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Practical Strategies for Acquiring Life Cycle Inventory Data in the Electronics Industry

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Abstract

The objective of this report is to help the electric and electronic industries to control the environmental performance of a product or process from a life cycle perspective, by giving an overview of the current environmental information system and guidance for deciding on strategies and methods for life cycle inventory data acquisition. However, the recommendations regarding strategies and methods are general and can be applied in other industries.

This report is based on two case studies, that is, two methods for data acquisition, "life cycle inventory data inquiries in the supply chain" and "life cycle inventory modelling" performed at Kraftelektronik and Ericsson, respectively. In addition, several interviews are made, e.g. with the French company Ecobilan Group and five life cycle assessment experts from Sweden and Denmark.

The current environmental information system involves deficient access of life cycle inventory data, especially regarding the manufacturing and assembling of electronic components. Acquired data is simply not made accessible to cover the needs. There is an incoherent picture of what information that is required and how it can be used beneficially. In addition, there is a need for life cycle inventory data acquisition strategies in order to utilise existing methods efficiently.

It is expensive to perform life cycle assessments today, mainly due to high costs in connection to the data acquisition. In addition, the data quality in the assessments does generally not meet the data quality requirements in ISO 14041, nor requirements to pass a review if the life cycle assessment is used to state a market position. The two methods for life cycle inventory data acquisition studied in this report, are both beneficial to involve in a strategy for developing an efficient environmental information system, mainly because they can provide high quality data, as defined in this study, for the whole life cycle of a product or process.

1 Reading Instructions

The chapters *Introduction, Objectives and Limitations*, and *Methodology* are all important in order to understand the scope of this study. The results can be found in *Final Conclusions* and *Recommendations*, but it could also be interesting to get a further description of the present access of life cycle inventory data for electronic components, which is presented in *The Access of Life Cycle Inventory Data for Electronic Components Today* in the chapter *Background*, as this can be considered as the platform for the study.

Knowledge about the life cycle assessment concept and tools is crucial in order to understand the discussions through out the report and such information can be found in *Life Cycle Perspective* in the chapter *Background.*

Further details regarding the procedures and outcome of the studied life cycle inventory data acquisition methods “life cycle inventory data inquiry in the supply chain” and “life cycle inventory modelling” can be found in case study 1 and 2, respectively.

Life cycle assessment practitioners can find detailed aspects regarding life cycle inventory data quality and life cycle assessment procedures related to this, in the chapter *Cost versus Quality – Pragmatics when Performing a Life Cycle Assessment*.

In *Further Work* possible development areas are discussed and some suggestions of how authorities and organisations can help the industry addressed.

2 Introduction

Historically, the electric and electronic industries have been regarded as "clean" industries, compared with heavy industries such as the steel and processing industries. In addition, it has been argued that the advent of electronics in fact has decreased the environmental impact of many activities, e.g. electronic communication has made it possible to reduce the environmental impacts arising from transportation and the use of paper [Beckman, 1997]. However, the fast development within the electric and electronic industries during the last decades has caused a widely spread use and consequently a mass production of electric and electronic products. This increasing volume of complex products, including many and often rare materials, is affecting the environment in various ways. At the same time the increased knowledge and concern regarding environmental issues has put pressure on the industry. This has forced the concerned businesses to adapt to a more environmentally sustainable production.

Environmental factors are of increasing strategic importance for the majority of companies and industries. The aim of developing strategies in the environmental work is to take advantage of the business opportunities that will inevitably arise from the changed market conditions due to sustainability requirements. At the same time it is important to minimise cost and risks, e.g. bad investments and environmental scandals. The authorities and the market supply the basic conditions, and it is up to each company to determine a strategy on how to apply to them. In order to utilise the business opportunities optimally, the companies must appear credible to their customers [Ingenjörsvetenskapsakademien et al, 1995]. In order to act trustworthy, the companies have to acquire knowledge about their own environmental impact and how they affect the total life cycle of the product.

Environmental data acquisition is the means to utilise the business opportunities optimally. This is why the acquisition of environmental data is so important and, as an important area, in turn requires strategies. Strategies enable good decisions on methods for data acquisition, which will contribute to an efficient environmental information system containing data with high quality. It will increase the access of life cycle inventory data so that the companies can get in control of the environmental performances of their products or processes, see *Figure 1*.

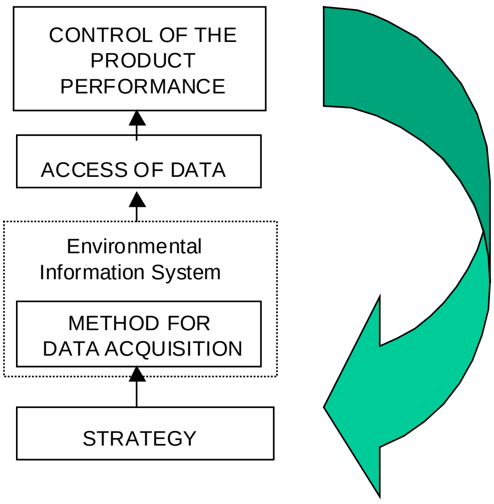

Figure 1 A schematic description of how strategies for environmental data acquisition facilitates the ability to control the environmental performance of a product or process.

A new environmental market situation has emerged and strategies, methods, practical tools, and standards to handle these issues are still under development. This report is primarily dealing with strategies and methods, but also addresses standards and practical tools regarding the acquisition of life cycle inventory data in the electric and electronic industries.

3 Objectives and Limitations

The objective of this report is to help the electric and electronic industries to control the environmental performance of a product or process from a life cycle perspective, by giving a status overview of the current environmental information system and guidance for the handling of environmental information. Thus, the compilation and structuring of experience and knowledge aims at supporting the development of an efficient environmental information system.

This report will focus on how to approach strategies for life cycle inventory data acquisition, mainly for electronic components[1], and may thereby supply valuable information to environmental managers, trade organisations, life cycle assessment practitioners and others involved in the data provision or use.

The reason for focusing on life cycle inventory data is because life cycle assessment involves the whole supply chain entailed in the production. Life cycle inventory data also often includes data used in other environmental tools, such as the environmental product declaration (EPD). Further, experience shows that life cycle inventory data is difficult to acquire, due to the comprehensive extent.

The outcome of this study is an overview of the current environmental life cycle information system for electric and electronic products, including weaknesses, opportunities and suggestions of how to improve the system. Specifically, the result involves:

- An overview assessment of the access of life cycle inventory data for electric and electronic products today,
- A summary of different methods applied to obtain life cycle inventory data for electric and electronic products, and identified obstacles, i.e. time consuming and costly parts, in the acquisition procedures,
- Assessments of two methods for data acquisition, namely “life cycle inventory data inquiries in the supply chain” and “life cycle inventory modelling”,
- Life cycle inventory data quality requirements according to ISO 14041 and life cycle assessment experts in Sweden and Denmark and related cost aspects, and
- Recommendations for approaching strategies and overcome obstacles in life cycle inventory data acquisition, mainly regarding electronic components.

To clarify the extent of this report, it should be emphasised that this does not deal with the practical integration of data supporting many different environmental tools in one

[1] Electronic components are components in which the current primary consists of electrons that are moving through vacuum, gas or semiconductors [Peterson, 1999] and they can be categorised in several ways. One is to divide them into passive components, e.g. capacitors and resistors and active components, e.g. diodes and integrated circuits.

environmental information system; neither does it handle the interpretation problems related to the handling of data, although the issue is addressed.

4 Background

Electric and electronic appliances are complex products and the production chains are often long and international, and consist of many actors. In addition, the trade often involves a variety of suppliers or wholesalers, which are engaged depending on the current price and access of a product at the so-called spot-market. These are conditions that complicate the flow of the information needed to control the environmental performance of the products. Moreover, the fast product development within parts of the electric and electronic industries entails difficulties in the form of moving targets, i.e. frequently modified product designs make it difficult to keep up with the updating of information along the production chain.

Data quality aspects constitute an important aspect to consider in a life cycle inventory data acquisition strategy. The user of a life cycle inventory data set also defines its data quality, i.e. the reliability, accessibility and relevance in relation to the specific application. As a platform for the discussions regarding data quality in this study, a description of the data quality concept developed at the Centre for Environmental Assessment of Product and Material Systems (CPM) is introduced in this chapter. The data quality concept is discussed in relation to the case studies, in order to state examples of the interpretation of the concept.

The access of life cycle inventory data today is different depending on which part of the life cycle that is studied. For specific steps, e.g. the manufacturing of electronic components, the access of life cycle inventory data is scarce while for the extraction and processing of raw material there are more easily accessible data. At the end of this chapter a schematic description of the data access in all life cycle steps is presented.

4.1 Material Content of an Electric or Electronic Product

There are several ways for the individual company to meet the environmental demands, for example by developing management systems in order to manage and control environmental impacts; make environmental product declarations (EPD) to communicate information to the customers and be comparable with similar products; perform life cycle or risk assessments to avoid sub-optimisations etc.

This study focuses on the life cycle assessment (LCA) tool, but also addresses the material content of a product since it is of strong interest to the electric and electronic industries. In addition, data needed for LCA also involve the material content of a product. For example, the raw material used in the production of a capacitor could constitute a part of the final product and thus be included in the product material content. However, the supplied raw material could also be consumed, i.e. emitted, somewhere in the production processes and thereby be excluded from the final product material content [Segerberg, 1995]. In both cases, life cycle inventory data would require information regarding all supplied raw material, together with a description of where it came from, how it is used and who will receive it in the next step. Hence, life cycle inventory data can be viewed as an extension of the material content of a product.

However, the environmental concern today, in the Swedish electric and electronic industries, is mainly focused on the huge waste deposits and the use of finite virgin raw material [SITO, 1999a]. It is based on the fact that the end of life deposits constitute a great risk to the environment in terms of leaking of hazardous substances, such as brominated flame-retardants, and that the use of finite virgin raw material is depleting the resources on earth.

There are also economical benefits in minimising the waste deposits and the exploitation of resources, as well as in reusing and recycling electric and electronic devices. In fact, global competitiveness in the industry will depend on its ability to minimise waste, enhance productivity, minimise material costs, and minimise the use of hazardous material because of regulatory costs and the high cost of waste disposal [MCC, 1993]. Among others, a discussion on EU level is dealing with the producer responsibility regarding electric and electronic waste and a directive is expected to be presented during 1999 [SITO, 1999b].

4.2 Life Cycle Perspective

Another approach to the environmental issues, besides the focus on the material content of a product, that are widely applied today, is the life cycle perspective. The system analysis in LCA proceeds from the product or function and follows the processes, from cradle to grave see *Figure 2*. The aim with LCA is to get a holistic view of the environmental impacts in a product's whole life cycle, i.e. the products environmental performance. The holistic approach in LCA implies that all activities and flows within the product's life cycle are of equal importance and must be addressed in the assessment. Some flows may not be considered as environmentally significant in the assessment, but the arguments for this should always be addressed explicitly.

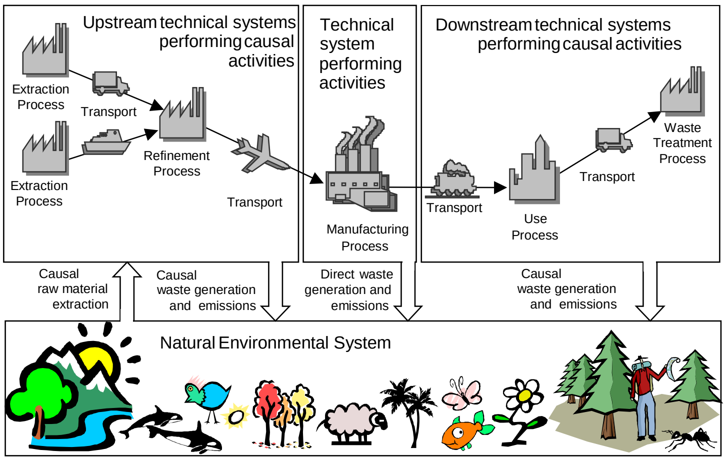

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Figure 2 Schematic picture of the life cycle assessment concept. [Carlson and Pålsson, 1998b]

4.2.1 Life Cycle Assessment (LCA) Tool

LCA methodology is developed to systematise the use of LCA as a tool. The LCA procedure is standardised by ISO [ISO 14040, 1997], which defines LCA as a "technique for assessing the environmental aspects and potential impacts associated with a product, by

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

The concept "product" in LCA refers not only to material products but also to services. A life cycle model, see *Figure 3*, is constructed from the procedure.

