collected. The first step is therefore to spread the knowledge about the new method and subsequently create an international co-operation on improvement of the database and adapt the method to include other types of working environmental impacts.

4.5.3 The long perspective

In the even longer perspective the efforts should be devoted to increase the precision of the working environmental LCA. It is obvious that development of a broader, international, database will increase the precision and applicability of the method, but using process assessment as an integrated part of the method can increase the precision further.

The Danish participation in international method development must therefore also be open for the possibilities in this area. Of special interest in this context are work place assessments and working environmental accounting. These tools are being developed and used in many Danish companies and they may form the basis for a more precise assessment of the working environment, without being too demanding in terms of use of time and resources.

The final target for working environmental LCA is therefore a method that with a common and international database gives the possibility for companies of using their knowledge about working environmental conditions in an operational way, also in the life cycle context.

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Appendix 1: The database

The database that was developed using the sector assessment procedure can be found on the following pages. An eletronic version can be downloaded from the web-site of LCA Center (www.lca-center.dk/cms/site.asp?p=2217).

As described in the present report, most information in the database has been established by using Danish Statistics concerning reporting of work-related diseases and accidents, respectively the Danish goods statistics. The information that has been derived in this way has a 6-digit DB93-code attached in the second column. DB93 is a Danish nomenclature for sectors, the main principle being a classification of economic activities. The first four digits are identical to those used in the analogous EU Classification system, NACE Rev. 1. The last two digits are Danish sub-divisions, giving an increased level of detail. These two digits may differ from Denmark to other countries.

For a few of the processes in the database, company-specific information has been used. These are characterised in the database by not having a DB93-code attached. The representativity of this information is not known, and the results of life cycle assessments where these processes play a significant role should be interpreted with great caution.

For the database on transportation impacts, it is suggested that the figures in bold are used in the calculations. These figures represent the aggregated impacts from the different transportation modes, e.g. transportation by truck is an aggregation of handling of goods at terminals and the truck transportation itself. In the same way, transport by ship is an aggregation of impacts when handling the goods in land-based terminals and impacts on-board traders.

The database all-in-all comprises more than 80 unit processes. The information in the present report can not at the moment be found in a computer programme, neither the EDIP PC-tool nor any other commercial programme. It should, however, be a very straightforward procedure to integrate the information in commercial LCA-programs as the data format is comparable to that for other impact categories.

Until the information has been integrated in a computer programme it is suggested that LCA-practitioners create a spreadsheet, where a parallel examination of working environmental impacts throughout the life cycle can be performed. It is judged that a parallel assessment can be performed in a few days when some experience has been achieved. The level of detail – or rather the possibilities for analysing the results - is not so good in a spreadsheet as in a specially designed LCA-programme. Therefore, a skilled spreadsheet manager may be a valuable member of the LCA-team.

Raw material production			Accidents and reported diseases per tons product									
	DB-93		Fatal accidents	Accidents	Cancer	Psycho-social damages	CNS function disorder	Hearing damages	Airway diseases (non-allergic)	Airway diseases (allergic	Skin diseases	Muscolo-sceletal diseases
	Energy carriers											
Note 1		Crude oil (1 liter)	1,2E-12	1,4E-10				3,5E-12			1,2E-12	1,3E-11
Note 1		Natural gas (1 Nm ^{3})	1,3E-12	1,5E-10				3,8E-12			1,3E-12	1,4E-11
		Coal	4,4E-08	7,8E-06			No information on reported diseases					
	401000	Electricity distribution (per kWh)	8,3E-12	8,6E-09	6,7E-11	2,5E-11	1,7E-11	6,6E-10	1,7E-10	1,7E-11	5,8E-11	7,1E-10
Note 2		Electricity production (per kWh, incl. Raw ma	1,2E-11	9,3E-09	6,7E-11	2,5E-11	1,7E-11	6,6E-10	1,7E-10	1,7E-11	5,8E-11	7,1E-10
	Metals											
	271000	Basic iron and steel (Denmark)		1,6E-04		1,8E-06	2,0E-05	2,2E-05	2,8E-06		4,6E-07	1,7E-05
Note 3	271000	Basic iron and steel (Sweden)	2,0E-07	1,1E-04		Not directly comparable to Danish statistics						
	274200	Aluminium production		7,5E-04	4,1E-06	4,1E-06	1,2E-05	4,5E-05	1,2E-05	8,1E-06	1,2E-05	1,5E-04
	274300	Lead, zinc and tin production		1,4E-02		7,3E-05	1,5E-04	2,2E-04		7,3E-05	7,3E-05	4,4E-04
	274400	Copper production (Denmark)		2,9E-03								7,2E-04
Note 4		Copper		6,0E-04			No information on reported diseases					
Note 4		Nickel	3,2E-05	1,9E-03			No information on reported diseases					
Note 4		Gold	6,0E-02	3,8E+00			No information on reported diseases					
	Other raw materials											
	141200	Quarrying of limestone, gypsum, chalk	2,3E-07	9,6E-06				2,3E-07		2,3E-07		2,3E-07
	142100	Sand and gravel production		2,4E-06			2,3E-08	1,6E-07	1,1E-07	2,3E-08	4,6E-08	1,6E-07
	201010	Saw milling	8,7E-07	2,2E-04	8,7E-07	8,7E-07	3,5E-06	1,8E-05	1,7E-06	2,6E-06	1,7E-06	2,6E-05
	211200	Manufacture of paper and cardboard	9,2E-07	1,6E-04		1,8E-06	9,2E-07	2,8E-05	9,2E-07	9,2E-07	1,8E-06	1,5E-05
	212100	Corrugated paper and paperboards		4,8E-04	1,2E-06	1,2E-06	5,2E-06	1,9E-05	1,2E-06	1,7E-06	7,6E-06	6,2E-05
	212500	Other articles of paper and cardboard	5,1E-06	9,9E-04		1,5E-05	5,1E-06	8,7E-05	5,1E-06	5,1E-06	1,0E-05	1,1E-04
	265100	Cement		1,6E-05	1,2E-07			3,1E-06	9,5E-07	1,2E-07	2,4E-07	1,1E-06
	266300	Ready-mixed concrete	9,1E-08	6,7E-06				6,3E-07	1,8E-07	9,1E-08		3,6E-07