In the goal and scope definition phase, the purpose of the LCA study is stated and used to specify the requirements for the modelling. According to ISO 14041 the goal "shall unambiguously state the intended application, the reason for carrying out the study and the intended audience" [ISO 14041, 1998]. The methodology is chosen with respect to the purpose of the study, i.e. the questions being posed. The requirements for the modelling can include assumptions, limitations, allocations i.e. division of environmental loads if one or more products share one or more processes [Baumann and Tillman, 1999], system boundaries, and data requirements.

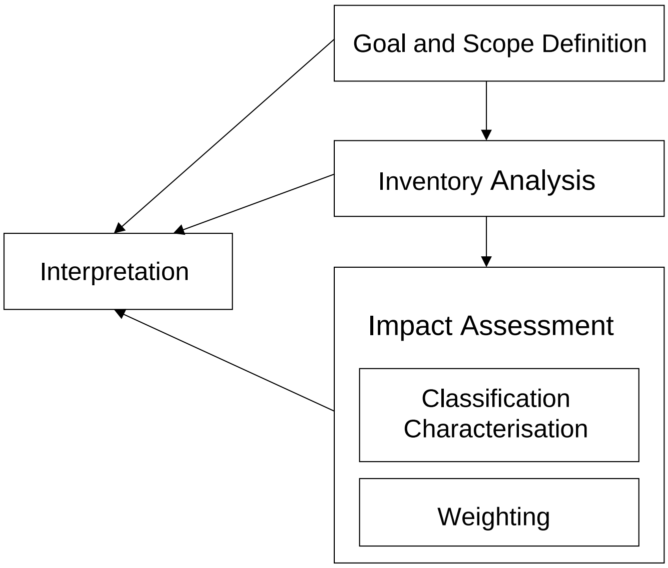


Figure 3 The LCA model in ISO 14040 based on the standardised LCA procedure.

The life cycle inventory (LCI) analysis results in a flow model of a technical system. The model may be described as an incomplete mass and energy balance over the system, where only the relevant flows are considered, i.e. substances regarded as harmful to the environment, more or less scarce resources etc [Baumann and Tillman, 1999].

The life cycle impact assessment aims at describing the environmental consequences of the environmental loads quantified in the inventory analysis. There are several different methods to interpret the life cycle inventory results and they all vary in the degree of information aggregation and the basis for weighting or prioritising between different environmental impacts.

Today, there are a lot of LCA tools, e.g. software packages found at the web site DEsign for Environment Decision Support [Manchester Metropolitan University et al, 1999], and literature regarding LCA methodology, e.g.

- ISO 14040 Life cycle assessment – Principles and framework [ISO 14040, 1998],
- ISO 14041 Life cycle assessment – Goal and scope definition and inventory analysis [ISO 14041, 1998],

- ISO 14042 Life cycle assessment – Life cycle impact assessment [ISO 14042, 1999] (Committe Draft),
- Livscykelanalyser LCA [Naturvårdsverket, 1996] (in Swedish),
- The Hitchhiker's Guide to LCA [Baumann and Tillman, 1999], and
- Nordic Guidelines on Life-Cycle Assessment [The Nordic Council of Ministers, 1995].

However, there is not much information regarding the acquisition of data and the quality issues belonging to this. This is one of the reasons for making this study.

4.2.2 Life Cycle Inventory (LCI) Data

When performing an LCA it is not sufficient to know what the product consists of, but in addition it is desirable to know what environmental impact the product may cause, for example, during the raw material extraction, processing, transportation, use phase and waste treatment. The environmental impact that these activities cause may derive from exploiting resources like finite virgin raw materials, emitting substances to air, water, and land etc.

In *Figure 4* a definition of an LCA data set is presented, according to the Swedish national competence centre Competence Centre for Environmental Assessment of Product and Material Systems (CPM) at Chalmers University of Technology [Pålsson, 1997]. CPM initiated the standardisation of a common LCA data documentation format in ISO 14048 [ISO 14048, 1999] and has developed the data documentation format SPINE [CPM, 1999] [Steen et al, 1995].

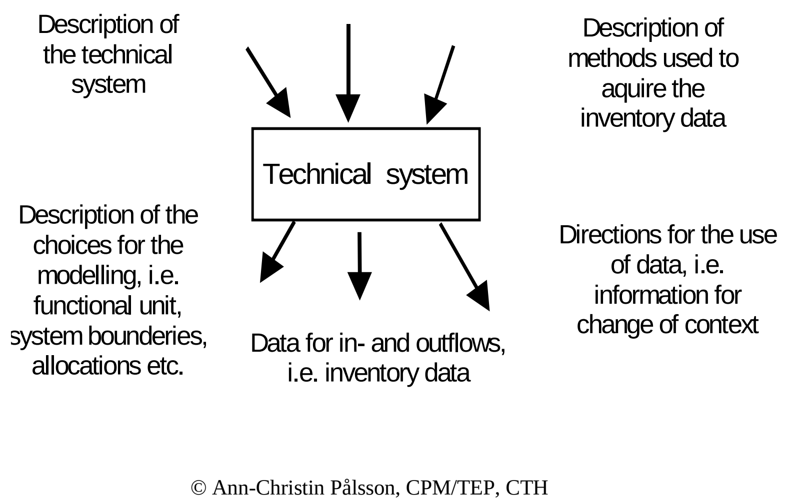


Figure 4 A schematic description of the definition of an LCA data set, according to the Swedish national competence centre CPM at Chalmers University of Technology in Göteborg. [Pålsson A-C, 1997]

A data documentation format should enable an efficient data treatment, storage, updating procedure, communication etc. There are several different data documentation formats available today, for example SPINE [CPM, 1999] and SPOLD [SPOLD, 1999]. The software for both the formats contain text fields, flow charts, and tables for LCI information. In other aspects, the two formats are quite different. The formats are compared and mapped in the report "An Assessment of the SPOLD-format, with comparisons between SPOLD and SPINE" [Erixon and Ågren, 1998].

4.3 The Data Quality Concept as Defined at CPM

The data quality concept that constitutes the platform for discussions in this report is developed at the Centre for Environmental Assessment of Product and Material Systems (CPM) at Chalmers University of Technology. It is built on three basic data quality aspects:

- Reliability
- Accessibility
- Relevance

Each of these three aspects is equally necessary in order to assess or judge the quality of a specific piece of data in a specific situation of data use. When the quality requirements, according to this definition, are fulfilled for a specific data set it will be referred to in this report as "perfect" LCI data. The aspects are explained in the following sections and a schematic picture of the concept can be viewed in *Figure 5*.

- **Reliability**
  Reliability concerns the degree to which one may have confidence with data. This is based on data's numerical precision and the credibility of the data origin.

Precision
Data precision concerns data's lack of bias and its uncertainty limitations. Precision is a valueless (pointless) entity, unless all other quality aspects of data are explicitly known.

Credibility
Credibility concerns trust, and how well a data user, a reviewer or the public trust, for example a precision statement concerning the data.

Transparency
Credibility is built on transparency. Unless data can be transparently reviewed, it can not be generally trusted and is therefore not credible.

Competence
Credibility is built on competence. Without competence concerning specific technology, specific equipment or actual state of affairs credibility may not be reached. For example, competence in performing life cycle assessments and in producing LCA reports does not imply competence in waste management procedures or environmentally significant aspects of production of electronic device.

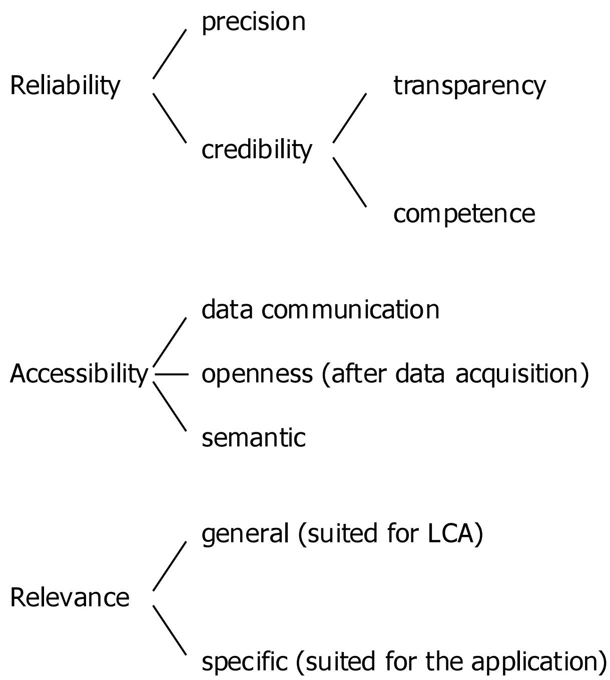


Figure 5 A schematic description of the data quality concept used at CPM. [Carlson and Pålsson, 1999]

- **Accessibility**
  Accessibility is not an intrinsic property of data quality, but is a property of how accessible a data set or a part of a data set is, for data users. Unless others can access data, regardless of its credibility and precision, it is useless.

  Data communication
  An important aspect of accessibility is data communication. Data needs to be mobile, it needs to be moved between its original location to where it is needed. This may be done in many different forms, such as via mail, or in a specifically developed electronic format.

  Openness
  One common problem with specifically LCI data is that it may not be acquired from data generators of different kinds, often because secrecy barriers hinder them. Regardless of data's mobility, credibility and precision, it is useless unless it can be moved from its origin to the data user.

  Semantics
  Data is often originally acquired in a specific context, i.e. in a specific site within a specific plant with a specific technology and where the culture has formed its own jargon. Regardless of openness and precision, when data is documented and otherwise described by use of such jargon, others may not understand it. For data to be truly accessible it also needs to be semantically accessible, i.e. understandable for the intended users.

- **Relevance**
  Quality is a contract between supplier and user. For data quality to exist, data needs to be relevant to the user's domain of interest.

  General
  For LCI data the general data quality requirement is that data reliably is suited for LCI (see also Reliability above).

  Specific
  When using data in a specific study the data needs to be suited for the study. No quality aspect can overrule this.

4.3.1 The Data Quality Concept in Relation to the Case Studies

The two methods for LCI data acquisition, "LCI data inquiries in the supply chain" and "LCI modelling", described in the case studies in this report have the capability of providing data with equal quality, according to the data quality concept derived at CPM.

A common point of view is that the inventory always provides data with higher numerical precision, as it is measured in practice and not estimated. However, the methods are both in some way models of real systems, one based on empirical studies and the other on experience and literature studies, and the quality of the data provided by these methods varies depending on the performance in each single case. For example, practical measurements at a site can be incorrectly performed, analyses or calculations negligently made, and, in addition, the information can be misinterpreted or transformed in the communication between the different levels of data aggregation. This can result in an undetected low numerical precision that decreases the data quality, and in comparison to a good LCI model is less representative in relation to the real system.

4.4 The Access of Life Cycle Inventory Data for Electronic Components Today

The access of LCI data for electric and electronic components varies depending on which part of the product chain you study. As earlier mentioned, the access of LCI data regarding the manufacturing and assembly of components is scarce. However, in other parts of the life cycle, such as the raw material extraction for metals, there are some LCI data to be found in databases, LCA reports, public environmental statements published by companies etc. In *Figure 6*, there is a schematic overview mapping of the access of LCI data in the product chain of electronic components.

4.4.1 Raw Material Extraction and Processing

Historically, heavy industries such as ore-mining, metal processing, refining and manufacturing of chemicals etc. were among the first businesses to have environmental constrains set by the government, and accordingly the first who worked with these aspects. These industries have gained much experience in the process and have consequently established a tradition in having good control of their activities.

4.4.2 Environmental Management Systems

As the implementation of environmental management systems (EMS) is increasing in number within the industry, companies are gaining control of the environmental aspects in their own production. The first step in this procedure is usually to collect site data for the production as a whole, that is, to get local control of the production plant as a whole [Carlson and Pålsson, 1998b]. The site data can be obtained by measuring and analysing the air and water emission from the production plant. In order to use this type of data for LCI, allocations, i.e. division of environmental loads if one or more products share one or more processes, often has to be made.

The next steps in the development of an EMS involve an extended control that also includes environmental aspects of technical systems controlled by business partners, e.g. by the choice of suppliers [Carlson and Pålsson, 1998b]. This step may also include a division of the total environmental load originating from the production plant as a whole, so that detailed information about the separate processes and/or products is gained. Hence, if one or more products share one or more processes, proper allocations, i.e. divisions of environmental load, can be made that would enable and improve any assessment of the production.