Intermediates/final products												
		Wood products										
	202000	Veneer sheets, plywood, etc.		2,8E-04	2,8E-06		1,4E-06	6,9E-06	1,4E-06	4,1E-06	5,5E-06	4,6E-05
	203020	Builders' carpentry		8,8E-04	2,1E-06	4,2E-06	7,1E-06	4,7E-05	4,2E-06	9,2E-06	1,8E-05	9,9E-05
	205190	Other wood products		1,2E-03	7,2E-06		7,2E-06	7,2E-05		3,6E-05	3,6E-05	1,1E-04
		Chemical products										
	232000	Refined petroleum products		1,2E-06	3,8E-08		7,6E-08	3,4E-07	3,8E-08			3,0E-07
Note 5	2413-14	Basic organic and inorganic chemicals		9,8E-05		9,1E-07	1,8E-06	2,7E-06	3,6E-06		1,8E-06	6,4E-06
	241600	Plastics in primary forms		2,7E-04		6,2E-06				6,2E-06	3,1E-06	2,5E-05
	245110	Soaps and detergents		3,1E-04		2,2E-06	2,2E-06	4,3E-06	6,5E-06		2,6E-05	3,2E-05
	246600	Other chemical products		2,5E-04	8,6E-06				1,7E-05	8,6E-06	1,7E-05	1,3E-04
	251300	Rubber products		4,0E-03	2,4E-05		3,5E-05	1,3E-04	3,5E-05	8,3E-05	1,4E-04	3,2E-04
Note 6	**Plastic products**											
	252	**Plastic products - average**	7,6E-07	1,4E-03	4,5E-06	1,1E-05	3,4E-05	4,0E-05	1,4E-05	1,8E-05	4,8E-05	2,0E-04
	2521	Sheets, films, tubes, hoses, profiles		8,3E-04	6,0E-06	8,0E-06	2,2E-05	2,6E-05	1,0E-05	6,0E-06	1,8E-05	7,8E-05
	252110	Sheets, films, flat products		1,0E-03	6,1E-06	9,1E-06	3,3E-05	3,3E-05	1,2E-05	6,1E-06	2,4E-05	1,0E-04
	252120	Tubes, piping and hoses		4,6E-04	6,1E-06	6,1E-06		1,2E-05		6,1E-06	6,1E-06	3,0E-05
	252130	Bars and profiles		2,1E-03					4,2E-04			4,2E-04
	2522	Plastic packing goods		1,4E-03	2,3E-06	7,0E-06	3,5E-05	4,5E-05	4,7E-06	7,0E-06	2,8E-05	1,7E-04
	2523	Builders ware of plastic	9,1E-06	1,3E-03		9,1E-06	1,8E-05	7,3E-05	9,1E-06	9,1E-06	3,6E-05	1,3E-04
	252310	Sanitary products		1,3E-03		7,4E-05	7,4E-05			7,4E-05	1,5E-04	7,4E-05
	252390	Building products	1,0E-05	1,3E-03			1,0E-05	8,3E-05	1,0E-05		2,1E-05	1,3E-04
	2524	Other plastic products		2,2E-03	6,9E-06	2,4E-05	5,9E-05	4,5E-05	3,8E-05	5,9E-05	1,3E-04	4,6E-04
	252410	Office and school products		2,1E-03				2,4E-05		2,4E-05	4,1E-05	2,7E-04
	252420	Table service and kitchen products		1,5E-03			9,5E-05					8,6E-04
	252490	Other products of plastic		2,3E-03	1,3E-05	4,5E-05	1,0E-04	6,4E-05	7,0E-05	8,9E-05	2,1E-04	5,8E-04