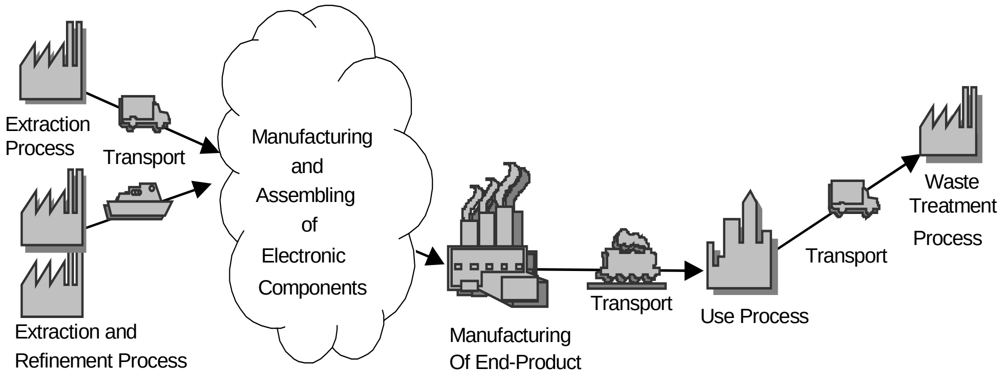


Figure 6 A schematic description of the access of LCI data in the production chain of electronic components. The cloud implies that the access of data regarding the manufacture and assemblage of components is scarce.

Moreover, the development of an EMS often involves an improvement of routines for documentation, communication and updating of information [The Council of the European Communities, 1993][SIS, 1996], which all support and simplify LCA and other environmental assessments that rely on this information. To get a certified environmental management system, e.g. by the EMAS (Eco-Management and Audit Scheme) regulation, the environmental aspects also have to be communicated in a public environmental statement. In addition, some companies have to consider governmental constraints regarding environmental aspects, which also can involve official environmental reporting [Erixon and Ågren, 1997].

4.4.3 Inquiries to Suppliers

Those companies that have gained control of their own environmental aspects, or those who have received a lot of inquiries about environmental issues such as the size of physical flows or the internal management system from clients and customers, usually turn their attention towards the suppliers. Thus, this may be a consequence of developing an EMS, or a consequence of environmental pressure from clients or business partners. By sending questionnaires or making inquiries directly to the suppliers, the companies try to collect information about the environmental aspects in the earlier or later activities in the product chain [Nordic Council of Ministers, 1998]. The questionnaires used are often separately developed, but there are some examples of formats designed to provide a common format, e.g. questionnaires developed within the SPOLD group, the Swedish Product Ecology

Association, the Centre for Environmental Assessment of Product and Material Systems [Carlson and Pålsson, 1998] and the Swedish Institute of Production Engineering Research [IVF, 1999].

4.4.4 Dismantling the Product

The waste industry has made some analyses of electric and electronic appliances in order to know how the products can or should be handled in the end of life phase [Stena Technoworld AB, 1999]. Thus, by sundering the products into pieces the materials and amounts of substances may be analysed and, in addition, a systematisation of the disassembly procedures can be developed, e.g. to be included in a Design for the Environment (DFE) tool for electric and electronic products. Such a tool can include databases, software tools for environmental analyses such as LCA, environmental support in the construction and disassembly procedures etc.

Likewise, many manufacturers of electric and electronic products, e.g. Ericsson, disassemble parts and components to learn about the material composition [Lenell , 1999] or commission others, such as the Swedish Institute of Production Engineering Research, to check the content against certain environmental requirements [Lindgren, 1999]. The dismantling is often done to be able to meet the future producer responsibility that will force the producers of electric and electronic devices to take responsibility for the reuse, recycling and/or final disposal of the products. The dismantling can generate and improve qualified guesses about the product material content. All in all, the analyses of dismantled products are often made due to not having enough information about the material content of the products from the suppliers and manufacturers in the product chain.

5 Methodology

This report is based on two case studies, several interviews and literature studies. The two methods for data acquisition “LCI data inquiries in the supply chain” and “life cycle data modelling” assessed in case study 1 and 2, respectively, is included in this study because they have the capability to generate complete LCI data. Other methods addressed in this report, such as collecting literature data or dismantling the product and analysing the material content, can only supply isolated parts or fragments of the LCI data needed to make an LCA of an electric or electronic product.

The first case study is performed at Kraftelektronik AB and it consists of a life cycle data inventory test for a specific product. The inventory is based on twelve questions regarding the technical description and environmental aspects of the manufacturing processes, and the ways in which the given data are acquired. The result is evaluated in regard of communication paths, time aspects, and quality of supplied information and it aims a giving guidance in the use of this method.

The second case study, made at Ericsson Enterprise Systems AB, consists of studying two methods for modelling electronic components in to LCI data groups. Life cycle data models constitute a feasible alternative to the data acquisition method in case study 1 by generating LCI data estimations for groups of electronic components. The utilisation of such models is both cheaper and faster than making LCI data inquiries in the supply chain and it generates estimations. In this study the two models are qualitatively evaluated but an extended evaluation is planned at Ericsson Enterprise Systems later this year.

The telephone interview with Hélène Lelièvre, an LCA practitioner who works at Ecobilan Group in France, is performed to compare the conditions in Sweden with those in another European country. Thus, it summarises Ecobilan's experiences internationally regarding the acquisition of LCI data for electronic components and the identification of obstacles in the process.

To find out the practical demands on LCI data used to evaluate the environmental performance of a product by LCA, five of the leading experts in LCA in Sweden and Denmark have been interviewed. By doing this, different ambitions for data quality and data acquisition strategies can be related to different ambitions for life cycle assessments.

Finally, the recommendations for data acquisition strategies are based on the conclusions from the case studies and interviews.

6 Case Study 1: Life Cycle Inventory Test at Kraftelektronik

This case study aims at summarising and evaluating a test for acquiring LCI data in the supply chain of Kraftelektronik, in order to give guidance in the use of this method. The collection of data has been made through inquiries to the supplier.

The method is included as a case study because it has the capability to generate complete LCI data. Other methods addressed in this report, such as collecting literature data or dismantling the product and analysing the material content, can only supply isolated parts or fragments of the LCI data needed to make an LCA of an electric or electronic product.

The results from this case study consist of a description of the communication paths and time aspects. Further, it includes an evaluation of the LCI data that each supplier could provide and a discussion concerning generalities of the outcome of the inventory.

6.1 Kraftelektronik

Kraftelektronik designs and manufactures electrical power transformation equipment and control systems for the industry and track bound vehicles all over the world. The company started in 1935 and the business volume 1998 was about 9,7 million US$ (80 million SEK) and it has approximately 80 employees.

When Kraftelektronik started to develop their environmental management system (EMS) during 1998, the focus was on the work environment and quality system. The company is certified according to the quality system ISO 9001. The preparatory environmental assessment was finished during the spring of 1999 and the goal is to be certified according to ISO 14001 in the turn of the year 1999–2000. The Production Manager and Quality Assurance Manager are running the practical environmental work and they are also part of the process development group and the company management. According to the Quality Assurance Manager, Håkan Johansson, the main environmental target at the moment, is to get control of the activities at Kraftelektronik by developing the Environmental Management System (EMS) and to meet the most common requirement from the big customers. The most common requirement from the customers is a guarantee that the product does not include any substances from the Observation List of the National Chemicals Inspectorate.

The chemicals used in the industrial activities at Kraftelektronik are identified. The problem is that it is very difficult to find out what the purchased components contain. This knowledge could lead to better environmental product declarations (EPD) for the customers and could be a base for decisions at Kraftelektronik, regarding the choice of suppliers when selected from an environmental performance perspective.

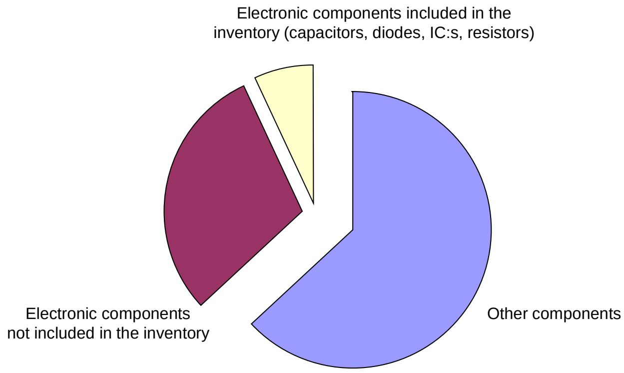
All in all, Kraftelektronik expects that the co-operation in this study will give them a starting point for further work in this area, e.g. by improving the environmental contacts with their suppliers. The LCA approach in this study can be used to reach the company's objectives since e.g. knowledge about the product content also is required in the LCI data set, see under the headline *Material Content of an Electric and Electronic Product* in the chapter *Background* for further explanations.

6.2 Description of the Inventory

A specific product was chosen by Kraftelektronik to be subject to the life cycle data inventory. Out of the 282 components, i.e. semi-manufacture and raw materials, which are purchased to manufacture the product, about 30% are electronic components, that is, resistors, diodes, capacitors, or integrated circuits, see *Diagram 1*. A total number of ten companies have been identified as possible suppliers for the electronic components.

When the suppliers were identified, one, two, or three electronic components were chosen for each supplier to be included in the data inventory subset. The choices were made according to the number of accessible components for each supplier, from a purchase list containing all components included in the product. The upper limit was set at three components for each supplier, see *Table 1*. The inventory is thereby performed in regard of nineteen electronic components, which constitute 20% of all electronic components in the product. Since all electronic suppliers are included, the subset was considered to be a representative amount of the case study.

Diagram 1 Components that constitutes the product in the life cycle inventory



However, one of the suppliers is excluded from the case study. The supplier in turn had difficulties to make inquiries to their supplier since they were not formally agents for the electronic component they had supplied.

At first, each supplier was contacted by phone and later, a letter and a questionnaire, containing twelve questions, were sent by e-mail, fax or/and by mail. The questionnaire was written in English so that the company could forward it directly to a supplier outside Sweden, see *Appendix 1* to find the questionnaire. The questions were based on the definition of an LCA data set presented under the headline *Life Cycle Inventory Data* in the chapter *Background*. However, considering the time aspects in this study, several limitations were made in order to simplify the sheet. Otherwise, it would have taken too long time to collect and assess the questionnaire.

The contacts were established in early April or May 1999. The first deadline to receive the answers was set to the end of May, but were later postponed to the end of June. When an answer came in, it was analysed to decide whether a new extended inquiry was going to be made or not. At the end of May a reminder was sent to all the suppliers that had not answered. At the end of June a short interview was made with the companies that still had not answered the inquiry in order to find out the reasons for this, i.e. identify the obstacles for the acquisition of data.

Table 1 The table enumerates the nine suppliers' of Kraftelektronik that are included in the inventory, together with the number and type of electronic components.

Supplier	Number of components	Type of electronic components
1. ACTE NC Sweden AB	3	capacitor, IC, resistor
2. ELFA AB	2	capacitors
3. IE Komponenter AB	1	IC
4. Jakob Hatteland Electronic AB	2	capacitor, resistor
5. Modern Elteknik AB	3	1 diode, 2 IC:s
6. OEM-Component AB	3	resistors (cylindrical metal film)
7. Pelcon Electronics AB	1	diode
8. Rune Ohlsson Electronics AB	1	capacitor (electrolytic)
9. Universal Import Elektronik AB	3	resistors (ceramic encased and silicone-coated)
Totally:	*19*	*5 capacitors, 2 diodes, 4 IC:s and 8 resistors*

6.3 Results from the Inventory

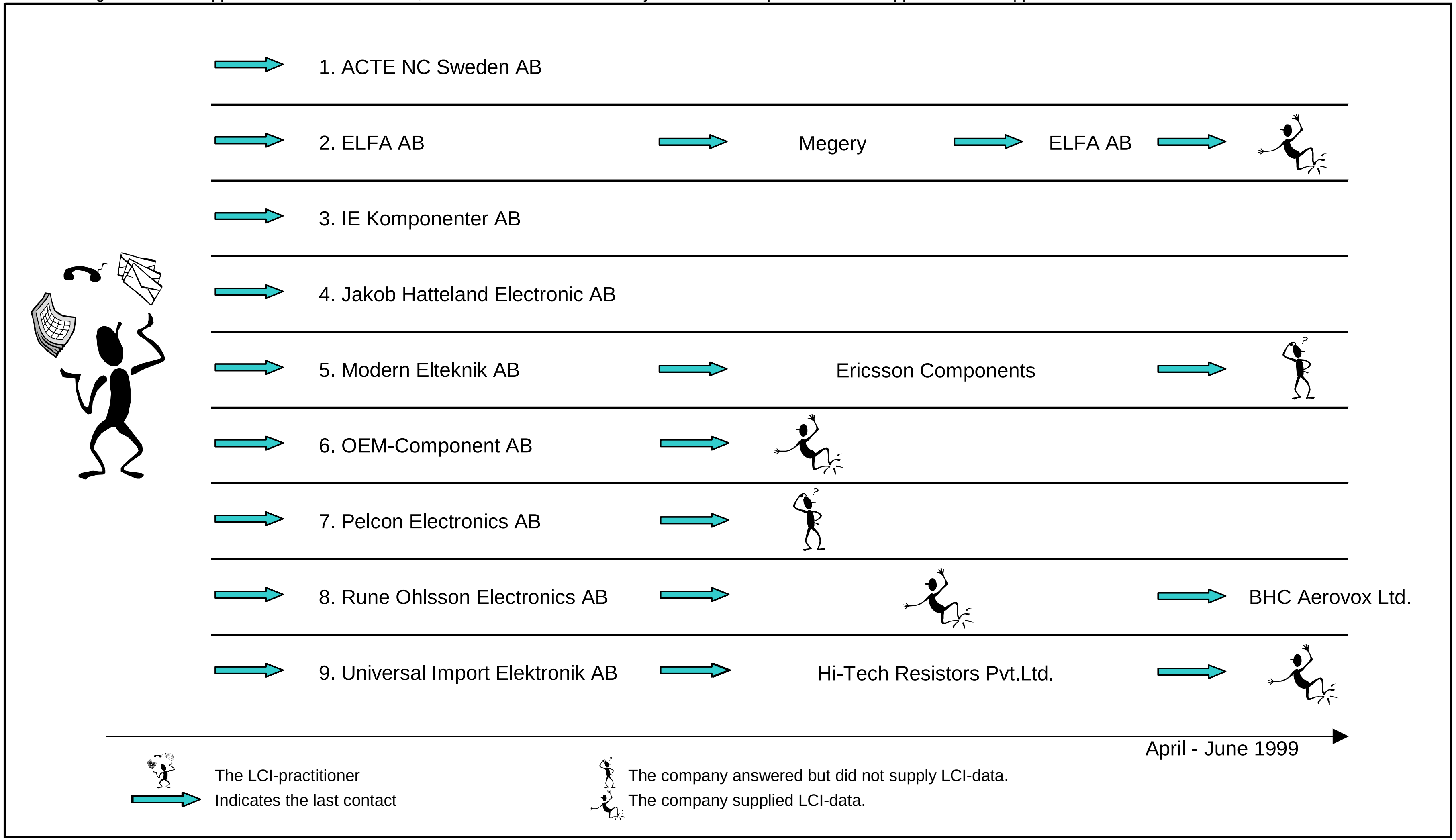
The results from this case study consist of a description of the communication paths and time aspects. Further, it includes an evaluation of the LCI data that each supplier could provide and a discussion concerning generalities of the outcome of the inventory. The contacts with each supplier are treated separately in *Appendix 2*.

6.3.1 Communication Paths and Time Aspects

Out of the nine suppliers, four came up with some kind of LCI data, two answered that they could not supply any data due to resource priorities, and three did not respond to the inquiry at all, see *Figure 7*. The companies that did not answer the inquiry at all gave different explanation for this; experiences regarding difficulties in data acquisition, such as communication problems, has shown it would take too much time; the questionnaire was forwarded to the supplier, but no answer was received.

4 suppliers came up with some kind of LCI data
2 could not supply data due to priorities
3 suppliers did not respond at all

Figure 7 The model shows the communication paths in, and the results of, the life cycle data inventory in case study 1. The nine numbered companies presented in the first column in the flow diagram are the suppliers' of Kraftelektronik AB, which are included in the study. The other companies are the suppliers' of the suppliers.



Two of the companies in the inventory contacted their supplier, who answered directly to me, while four of them answered in place of their supplier. In two of the cases complimentary information was sought for by contacting the supplier of the supplier directly, but this did not lead to any progress.

2 of the companies' supplier answered directly to me
2 of the companies answered in place of their supplier
Contacting the supplier of the supplier did not lead to any progress

LCI data collection take time, even though you are working for a company and can use their name as a pressure in the contact. In this case study, the first contact was initiated in the beginning of April or early May and 4-8 weeks later, at the first deadline in the end of May, only three answers had been received. As earlier stated, six answers were received four weeks later.

3 answers were received after 4-8 weeks
6 answers were received after 8-12 weeks

An estimation of the effective time spent on these contacts would be about two working weeks. This includes telephone calls, writing and sending letters, treat the incoming answers to be able to make new inquiries if necessary, and sending out reminders.

The inventory took about 2 weeks effective time

6.3.2 Evaluation of the Collected LCI Data

The LCI data resulting from the data inventory covered altogether nine components. Thus, approximately half of the components included in the study have been addressed in some way. It is noticeable that only capacitors and resistors were represented in this group, even though diodes and IC:s were included in the study. This is discussed further under the headline *Discussion*, later in this chapter.

Some data were required for half of the components in the subset inventory
Only capacitors and resistors were represented, no diodes or IC:s

Two of the suppliers sent the information in the form of catalogues, one returned the questionnaire with a few comments on, and one addressed some of the inquiries in a letter.

2 suppliers sent catalogues
1 supplier returned the questionnaire
1 supplier sent a letter

Here follows an evaluation of the supplied LCI data in general and in regard of the questionnaire. The environmental performance questionnaire can be found in *Appendix 1*.

- **ELFA AB** (supplier number 2 in *Table 2*)
  ELFA sent a fax answer from their Taiwanese supplier Megery. The answer consisted of comments made on the questionnaire and a one-page document with a schematic description of the process steps and material used in the production of the two ceramic capacitors. It contained no information beyond inquired.

  The received LCI data was scanty and no quantitative information was given, see *Table 2* to compare to the other answers. Two questions were not addressed at all, for example the inquiry about the energy source and quantity of energy use. In addition, the information on the two received sheets was somewhat contradictory. For example, the raw material input was the same as the material content in the product according to the filled in questionnaire, but in the general process information additional substances and materials were stated.

  A conclusion is that this information alone is not sufficient to use for LCI. However, ELFA has been obliging and a complementary inquiry could perhaps fill in the gaps of information.

  > **The comments made on the questionnaire are, together with the schematic description of the process steps and material used in the production, not sufficient to use for LCI.**

- **OEM-Component AB** (supplier number 6 in *Table 2*)
  OEM-Component sent an impressive Environmental Statement catalogue for 1998 from Beyschlag [Beyschlag, 1998], their supplier of the cylindrical metal film resistors. The catalogue contained at lot of information beyond the inquired. Some of the interesting headlines were: Manufacturing processes, Environmental aspects of the production processes (energy consumption, emission of pollutants, waste, water consumption, noise pollution and odour emission, input-output balance for variable environmental data, etc.), Environmental aspects related to the products, Packaging and transportation, and Environmental Management System (EMS).

  The catalogue was very informative and comprehensive, and had a clear life cycle aim and direction, for example in regard of the input-output balance. It contained a lot of quantitative information, see *Table 2*, although the functional unit was an average product from their manufacturing of two different resistors. In addition, there were some references in the catalogue, to other sources where complementary or extended information could be found, for example to the 1997 Annual Environmental Report and complete material balances for each product, which can be ordered from Beyschlag. The address can be found in the list of references in this report. It is of course preferable that a reference is given, rather than no information at all, but it still leaves a lot of work for the LCI practitioner.

  The received LCI data is, together with the references, sufficient to answer the questions in the questionnaire, and further to use in an LCI. Since the German company Beyschlag has very good control of the environmental aspects in their own production there is also reason to assume that they are into getting information about and affecting environmental aspects outside their own production. This can be of great help when you want to find further information about the previous steps of the life cycle.

The information in the Environmental Statement catalogue is, together with the references, sufficient to use for LCI.

Table 2 The table describes to what extent the supplied information was enough to answer the questions in the questionnaire. The suppliers can be identified e.g. In *Table 1* or *Figure 6*.

Supplier	1	2	3	4	5	6	7	8	9
Question 1		some				some		some	some
2		no				yes		no	no
3		some*				yes		some*	no
4		some*				some*		no	some*
5		some*				no		some*	no
6		some*				yes		no	some*
7		no				no		no	no
8		some				some		no	no
9		yes				yes		no	no
10		yes				some		no	no
11		yes				some		no	no
12		yes				yes		no	no

no	No information is given to answer the question.
some	Some information (or a reference) is given to answer the question.
yes	Information is given to answer the question.
*	The information is only or partly qualitative, in spite of the fact that it could be quantitative (regarding question number 2 - 6).

- **Rune Ohlsson Electronics AB** (supplier number 8 in *Table 2*)
  Rune Ohlsson Electronics sent a Technical Report [BHC Aerovox Ltd.] containing technical data and product information from BHC Aerovox, their supplier of the electrolytic capacitor. The catalogue contained some information beyond the inquired. Some of the interesting sections were: Basic construction, Manufacturing process, Application, Life expectancy, Cleaning solutions and solvents, Component weights and Product safety (material content, toxicology, and safety precautions), and Disposal.

  The received LCI data was, in regard of the questionnaire, scanty and no quantitative information was given, see *Table 2* to compare to the other answers. In fact, only three questions in the questionnaire were addressed: the description of the manufacturing process, raw material input, and material content in the product. Moreover, no date for the edition could be found in the report.

  A conclusion is that this information alone is not sufficient to use for LCI. On advice of Rune Ohlsson Electronics, BHC Aerovox in the United Kingdom has been contacted via e-mail and fax in order to get the missing information. However, in spite of several reminders the company has not answered the inquiries.

  The Technical Report is not alone sufficient to use for LCI.

- **Universal Import Elektronik AB** (supplier number 9 in *Table 2*)
  Hi-Tech Resistors, the supplier of the ceramic encased and silicone-coated resistors, sent a personal letter directly to me regarding the questionnaire. It contained no information beyond inquired.

The received LCI data was, in regard of the questionnaire, scanty and no quantitative information was given, see *Table 2* to compare to the other answers. In fact, only three questions in the questionnaire were addressed: the description of the manufacturing process, emissions and waste.

A conclusion is that this information is not sufficient to answer the questions in the questionnaire. Hi-Tech Resistors in India has been contacted via fax, in order to get the missing information. However, the company has not answered the inquiries.

The information in the letter is not alone sufficient to use for LCI.

6.4 Discussion

In spite of the scarce information resulting from the subset inventory, this way of acquiring data has its benefits. It corresponds to the LCA concept as knowledge regarding the unique product processes in a specific supply chain can be obtained. In fact, the supply chain is the spine in LCA. Such an information system, involving all actors in the supply chain, can generate the perfect LCI data set and entails averages, qualified guesses, and other estimations to be avoided when desirable, see under the headline *The Data Quality Concept as Defined at CPM*, in the chapter *Background* for a definition of a “perfect LCI data set”. Thus, it will be possible to perform more detailed assessments and consequently get more reliable and useful results. Further, this way of collecting LCI data also supports an Environmental Management System (EMS). An established information system involving all the suppliers in the supply chain can entail environmental advantages, e.g. it can enhance the possibility to supply the clients with better information, to affect the suppliers and to choose the most environmentally favourable business partners. The LCA based environmental product declaration (EPD) is an example of an environmental tool depending on such an information system, the supply chain management (SCM) is another.

However, this way of collecting data is very extensive in time and has to be well planned. In this test inventory it took about three months, two weeks effective time, to receive two thirds of the LCI data sets. In addition, further information is required for all of them to be able to use them for LCA. Thus, strategies for data acquisition that entail supply chain communication will be profitable, especially in the long run. An established information system in the supply chain has the capability to generate perfect LCI data (see under the headline *The Data Quality Concept as Defined at CPM*, in the chapter *Background* for the definition of a “perfect LCI data set”) and to make it accessible, which in turn enhances the utilisation of many of the future environmental tools, e.g. EMS, LCA and Environmental Product Declaration (EPD). Not only will it become feasible to utilise those tools, but also efficient, i.e. quick and less expensive. Once the contact with the supplier has been established, one can assume that improvements of the information system can be made with less effort.

This case study has demonstrated the importance of using the supply chain properly when making data inquiries. The responses to the inquiries came exclusively from the companies that had a direct contact with their suppliers. Thus, if a link, i.e. a company in the supply chain, was excluded from the communication path, the reply was consequently left out.

The Environmental Statement catalogue from Beyschlag [Beyschlag, 1998] is a prominent example of public environmental information that entails data suitable for LCI. The catalogue is very informative and comprehensive, and has a clear life cycle aim and direction, for example in regard of the input-output balance. It also contains a lot of quantitative information, as opposed to the other answers in the subset inventory. Further, it is a quick and easy way to communicate the environmental information to other manufacturing companies, wholesale dealers, retail chains, stores and customers. Once the catalogue is made, the effort can be concentrated on updating and adding complementary information.

The fact that only capacitors and resistors, i.e. neither diodes or IC:s, were represented in the results can imply that LCI data for capacitors and resistors are more easy to find in general, though this is something that has to be assessed further. However, IC:s and diodes consist not only of circuits, but also of semi-conductors. Therefore, a reason for the difficulties in finding LCI data regarding diodes and IC:s, could be that the manufacturing of those components involves a longer and more complex production chain than for capacitors and resistors.