	Intermediates/final products											
	Glass and ceramics											
	2612	Shaping and processing of flat glass		1,5E-03		4,0E-06	1,2E-05	3,6E-05		4,0E-06	4,0E-06	1,3E-04
	2613	Hollow glass (bottles, drinking glass)		1,9E-04	1,1E-06	1,1E-06		1,5E-05	2,2E-06	1,1E-06	4,3E-06	1,7E-05
	2621	Household ceramics		8,2E-03	2,7E-04	1,4E-04		6,9E-04	8,2E-04	1,4E-04	6,9E-04	5,3E-03
	Insulation											
	2614	Glass wool, glass fibres		1,0E-03		6,2E-06	8,7E-05	3,7E-05	1,2E-05	6,2E-06	6,8E-05	1,4E-04
	268220	Rock wool					Confidential information					
	Building products											
	264000	Bricks, tiles in baked clay		3,0E-05	4,1E-07			4,1E-06	8,3E-07		4,1E-07	5,8E-06
	266110	Concrete products	6,7E-07	4,5E-05	6,7E-07	3,3E-07		9,3E-06	2,0E-06		1,3E-06	8,7E-06
	266120	Concrete elements	5,9E-07	1,7E-04	2,0E-07		4,0E-07	6,3E-06	1,6E-06	4,0E-07	6,1E-06	1,1E-05
	266500	Fibre cement products		1,5E-04	4,5E-05			2,5E-05	1,3E-04		5,6E-06	2,5E-05
	Iron, steel and metal products											
	2722	Steel tubes		7,4E-04	3,1E-06		3,1E-06	1,8E-05	3,1E-06		1,7E-05	5,7E-05
	2731	Cold drawing of iron and steel		1,8E-04		5,7E-06		5,7E-06				1,1E-05
	2811	Metal structures	1,8E-06	1,5E-03	8,8E-07	4,4E-06	8,8E-07	6,3E-05	1,3E-05	7,0E-06	1,5E-05	8,5E-05
	2872	Light metal packaging, e.g. tin cans		1,5E-03			7,7E-06	7,3E-05	3,8E-06		5,0E-05	1,5E-04
	2874	Fasteners, springs, screw machine products		1,6E-03				1,3E-04		2,6E-05	5,1E-05	1,8E-04
	287590	Other finished metal products		2,6E-03	1,7E-05	7,6E-06	1,3E-05	1,5E-04	4,6E-05	1,1E-05	6,3E-05	2,8E-04
	2913	Taps and valves		6,5E-03	1,1E-05	1,6E-05	4,9E-05	4,4E-04	5,4E-05	4,3E-05	6,0E-04	1,4E-03
Note 7	285100	Surface treatment of metal					Cannot be calculated					
	Textiles											
	171	Preparation and spinning		3,8E-03				1,8E-04	2,1E-04	3,5E-05		4,2E-04
	172	Weaving		2,7E-03	4,2E-05			5,1E-04	1,7E-04		2,5E-04	3,4E-04
	177200	Pullovers and cardigans		1,4E-03		5,3E-05		2,6E-04	1,1E-04	1,6E-04	1,1E-04	4,3E-03
	191	Tanning and dressing of leather	5,8E-05	4,7E-03		5,8E-05		5,8E-05	1,2E-04		6,9E-04	6,9E-04
	321010	Printed circuit boards		1,8E-02			1,2E-03	2,9E-04	2,9E-04	2,9E-04	1,8E-03	5,0E-03