Two suppliers did not provide any data although they replied to the inquiry. The given explanation was, in both cases, resource priorities. The companies that did not answer the inquiry at all gave different explanation for this; experiences regarding difficulties in data acquisition, such as communication problems, have shown that it would take too much time; the questionnaire was forwarded to the supplier, but no answer was received.

7 Case Study 2: Study of Life Cycle Inventory Models at Ericsson

This case study aims at describing two ways of dividing electronic components into LCI data groups. Life cycle data models constitute a feasible alternative to the data acquisition method in case study 1 by generating LCI data estimations for groups of electronic components. The utilisation of such models is both cheaper and faster than making LCI data inquiries in the supply chain and it generates estimations. In this study the two models are qualitatively evaluated, through personal contacts and document studies, and an extended evaluation is planned at Ericsson Enterprise Systems later this year.

7.1 Ericsson Enterprise Systems

Enterprise Systems is the business unit within the Ericsson organisation that provides products, solutions and services for the business customer. Business units within Enterprise Systems are Medium & Large Communication Systems, Computer Telephony Integration, Small Communication Systems (based in Vienna) and Customer Services.

The core product in the Enterprise Systems portfolio is a digital voice-and-data Private Branch Exchange (PBX) called MD110. The development of enhanced services is based upon this PBX and the solutions that these services offer are various, and bring in new areas of capability including multimedia and wireless communications and networking. Among the areas of business interest developed by this fusion are Mobility, Call Centers and Personal Efficiency.

Enterprise Systems is active in 103 countries, employ 7 500 people, and has an annual turnover of nearly US$ 2 billion.

Enterprise Systems has three full-time employees, external consultants and thesis employees working with environmentally related issues. Lars Lenell is the manager of the environmental work within Enterprise Systems. Enterprise Systems started LCA related work in 1995, which involved life cycle assessments on documentation systems and packaging [Beckman, 1997] [Baumann, 1998]. They have consequently performed inventories of their own activities and some of their suppliers', both in connection with the LCA work and in the performance of environmental material declarations. Furthermore, Enterprise Systems has established an LCI database, using the format [CPM, 1999], and are currently working on the development of LCA techniques that are applicable for future demands. In the beginning of 1999 the implementation of an Environmental Management System (EMS) was initiated that will be finished by the year 2000. Finally, Enterprise Systems is developing routines and methodology for handling scrap.

7.2 Description of the Life Cycle Data Models

7.2.1 Model 1

The purpose of this first model is to give estimated LCI data for a line interface board (LIB), which controls digital telephones in telephone exchanges. The model started to be developed in 1994, and the data has been currently updated. The components that constitute the product are divided into three LCI data groups:

1. Integrated circuits
2. Printed circuit boards
3. Others (cables, oscillators, and other components)

In addition, the printed board assembly and the final product assembly can be added to the calculation of the environmental performance of the product, see *Figure 8*.

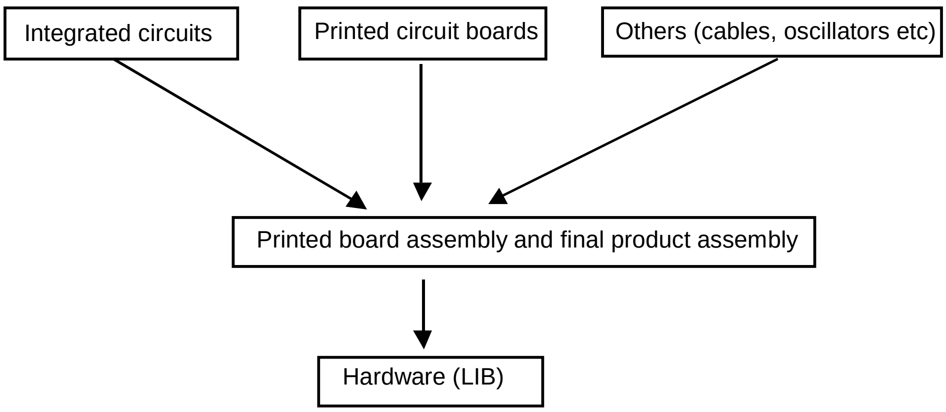


Figure 8 The LCI model, developed at Ericsson Enterprise Systems, shows how the components included in a line interface board (LIB) are divided into three LCI-data groups. Further, the assembly can be added in the model.

The division is based on experiences and knowledge at Ericsson, regarding what is considered to be of major importance in the environmental product performance of line interface boards. The determining factors for the division are the weight of the materials, the cost of buying or manufacturing certain components, and finally the application of results from earlier studies made internally, at MCC (Microelectronics and Computer technology Corporation), IBM, and Hewlett Packard. The printed circuit boards constitute about 60% of the product's weight and the integrated circuits about 10%. Both the components are relatively expensive.

In the beginning of the development of the model, Ericsson contacted some suppliers in order to collect the LCI data. However, only a few answers were usable due to insufficient inventories. LCI data for some components were then taken from LCA studies at IBM and Philips, and databases, for example at Ecobilan and, regarding the extraction and manufacturing of some materials, Chalmers Industriteknik (CIT) and the Swiss Federal Institute of Technology (ETH). However, mainly data from Ericsson's own manufacturing were used. All the data that was found valuable from the different sources was included in the model, thus, no uniform LCI data boundary, e.g. regarding the inclusion of physical flows such as emissions or waste, was applied throughout the LCI. The latest inventories, in connection with the development of the second model (see further down), have entailed an actualisation of the LCI data.

An estimation of the time spent to develop the model is 360 hours, that is, nine working weeks where about half of the time was spent on data acquisition and the other on intellectual work and model construction.

7.2.2 Model 2

The purpose of this second model is to give average LCI data for components included in a Private Branch Exchange (PBX). Ericsson started to develop this more detailed model in May 1998, in order to perform an LCA and learn something in the process. It has been discussed whether the two models should be compared, for example by analysing LCA results based on the different models. The two models could, for example, prove to be applicable in different situations or types of assessments due to differences in detail levels, quality aspects etc. The LCA based on this second model will be finished around September 1999 and a comparison of the two models will be performed later.

The PBX can contain up to 2500 different components. The components was in a first step classified into 27 groups, according to the extension of their use in the PBX and in order to cover the most frequently occurring components. In the second step the classification was partly modified, according to the data availability.

Ericsson contacted about eighty suppliers, in order to collect data for the 27 groups of components that compose the product, a PBX. Approximately 50% of the suppliers answered the SPINE based LCI questionnaire [Carlson and Pålsson, 1998a] that was sent out. The questionnaire included inquiries about e.g. waste, energyware input, material, components and natural resource input such as plastics, flame-retardants and/or metals. If Ericsson received more than one answer in a group of components, they made arithmetical average calculations, otherwise they used the only answer received. If they had not received any answer, they used an LCI model for a similar component. LCI data for raw materials such as metals was taken from the database at CIT. The LCI data is documented in the data documentation format SPINE [CPM, 1999] as interpreted by the Centre for Environmental Assessment of Product and Material Systems (CPM) at Chalmers University of Technology in Göteborg, Sweden.

The final model contains nineteen groups, from which sixteen are defined as electronic components and the other three are metals, main plastics, and other plastics, see *Figure 9*. The division was based on structural resemblance, electrical function and material content of the different components. The sixteen groups are:

1. Display units and indicators
2. Diodes

3. Microcircuits, oscillators, quartz crystal units and delay lines
4. Transistors and opto couplers
5. Connectors and holders
6. Cables
7. Relays
8. Transformers and inductors
9. Potentiometers
10. Resistors, varistors and thermistors; hole mounted devices
11. Resistors; surface mounted devices
12. Resistor networks
13. Capacitors and filters; hole mounted devices
14. Capacitors; surface mounted devices
15. Printed boards
16. Others (fuses, loudspeakers, and switches)

Administration was not included in the LCA that initiated the model, but can easily be integrated in the model, see *Figure 9*. This is compared with model 1, which only divides the components into three groups.

An estimation of the time and financial means spent to develop the model is 600 hours, that is, 15 working weeks, and 48 000 US$ (400 000 SEK). Included in the estimation is the data collection, which took about 400 hours and cost approximately 32 000 US$ (260 000 SEK), and the compilation of data and construction of the model.

7.3 Discussion

LCI models are simplifications of real systems. By structuring electronic components and dividing them into groups in an intelligent and transparent way, feasible estimations about the environmental load for a single component can be made. In addition, a proper approach enables further improvements of the model.

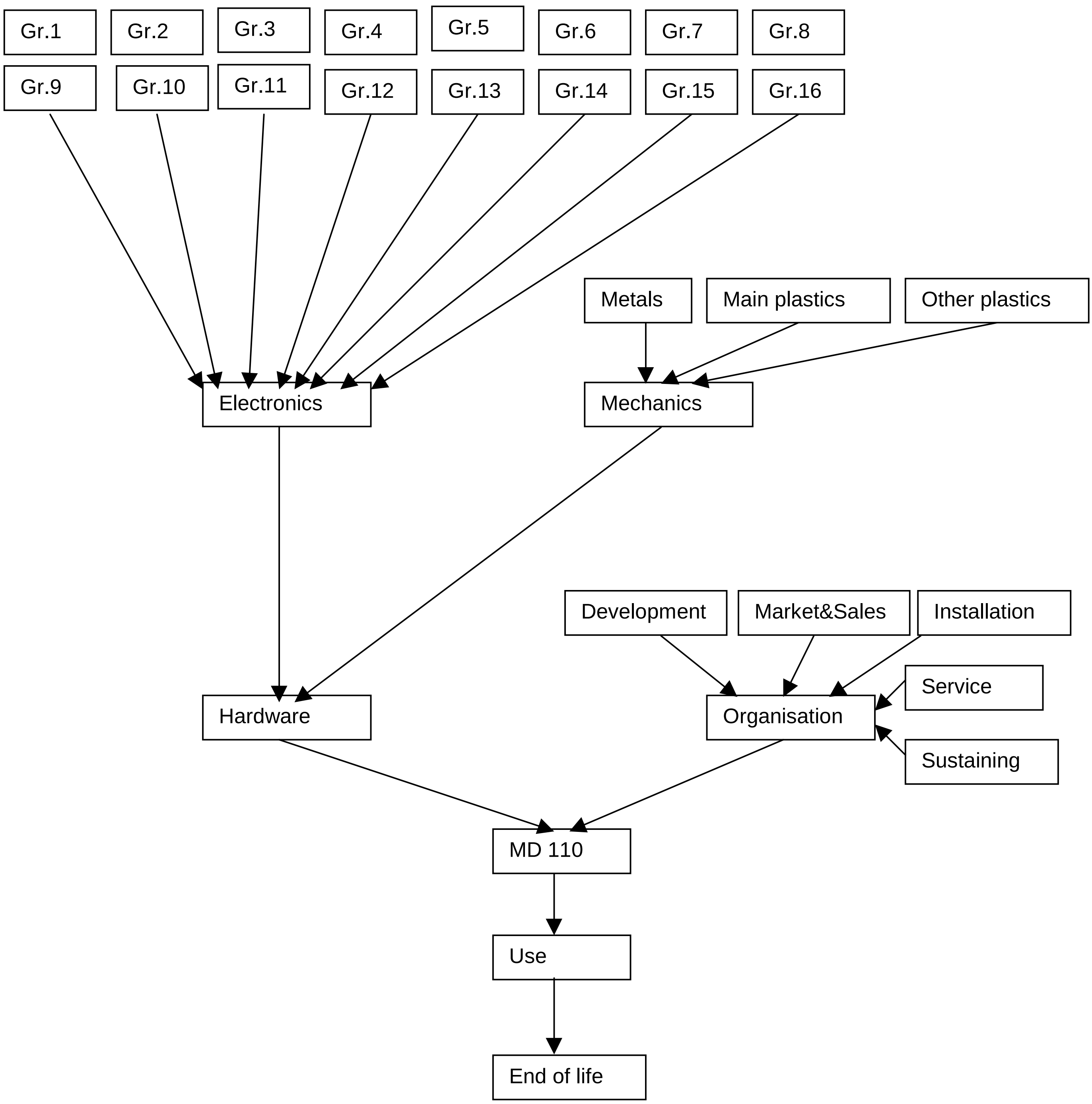
7.3.1 Model 1

The structure in Model 1 is based on factors as the weight of the components, the cost of buying or manufacturing them, and the application of results from earlier LCA studies.

This may be a natural choice from a financial perspective, but it is questionable whether these factors constitute a relevant and stable base for an environmental LCI model. The cost and weight of a component does not necessarily give any information about the environmental aspects e.g. regarding the emissions in the manufacturing processes.

Another weakness is the use of former LCA results, where some major impacts from the electronic components have been identified. Firstly, the results from such earlier assessments are not explicitly compiled, or referred to, so that a reviewer can estimate the value of these. Secondly, in regard of the knowledge described in *The Access of Life Cycle Inventory Data for Electronic Components Today* in the chapter *Background*, there are reasons to question the results from these studies, since the data availability in this area is extremely scarce. Thus, the structure in Model 1 can be based on unreliable and even misleading results from earlier life

Figure 9 Schematic structure of model 2, developed at Ericsson Enterprise Systems in Sweden. The groups with electronic components are divided into 1.Display units and indicators, 2.Diodes, 3.Microcircuits, oscillators, quartz crystal units and delay lines, 4.Transistors and opto couplers, 5.Connectors and holders, 6.Cables, 7.Relays, 8.Transformers and inductors, 9.Potentiometers, 10.Resistors, varistors and thermistors; hole mounted devices, 11.Resistors; surface mounted devices, 12.Resistor networks, 13.Capacitors and filters; hole mounted devices, 14.Capacitors; surface mounted devices, 15.Printed boards, 16.Others (fuses, loudspeakers, and switches)



cycle assessments. This issue is discussed further under the headline *System Analysis* in the chapter *Cost versus Quality – Pragmatics when Performing a Life Cycle Assessment*.

Finally, the lack of documentation regarding the systematic approach and the LCI data used in Model 1 makes the model difficult to comprehend, i.e. assess, use and further develop. For example, the LCI data is taken from miscellaneous sources and the different LCI data boundaries have not been identified nor documented. The system boundaries give important information about a data set, e.g., which processes, transports, and parameters that are included. This information is crucial e.g. when several data sets from different sources are compiled to represent the whole life cycle of a product.

In spite of the weaknesses identified in this model, it constitutes a good starting point in the development an LCI data model. This work takes time and the development is dependent on constant reviews, hence, it is impossible to make a good LCI model without learning from earlier experiences. In addition, the model enables some kind of estimations of the environmental impact, which is better than ignoring the fact that the impact exists.

7.3.2 Model 2

The classification in Model 2 is based on structural resemblance, electrical function and material content of the different components. Again, it is relevant to question if these factors are the only and/or the best parameters to take into consideration in an LCI model. However, the systematic approach is transparent and the obtained data well documented in the SPINE format [CPM, 1999]. Summarising the experiences, Model 2 is a structured platform, well suited for further development. It seems like a simple, but well documented and structured, model is a good starting point for a company whose LCI data acquisition strategy includes LCI modelling. After some time, one can learn from the experiences and develop the model further.

The time spent in constructing the model is approximately the same in both cases, between 180 and 200 hours. However, the time spent on LCI data acquisition differs and is 180 hours in the first model and 400 hours in the second.

8 Methods and Obstacles for Acquiring Life Cycle Inventory Data for the Electronic and Electric Equipment Database at Ecobilan Group

This chapter is based on a telephone interview with Hélène Lelièvre, an LCA practitioner who works at Ecobilan Group with the Environmental Information and Management Explorer. Ecobilan Group is a French company working in the field of LCA and strategic environmental management and it has several offices worldwide, in US, UK, Italy, and Japan.

The interview is performed to compare the conditions in Sweden with those in another European country. Thus, it summarises Ecobilan's experiences regarding the acquisition of LCI data for electronic components and the identification of obstacles in the process.

8.1 The Environmental Information and Management Explorer (EIME™ tool)

Ecobilan Group, in partnership with Alcatel Alsthom, IBM, Legrand, Schneider Electric, Thomson Multimedia and ADEME (the French Environmental Agency), developed a Design for the Environment (DFE) tool for electronic and electric equipment. This tool is called the Environmental Information and Management Explorer (EIME^{TM}) and it started to take shape during 1996. EIME^{TM} encompasses a software design tool, an environmental database and an Environmental Management System (EMS). It has different interfaces to meet the specified needs of different departments within a company, for example environmental, design, marketing etc. However, EIME^{TM} is mainly aimed at the designers and development staff. All the interfaces have access to the same database.

8.2 The Database

The database contains approximately 180 data sets or modules. The modules are built mainly from generic LCI data on materials, energy, industrial processes, electronic components and transports. The data for most of the materials, energy and transports are taken from different databases such as the Association of Plastics Manufacturers in Europe (APME) for plastics, the Swiss Federal Institute of Technology (ETH-Z) for metals and the Swiss Agency for the Environment, Forests, and Landscape for some chemicals.

The EIME database contains 36 modules presenting electronic components or parts such as batteries, resistors, capacitors, integrated circuits, diodes etc. In the preparatory work, the industry partners within the EIME collaboration established a list of the electronic components that they wanted to find in the database. However, for a few cases the requirements were not possible to fulfil. In those cases, LCI data for other or similar electronic components have been entered into the database instead.

To obtain LCI data for the electronic components, Ecobilan Group contacted the suppliers of the five co-operating industry partners. Data was also directly collected at the industrial sites of the partners' companies. Ecobilan made LCI data inquiries by sending questionnaires and in some cases by visiting the site, although no direct measurements have been made. Usually, it has been enough to contact the industry partner, and one or two of their suppliers upstream in the production chain, to get good data quality.

Finally, Ecobilan Group has also contacted some other companies, outside the EIME collaboration, to try to obtain LCI data for certain electronic components. However, only a few answers have been received from these companies and the data has been modulated to fit the needs. The modulation can consist of a mixture with literature data.

The database has data quality indicators that contain information about the completeness and reliability of the data set. The source of the data used for the LCI is also systematically mentioned in the data set.

8.3 Obstacles in the Collection of Data

According to Hélène Lelièvre, many companies are not familiar with the LCA method and can not see the direct benefit of contributing to LCI data generation. The companies may have some kind of environmental information, but it is usually based on requirements from legislation, and consequently consists of data for the site as a whole. If the manufacturing plant produces many different components, which often is the case in the production of electronic components, you get allocation problems, i.e. problems separating the environmental loads when one or more products share one or more processes.

Another obstacle in the collection of data is that it is seldom one person at a company that has all the information needed for an LCI. In addition, the organisation, communication and/or inventory documentation within the company is insufficient, which makes the data hard to get although it exists.

Moreover, Hélène Lelièvre emphasised that one of the main obstacles encountered in the data collection was the lack of time and resource of the contacted companies. The environmental queries were, most often, not considered as a priority for the company and represented too much additional work, especially when the site did not have a good reporting system.

Because of deficient resources when it comes to aggregating raw data, knowledge about environmental assessment, communication issues, e.g. exchange of data and related secrecy issues, Hélène Lelièvre suggested that companies could benefit from using a third party to handle the data. The third party could for example be an independent consultant collaborating with the environmental protection agency in the country and a group of companies within the same line of business, as in this case.

9 Cost versus Quality – Pragmatics when performing a Life Cycle Assessment

When deciding on which strategy to apply for data acquisition, it is important to know how the data is used. The purpose of this chapter is to describe the requirements today in the practical use of LCI data. By doing this, different ambitions for data quality and data acquisition strategies can be related to different ambitions for life cycle assessments. The data quality requirements addressed in this study derive from ISO 14041 and from LCA experts in Sweden and Denmark. The interviewed LCA practitioners and reviewers are chosen due to their extensive experiences from practical LCA work. This chapter also deals with how the cost issues can be related to the data quality.

9.1 Data Quality Requirements According to ISO 14041

In the international standard "Environmental management – Life cycle assessment – Goal and scope definition and inventory analysis" ISO 14041 [ISO 14041, 1998] there are some data quality and documentation requirements, which are summarised and presented in brief in this section.

ISO 14041 specifies, in addition to ISO 14040 "Environmental management – Life cycle assessment – Principles and framework" [ISO 14040, 1998], the requirements and the procedures necessary for the compilation and preparation of the definition of goal and scope for an LCA and for performing, interpreting and reporting an LCI analysis.

According to section 4.5 in ISO 14041 the product system used in the LCA should be described and the assumptions underlying the choices identified. For example, section 5.3.3 states that each of the unit processes should be described to define:

- the beginning and the end of the unit processes in terms of the receipt of raw material or intermediate products, and the destination of the intermediate or final product, and
- the nature of the transformations and operations that occur as part of the unit processes

In addition, allocations and system expansions must be well-described (section 5.3.2).

Sometimes the access to data is limited and one has to change or modify the data quality requirements stated in the goal and scope definition. For example, if the goal and scope of a study requires average data for production of electricity, and there are only site specific data available, the representativeness of this data must be discussed and the consequences for using it evaluated. Section 5.3.1 in ISO 14041 states: “In some cases, the goal of the study itself may be revised due to unforeseen limitations, constraints or as a result of additional information. Such modifications, together with their justification, should be duly documented.”

According to section 5.3.6 in ISO 14041 the data quality requirements should be included for the time-related, geographical, and technology coverage. One should specify how old the data is and during what time period it has been collected. Further, one should give information about from which geographical area it has been collected and what process mix, technology and operating conditions that is relevant. Other important issues are what the data represents in terms of business averages or specific sites, and whether the data is measured, calculated, or estimated etc.

Additional data quality requirements should be considered in level of detail depending on the goal and scope definition. However, where a study is used to support a comparative assertion that is disclosed to the public, all data quality requirements described shall be included in the study. The additional data quality requirements are:

- precision, a measure of the data variability
- completeness, a measure that says something about the flow coverage, in question of raw material inputs, emissions to air etc., for the different parts of the system (in comparison to each other)
- representativeness, qualitative assessment of degree to which the data set reflects the true population of interest stated in the goal and scope definition
- consistency, qualitative assessment of how uniformly the study methodology is applied to the various parts of the analysis
- reproducibility, qualitative assessment of the extent to which information about the methodology and data values allows an independent practitioner to reproduce the results (this can be compared with the quality aspect “transparency” in the data quality concept defined at CPM, see under the headline *The Data Quality Concept as Defined at CPM* in the chapter *Background*)

The procedures used for data collection, and reasons for using these, should be documented as well as the treatment of missing data (section 6.3 and 6.4.2). A reference to the data source should also be found in the LCA (section 6.3).

Finally, in section 7 ISO 14041 states: “The interpretation shall include a data quality assessment and sensitivity analyses on significant inputs, outputs and methodological choices in order to understand the uncertainty of the results.” Further, “ The data quality assessment, sensitivity analyses, conclusions and any recommendations from the LCI results shall be documented.”

9.2 Pragmatics as Interpreted from Interviews with Life Cycle Assessment Experts

To find out the practical demands on LCI data, used to evaluate the environmental performance of a product by LCA, five LCA experts in Sweden and Denmark were interviewed. By doing this, different ambitions for data quality and data acquisition strategies can be related to different ambitions for life cycle assessments. Thus, the intention is to give a practical overview of LCA at its best.

The five interviewees have worked as LCA practitioners and/or reviewers and are chosen due to their extensive experiences from practical LCA work. They are presented shortly below:

Professor Ann-Marie Tillman from Technical Environmental Planning at Chalmers University of Technology has been working with LCA since 1990 and e.g. manages the development of LCA methodology within CPM.

Adjunct Professor Bengt Steen from Technical Environmental Planning at Chalmers University of Technology has laid the foundation of the EPS method and e.g. is involved in the development of ISO 14042 on CPM´s account.

Ph.D. Tomas Ekvall at Chalmers Industriteknik (CIT) has many years of experience from practical LCA work and development of allocation methods.

M.Sc. in Chemical Engineering Lars-Gunnar Lindfors at the Swedish Environmental Research Institute (IVL) has many years of experience from practical LCA work and environmental measuring techniques.

Ph.D. Bo Weidema from the Department of Manufacturing Engineering at the Technical University of Denmark has many years of experience from practical LCA work, e.g. as a member of the SETAC Steering Committee on LCA and a developer of the data exchange format SPOLD.

The interviews are based on the following questions:

- What is the common/your data quality requirement today for an LCA?
- What are the characteristics of an LCA? (What separates it from other environmental assessments?)
- What time/financial means have to be spent to make a good LCA?

Each interview is compiled and presented in *Appendix 3*. A recommendation is to read these in order to get the right context of the statements and to further understand the circumstances of the LCA work for each expert.

9.2.1 Practical Data Quality Requirements

From the interviews of the five LCA experts one may get the impression that about the only data quality requirement that is fundamental in the established LCA sphere, is that the data sources should be stated in the LCA report. This strengthens the reliability, that is, the credibility of the study by increased transparency, see under the headline *The Data Quality Concept as Defined at CPM* in the chapter *Background* for further explanations of the quality aspects. Apart from this common requirement, the opinions of practitioners and reviewers about the data quality diverge. Some of the ideas that were mentioned in the interviews are presented below.