Final products/assembly												
	291220	Fluid pumps and compressors		2,8E-03		4,4E-06	8,9E-06	1,1E-04	3,6E-05	2,2E-05	1,7E-04	3,2E-04
	292310	Commercial cooling and refrigeration equip		4,4E-03		8,8E-06	4,4E-05	8,8E-05	7,1E-05	4,4E-05	1,7E-04	4,7E-04
	297110	Refrigerators, freezers		2,2E-03	4,2E-06	1,2E-05	1,7E-05	8,7E-05	1,7E-05		4,2E-05	2,8E-04
	297120	Stoves, ovens		5,3E-03				9,6E-05			1,4E-04	1,2E-03
	297190	Vacuum cleaners		5,1E-03		4,7E-05		4,7E-05	4,7E-05		1,9E-04	6,6E-04
	315000	Lighting fitting		3,7E-03		5,6E-05	7,4E-05	1,9E-04	1,1E-04	3,7E-05	1,5E-04	8,5E-04
	323010	Radios, televisions		8,3E-04			2,0E-05	2,0E-05	4,0E-05	2,0E-05	6,1E-05	5,7E-04
	361110	Chairs	5,6E-06	2,1E-03	1,1E-05	2,8E-05	4,5E-05	1,6E-04	1,7E-05	2,2E-05	6,2E-05	5,8E-04
	361200	Office and shop furniture		1,6E-03	1,1E-05	1,7E-05	1,1E-05	5,7E-05	2,9E-05		1,7E-05	1,8E-04
Transport			**Accidents and reported diseases per tons-kilometers**									
Note 8	**Transport by railway**		**6,0E-10**	**1,1E-07**	**6,0E-10**	**1,8E-09**		**3,0E-09**			**6,0E-10**	**1,9E-08**
	632110	Stations and goods stations, depots	6,0E-10	1,1E-07	6,0E-10	1,8E-09		3,0E-09			6,0E-10	1,9E-08
			Accidents and reported diseases per tons-kilometers									
	Transport by truck		**3,4E-10**	**3,1E-08**	**9,2E-11**	**4,6E-11**	**1,5E-11**	**9,2E-10**	**2,8E-10**	**7,7E-11**	**7,7E-11**	**3,0E-09**
	602410	Haulage contractor	3,2E-10	2,8E-08	7,7E-11	4,6E-11	1,5E-11	6,9E-10	1,7E-10	7,7E-11	6,1E-11	2,7E-09
	631100	Transportation of goods	1,5E-11	3,0E-09	1,5E-11			2,3E-10	1,1E-10		1,5E-11	2,8E-10
			Accidents and reported diseases per tons									
Note 9	**Transport by ship**		**5,6E-07**	**6,2E-05**	**9,7E-07**	**2,9E-07**	**7,1E-07**	**1,0E-05**	**1,0E-06**	**1,7E-07**	**1,6E-06**	**5,9E-06**
	611010	Carriage of goods		9,1E-07	2,4E-07	1,1E-07	1,1E-07	3,2E-06	2,4E-07	5,3E-08	4,5E-07	1,3E-06
	611020	Carriage of passengers	5,3E-08	2,8E-06	1,9E-07	1,6E-07	1,3E-07	1,3E-06	1,1E-07	5,3E-08	3,5E-07	1,5E-06
	632210	Commercial harbours		3,2E-06	1,1E-07	2,7E-08	2,7E-08	3,2E-07	1,3E-07	2,7E-08	2,7E-08	2,7E-07
Note 10		Traders and passenger ships	5,1E-07	5,5E-05	4,4E-07		4,4E-07	5,4E-06	5,2E-07	4,0E-08	8,0E-07	2,8E-06

Explantory notes

Note 1: Calculated for 1995-1997 on the basis of information in "Denmarks oil and gas production 1997". Energistyrelsen, 1998.

Note 2: This is a total number of accidents and diseases for both raw materials production (oil, gas and coal), and for the production and distribution of electricity. The number of diseases is underestimated because no diseases are reported for coal production.

Note 3: Calculated by using figures for Swedish steel production (average 1994 to 1996). Only data for accidents have been integrated.

Note 4: Calculated by use of information from WMC (1996 or an average of 1996-1997). WWW-address:http://www.wmc.com.au/

Note 5: The basic chemicals are made in the sectors 241300 "Manufacturing of other inorganic chemicals" and 241400 "Manufacturing of other organic chemicals".

Note 6: Notice the difference in level of detail in the DB93/NACE-codes (3-, 4-, 5-digit level). It is recommended that the highest level of detail is used.

Note 7: The goods statistics cannot be used for this sector because of differences in the collected information.

Note 8: Average figures for national and international transport with Danish carriers, because the accidents are reported for both national and international haulage.

Note 9: Notice, that in transport by ship accidents and diseases are reported per ton and not per ton-kilometer. The numbers also includes impacts from passenger transportation as most ships carry goods one way or the other. The amount of goods transported include transportation on Danish as well as foreign ships and the figures are therefore underestimated, because only the impacts on Danish ships are used in the calculations.

Note 10: For 1996 no diseases are reported. The average is therefore calculated for two years.

1 "EDIP97" is in the present report a common denominator for the methodology descriptions that can be found in Hauschild (ed.): Baggrund for Miljøvurdering af produkter, Miljøstyrelsen/Dansk Industri 1996, (English version: Hauschild and Wenzel: Environmental Assessment of products. Volume 2: Scientific background. Chapman & Hall, 1997), Wenzel, Hauschild and Rasmussen: Miljøvurdering af produkter, Miljøstyrelsen/Dansk Industri 1996, and in Broberg og Rasmussen: Arbejdsmiljø fra vugge til grav, Arbejdsmiljøfondet 1996.