- The data quality requirements depend on how the results and conclusions are going to be used. For example, if the LCA aims at establishing a policy, the assessment will be subject to extensive reviews and examinations and must therefore have high data quality requirements to be solid.

- The representativeness is the most important aspect among the data quality requirements. It should give information about the technical system, the geography in question, and the age of the data.
- The quality requirements concerning the relevance (technical system, the geography in question, and the age of the data) of the data should be expressed in the goal and scope definition.
- It is important to know the uncertainty of the data and in addition the cause of the uncertainty.
- The traditional quality conception includes reliability, relevance and accessibility. They are unfortunately often in conflict with each other. However, the reliability should always be presented by assigning the data two measures, the calculated or measured number (mean) and the standard deviation.

A majority of the experts mention the importance of interpreting the results with regard to the data accuracy. However, the quality of the available data often limits the possibility to make correct conclusions considering the purpose or question asked in the goal and scope definition. One of the practitioners turns over the discussion and says: "As an LCA practitioner you have to be able to reduce the uncertainty so that you can make a conclusion."

9.2.2 The Characteristics of an LCA

This section compiles what the interviewed LCA experts define as the characteristics of LCA.

The main purpose for performing an LCA, according to interviewed LCA practitioners and reviewers, is to widen the perspectives and give a survey of all environmental impacts. This implies that the whole life cycle must be considered, i.e. one has to address all human activities within the life cycle and all consequences in all steps must be included.

Note, however, that this does not mean that all details have to be included in an LCA, with perfect numerical precision, but one has to give a transparent picture of the modelled system.

9.2.3 Cost Issues Related to LCA

Data quality is really a matter of cost. Earlier in this chapter, the LCA practitioners and reviewers have briefly defined what they regard as important when it comes to the concept of LCA and the data quality requirements, in practice. This section will deal with the cost for fulfilling these requirements. Hence, below the practitioners and reviewers state their experiences in regard of time and cost issues when performing LCA.

The statements are based on somewhat different circumstances and they are in some way disconnected from their right context. Nevertheless, it is possible to get a fairly good understanding about the pragmatics when performing different types of life cycle assessments. Each interview is compiled and presented in *Appendix 3*.

- It will take about five minutes to make a survey LCA in the construction phase.
- You will have to spend a few hours to make a qualitative matrix LCA.
- A couple of weeks work is enough to perform a simplified LCA and it will cost less than 12 000 US$ (100 000 SEK).
- A well-documented screening LCA takes a few weeks to finish.
- It will take about ten weeks to make a traditional LCA on a moderately complex product.

- A traditional LCA will be performed in approximately one year and cost a couple of hundred thousand US$ (million SEK).
- A conventional LCA cost between 12 000 and 85 000 US$ (100 000 and 700 000 SEK).
- A conventional LCA that includes data collection can take as from four month until two years to perform.

A summary of the statements give that the time spent to perform an LCA is between 5 minutes and two years and the cost between 12 000 and 240 000 US$ (100 000 and 2 million SEK). This shows a wide range of time and money spent on an LCA. However, it is noticeable that the experts refer to different types of life cycle assessments and not all of them have included the data acquisition in their approximations, e.g. the five minutes LCA implies that LCI data is accessible.

The interviews also show that the acquisition of data is one of the most time and consequently cost consuming part of an LCA.

9.3 Conclusions and Discussion

General conclusions based on the interviews with the LCA experts are:

- It is expensive to perform life cycle assessments, mainly due to high costs in connection to the data acquisition and, in addition,
- The data quality in performed life cycle assessments does generally not meet the data quality requirements in ISO 14041 [ISO 14041, 1998].

These conclusions are further explained and discussed in this section, together with some other aspects of the performance of LCA that were identified in the interviews.

9.3.1 Data Quality Requirements

From the interviews with LCA experts, summarised in the chapter *Cost versus Quality – Pragmatics when Performing a Life Cycle Assessment*, one gets the impression that the only data quality requirement that is fundamental among LCA experts, is to state the data sources used in the LCA. Apart from this common requirement, the experts' opinions about the practical data quality demands diverge. Hence, the conclusions based on the interviews are that in practice, the data quality requirements are not stringent, a common view of data quality is lacking, and the quality issues are certainly not stressed to a sufficient level in practice.

However, the different requirements stated by the LCA practitioners and reviewers all coincide with or originate from the ISO standard [ISO 14041, 1998], even though only some of the requirements are mentioned by each expert. The data quality requirement in the ISO standard is a natural common target for the ambition level for documentation and handling of data at a company. There are also data documentation formats, e.g. SPINE [CPM, 1999], which includes the requirements in ISO and thereby simplifies the interpretation and structuring of the requirements in practice.

9.3.2 Cost Issues Related to LCA and LCI Data Acquisition

The time spent to perform an LCA, according to the interviews, lies between five minutes and two years. The cost lies between 12 000 and 240 000 US$ (100 000 and 2 million SEK), excluding the five minutes LCA. This shows a wide range of time and money spent on an LCA. One can assume that the truth is somewhere in between these extremes. It is noticeable that the experts refer to different types of life cycle assessments and not all of them have included the data acquisition in their approximations, e.g. the five minutes LCA implies that

LCI data is accessible. Anyhow, the financial means that are required today for performing an LCA are hardly acceptable. One can assume that this realistic picture has to be developed to a more efficient level.

The interviews show that the acquisition of data is one of the most time and consequently cost consuming part of an LCA. Thus, in this area large savings can be made. According to this fact, it is important that the collection procedure is performed thoroughly and that the data set is well documented so that it can be reused, partly or as a whole, and easily actualised. If the same LCI data is made accessible to others, the total cost, e.g. of performing life cycle assessments will be reduced.

9.3.3 System Analysis

According to the experts' way of defining the characteristics of LCA, all activities and flows within the studied system are equally important and must be considered, i.e. one has to address all human activities within the life cycle and all consequences in all steps. This does not mean that all details has to be included in the LCA, with perfect numerical precision, but one has to give a transparent picture of the modelled system. This is also pointed out in the chapter *Background*, as a fundamental element in the LCA concept. Thus, the requirements for the data quality should be regarded as equal, regardless of the type of LCA. However, this is not always the case in performed life cycle inventories or assessments. One reason could be the practitioners' lack of knowledge about the specific life cycle concept when performing this type of assessment. Another reason may follow from the fact that it is difficult to obtain some data, which makes the practitioner to relinquish the concept. A third explanation is discussed below.

Experiences from this study and other data quality reviews indicate that in many life cycle assessments, the requirements for the data quality standard are set from a very "self-centred" point of view. The phenomenon arises that the requirements on the data quality decreases by the distance to the main process of interest in the LCA. That is, the data quality concerning the processes closest to the main process, often where the functional unit occurs, is regarded as the most important. As a consequence, lack of data concerning processes further down the production chain is not always regarded as the major drawback it ought to be. Some life cycle assessments are even performed as if this lack of data has no, or very little, impact on the result. Mathematically, this may lead to dimensional faults in the results, as the proportions of the environmental impacts originating from each process within the system can be incorrect. In fact, this is a contradiction to the very idea of LCA, i.e. to get an environmental overview of the impacts in the life cycle of a product or process and, thus, such an assessment is simply not an LCA. If, for example, the assessment should be used in marketing a product as environmentally preferable, the holistic view in LCA is crucial. It does not matter if one or a few processes in the life cycle of a product are environmentally sustainable, when the impact from the rest of the processes is not known. This also reverses the arguments that if the LCA commissioner can not affect certain activities, they can be represented by data with less quality.

9.3.4 Intuition About the Quality in Data

Many of the interviewed experts are talking about how they can sense the data quality without confirming their sense with calculations or estimations:

- There are rules of thumb for predicting the quality of data for certain flows. For example, the data representing emissions of sulphur dioxide from combustion of fuel are often reliable because it is based on the consumption, which generally is well known.
- Often, or at least with some experience, you can in advance estimate how large the inherent (irreducible) uncertainty is, and thereby in advance conclude whether it is sensible to refine the data that you already have. For example, you can use the fact that some data sets or industry activities are comparable.
- If the LCA does not include information concerning the representativeness of the data, that is the boundaries of the technical system, the collection date, the geography, and the type of data, it is helpful if the reviewer is familiar with the data source and knows the representativeness by experience.

The intuitive practice seems to be based on experience and sometimes knowledge about one data set that is transferred to another. However, it would be preferable that these qualified guesses were handled and documented in a more scientific and structured way. The main objection to the present practice of intuition lies in the fact that these discussions seldom or never can be found in the LCA report. Thus, the LCA is not transparent. Further, if this kind of information is included in an LCA, there is no systematic way of handling it. The consequences could be that it is difficult to evaluate the information and compare it with similar conditions in other assessments.

Moreover, if the reasoning were properly documented, it would probably force the practitioners and reviewers in question to find better and more tenable arguments for using or accepting a specific data set.

One may assume that a development to more prevalent and adequate use of the recently finished standard ISO 14041 [ISO 14041, 1998] is ahead and that this might be the end of LCA as an intuitive form of art. ISO 14041 requires descriptions and explanations of the circumstances and methods used in an LCA to be presented so that an independent reviewer can study and evaluate the performance in detail. Intuition was a useful and important tool in the development of LCA into the clear and structured method it is today, but in the future the performance will require full transparency.

10 Final Conclusions

The general conclusions, derived from the case studies and interviews in this study, are summarised in this chapter.

10.1 Conclusions in Short

The current environmental information system, supporting the companies to control the environmental performance of a product or process from a life cycle perspective, involve deficient access of LCI data. Acquired data is simply not made accessible to cover the lack of LCI data. There is an incoherent picture of what information that is required and how it can be used beneficially. In addition, there is a need for LCI data acquisition strategies in order to utilise existing methods efficiently. This, in turn, will lead to a better access of LCI data and, thus, faster and cheaper life cycle assessments.

The two methods for LCI data acquisition studied in this report, the LCI and the LCI modelling, are both beneficially to involve in a strategy for developing a good environmental information system, mainly because they can provide data for the whole life cycle. The LCI is the most time consuming method, but it also has the capability of generating perfect LCI data, see under the headline *The Data Quality Concept as Defined at CPM*, in the chapter *Background* for a definition of a "perfect LCI data set".

It is expensive to perform life cycle assessments today, mainly due to high costs in connection with the data acquisition. In addition, the data quality in the assessments does generally not meet the data quality requirements of ISO 14041 [ISO 14041, 1998], nor requirements to pass a review if the LCA is used to state e.g. a market position.

10.2 Lack of Life Cycle Inventory Data for Electronic Components

A conclusion within this study is that the LCI data for electronic components, which is available today, does not cover all activities in the life cycle of the product, i.e. from cradle to grave, especially the manufacturing and assembling of electronic components. Produced LCI data for electronic component production are often suffering from many and sometimes severe gaps, e.g. regarding the emission of environmentally hazardous substances such as lead and bromined flame retardants [Atlantic Consulting, IPU, 1998]. However, LCI data for activities as extraction and processing of metals and other raw materials are more easily accessible. This is described further under the headline *The Access of Life Cycle Inventory Data for Electronic Components Today* in the chapter *Background*. The consequences of the lack of LCI data are that it is difficult to make life cycle assessments for electronic components and, if an assessment based on available data is performed, the results can not be regarded as reliable since they can not be confirmed.

What happens if the production of electronic components is excluded from an LCA on electric or electronic products? Not only is the environmental load arising from energy use, emissions, and waste in the production excluded, but in addition the total environmental load originating from the earlier steps in the production chains belonging to the manufacturing processes, such as the production of energyware and maintenance material, the processing of waste etc. This may or may not be a negligible part in the LCA of an electric or electronic product, we do not know. Hence, this is something that has to be properly assessed before making general assumptions.

Under the headline *System Analysis* in the chapter *Cost versus Quality – Pragmatics when Performing a Life Cycle Assessment* there is a discussion regarding a "self-centred" way of proceeding with LCA. It implies that the requirements for the data quality decreases by the distance to the main process of interest in the LCA. Now, suppose that an LCA is performed on an electric or electronic appliance, e.g. a microwave oven. The long production chain of such a product will, with this approach, result in decreased data quality concerning the processes a few steps from the end-production, i.e. for example the production of capacitors and resistors. The lessened quality aspects can in fact result in estimations about the environmental aspects when manufacturing capacitors and resistors that are unfavourable for a specific site and, as a consequence, a component can be exchanged in the supply chain for the production. As earlier stated, the approach can also lead to unconfirmed and perhaps misleading LCA results, and it should be of great interest to environmentally concerned electric and electronic industries to change this fact by providing good LCI data.

10.3 Methods for Life Cycle Inventory Data Acquisition

In this study several methods for LCI data acquisition for electronic components are identified. They are all listed below and two of the methods, "LCI data inquiries in the supply chain" and "LCI modelling", are further assessed later in this chapter. Those two methods have the capability to generate complete LCI data, in contrary to the other methods addressed in this report, which can only supply isolated parts or fragments of LCI data needed to make an LCA of an electric or electronic product.

- Data is taken from databases. LCI data for extraction and processing of raw material are often taken from databases, but also separate data sets representing the manufacturing of some electronic components can be found. LCI databases are provided by e.g. CIT [Chalmers Indutriteknik, 1999], Ecobilan Group [Ecobilan Group, 1999], CPM [Competence Centre for Environmental Assessment of Product and Material Systems, 1999], PRé [Product Ecology Consultants, 1999], ETH-Z [Swiss Federal Institute of Technology, 1999], APME [Association of Plastics Manufacturers in Europe, 1999] and BUWAL [Swiss Agency for the Environment, Forests, and Landscape, 1996].

- Data is taken from LCA reports. Examples of public LCA reports that contain LCI data for extraction and processing of raw material and the manufacturing of some electronic components are "Life cycle Assessment of aluminium, copper and steel" [Sunér, 1996] and "A life cycle assessment of two capacitors" [Segerberg, 1995].

- Data is acquired, i.e. measured, calculated or estimated at sites by employees, consultants or LCA practitioners within the frame of an Environmental Management System (EMS). To get a certified EMS, e.g. by the EMAS (Eco-Management and Audit Scheme) regulation, the environmental aspects also have to be communicated in a public environmental statement. In some cases, the environmental statement can be a very good source for LCI data, e.g. the Environmental Statement 1998 from Beyschlag [Beyschlag, 1998]. In addition, some companies have to take governmental constraints regarding environmental aspects into consideration, which also can involve official environmental reporting [Erixon and Ågren, 1997].

- Data is collected by making inquiries in the supply chain. See case study 1 in this report for further explanations etc. of the method, and the next section *Life Cycle Inventory Data Inquiries in the Supply Chain* in this chapter for summarising conclusions regarding it.

- Data is estimated with LCI models. See case study 2 in this report for further descriptions etc. of the method, and *Life Cycle Inventory Models for Electronic Components* in this chapter for summarising conclusions regarding it.

- Data is estimated by dismantling the product. The dismantling can generate and improve qualified guesses about the product material content and e.g. supply models with some of the information needed. The analyses of dismantled products are often made due to not receiving enough information about the material content of the products from the suppliers in the product chain.

The two methods for LCI data acquisition studied in this report, the LCI in the supply chain and the LCI modelling, are both beneficial to involve in a strategy for developing a good environmental information system, mainly because they can provide data for the whole life cycle. The LCI in the supply chain is the most time consuming method, but it also has the capability of generating perfect LCI data. In addition, the method is used in several other environmental tools, e.g. Environmental Product Declaration (EPD) and Supply Chain Management (SCM). According to the data quality concept derived at CPM, the quality of the data provided by the two methods varies depending on the performance in each single case, that is, it is not obvious that the inventory generates data with better numerical precision.

10.4 Life Cycle Inventory Data Inquiries in the Supply Chain

In spite of the scarce information resulting from the subset inventory in case study 1, this method for acquiring LCI data has its benefits. An information system involving all the actors within the supply chain has the capability to generate the perfect LCI data. One may say that the supply chain is the spine of the LCA of a product. As earlier mentioned, supply chain management also gives means to e.g. acquire good environmental information for the customers, influence the supply chain, and make environmentally preferable choices that contribute to a more sustainably produced product.

The responsibility and the domain of control of an Environmental Management System (EMS) can be further extended by the application of LCA methodology [Carlson and Pålsson, 1998b]. Such an extension implies the inclusion of all relevant activities in the product chain, from the raw material extraction to the final disposal of the product. This approach coincides with the application of environmental supply chain management and it entails environmental sub-optimisations to be avoided, e.g. the use of scarce resources or environmentally unfavourable waste management procedures for the final disposal of products. Within the frame of this study, no information system fully based on the LCA methodology has been found for electronic components. Efforts can be seen, however, on establishments of such information systems, e.g. Ericsson is working in this direction. There are also several tools under development that will support this work, e.g. the LCA data documentation format ISO 14048 [ISO 14048, 1999] and Type III Environmental Product Declarations (EPD) ISO 14025 (technical report to be determined).

However, this way of collecting data is very extensive in time and has to be well planned. Thus, strategies for acquiring LCI data that entail supply chain communication will be profitable mainly in the long run. An information system involving LCI data will facilitate the utilisation of environmental tools such as Environmental Management System (EMS), LCA, and Environmental Product Declarations (EPD), and make them more efficient, i.e. fast and less expensive. Once the contact with the supplier has been established, one can assume that improvements of the information system can be made with less effort.

Case study 1 points at the importance of approaching the supply chain correctly when proceeding with the collection of data. The best results from the inquiries were reached when each company had a direct contact with their own suppliers.

A prominent example of public environmental information that entails data suitable for LCA, is the Environmental Statement catalogue from Beyschlag [Beyschlag, 1998]. It is a very comprehensive catalogue, which has a clear life cycle aim and direction, e.g. in regard of the included input-output balance of materials. It also contains a lot of quantitative environmental information for the resistors. This catalogue enables a quick and easy way to communicate environmental information to other manufacturing companies, wholesale dealers, retail chains, stores and customers. A company should also possess a complementary more detailed documentation format for environmental data, which constitutes a part of the internal information system. The format should enable the updating of information and constitute the base for decisions on secrecy issues in the communication of data.

10.4.1 Obstacles in the Provision and Acquisition of LCI Data

The fact that the electric and electronic industries involves spot-markets and moving targets, i.e. frequently modified product designs, may complicate the flow of information in a supply chain. However, experiences from the development of quality systems points to the fact that information can be connected to a product throughout parts of the production chain. These experiences should be applied when developing an environmental supply chain information system.

As shown in case study 1, the procedure of making inquiries to the suppliers can be extensive in time. Frequently mentioned obstacles in the providing and acquiring of data are:

- Unstructured information systems within the companies
  It is seldom one person, or even department, that has control of all the information needed for an LCA and the LCA practitioner has to turn to different persons and departments at the company to collect data. An efficient information system is a part of a well-developed Environmental Management System (EMS) and it should involve suitable communication facilities such as IT to enable the supply of data.

- Lack of standardised collection forms including a well-defined common vocabulary
  The miscellaneous spectrum of questions appearing in environmental inquiries entails a lot of work in interpreting the questionnaires and collecting or compiling the required information. In addition, different communication formats is used, both internally developed but also more general formats such as SPOLD and SPINE, or questionnaires e.g. from the Swedish Product Ecology Association, the Centre for Environmental Assessment of Product and Material Systems [Carlson and Pålsson, 1998a] or the Swedish Institute of Production Engineering Research [IVF, 1999]. It is likely that the provision of a standardised LCA data documentation format [ISO 14048, 1999] will improve the situation and facilitate the inquiry procedure in the long run.

- Unawareness of how to organise and benefit from environmental works in general and LCA in specific
  Many companies are not familiar with the LCA concept and can not see the benefit of contributing to LCI data generation. Authorities, trade organisations and other company networks have an important role in spreading information regarding these issues. The development of an Environmental Management System (EMS) often constitutes a good starting point for the company in learning more about this field of knowledge, as knowledge related to the specific industrial activities is a requirement in the development process.

- Resource priorities
  There are simply not enough resources within the company to supply the information asked for. Authorities, trade organisations and other company networks have an important role in supporting small and medium large companies in their environmental works. There are also several environmental tools available or under development, that will facilitate the data acquisition and provision, e.g. the standardised LCA data documentation format ISO 14048 [ISO 14048, 1999] and software tools such as the data documentation format SPINE [CPM, 1999] and SPOLD [SPOLD, 1999].

- Trade secrets
  Companies are afraid of leaking too much information to their competitors on the market. In addition, the secrecy issues are not always assessed and identified, and therefore whole data sets may be classified instead of isolated parts of data sets. This circumstance contributes to the scarce access of proper LCI data, but it could relatively easily be improved, e.g. by deciding on the levels of data accessibility and by making proper agreements for the exchange of data.

A frequently mentioned issue in the handling of data, e.g. stated by Hélène Lelièvre at Ecobilan Group, is the absence of business institutes or other third-parties, to co-ordinate the manaement of information. Since the production chains contain several different businesses, involving many small companies from all over the world, it would be profitable if one or several organisations were established in order to unify and keep a survey of the electric and electronic businesses. The organisations could be able to provide information, education and consultation about environmental information related issues, such as e.g. secrecy issues in the handling of data. In addition, the interview with Hélène Lelièvre showed that the obstacles in LCI data acquisition identified at the Swedish companies also apply for countries other than Sweden.

10.5 Life Cycle Inventory Models for Electronic Components

Another way of acquiring LCI data, besides making inquiries to the suppliers, is to make LCI models, i.e. classify electronic components in order to make appropriate estimations about the environmental load for a component in a certain predefined group. If the classification is performed in a structured way and the model is well documented, so that it can be understood, used and improved, this method for obtaining LCI data is very useful.

The method enables simplifications of real technical systems. An LCI model can be useful as a complement to the LCI data inquiries to the suppliers, which can be extensive in time, but also in connection with the results from such inquiries. Models based on such inquiries can, for example, facilitate quick screening, i.e. overview, life cycle assessments in the product development phase.

The requirements for using the modelled LCI data in LCA, and further to make it feasible to develop the model, are a thorough documentation of the model, the collected data, and the assumptions involved. In addition, it is important that the model structure is based on relevant factors, i.e. factors that coincide with or affects the environmental load of the component.

In case study 2 two different models are described, both performed at Ericsson. The classification in Model 1 is based on factors such as the weight of the components, the cost of buying or manufacturing them, and the application of results from earlier LCA studies. The classification in Model 2 is based on structural resemblance, electrical function, material content of the different components, and the access of LCI data. The latter model involves parameters that, according to the conclusions derived from this study, seem more relevant in an LCI model, although it is obvious that the access of data should not constitute a limit in the modelling. The latter model is also well documented.

The time spent to construct the models is approximately the same in both cases, between 180-200 hours. However, the time spent on LCI data acquisition in connection to the modelling differs and is 180 hours in the first model and 400 hours in the second.

It seems as if a simple, but well documented and structured model is a good starting point for a company whose LCI data acquisition strategy includes LCI modelling. After some time, one can learn from the experiences and develop the model further.

10.6 Quality Requirements of Life Cycle Inventory Data and Cost Issues Related to Life Cycle Assessment

From the interviews with LCA experts, summarised in the chapter *Cost versus Quality – Pragmatics when Performing a Life Cycle Assessment*, one gets the impression that about the only data quality requirement that is fundamental among LCA experts, is to state the data sources used in the LCA. Apart from this common requirement, the experts' opinions about the practical data quality demands diverge. Hence, the conclusions based on the interviews are that in practice, the data quality requirements are not stringent, a common view of data quality is lacking, and the quality issues are certainly not stressed to a sufficient level in practice.

However, the different requirements stated by the LCA practitioners and reviewers all coincide with or originate from the ISO standard [ISO 14041, 1998], even though only some of the requirements are mentioned by each expert. The data quality requirement in the ISO standard is a natural common target for the ambition level for documentation and handling of data at a company. There are also data documentation formats, e.g. SPINE [CPM, 1999], which includes the requirements in ISO and thereby simplifies the interpretation and structuring of the requirements in practice.

The time spent to perform an LCA, according to the interviews, lies between 5 minutes and two years and the cost between 12 000 and 240 000 US$ (100 000 and 2 million SEK). This shows a wide range of time and money spent on an LCA. One can assume that the truth is somewhere in between these extremes. It is noticeable that the experts refer to different types of life cycle assessments and not all of them have included the data acquisition in their approximations, e.g. the five minutes LCA implies that LCI data is accessible. Nevertheless, the financial means that are required today for performing an LCA are hardly acceptable; LCA has to be developed to a more efficient tool.

The methods for and results from the acquiring of data should be well documented so that the data can be reused (accessible), partly or as a whole. The interviews clearly point to the fact that the acquiring of data constitute a great part of the financial means spent to perform an LCA. In addition, if the data is acquired and documented properly the first time, updating the data will become more effective.

11 Recommendations

The recommendations derived from this study are summarised in this chapter in order to guide companies in the electric and electronics industries in the decision on strategies and methods for life cycle inventory (LCI) data acquisition.

Environmental data acquisition is the means to utilise the business opportunities optimally. This is why the acquiring of environmental data is so important and, as an important area, requires strategies. Strategies enable good decisions on methods for data acquisition, which will contribute to an efficient environmental information system containing data with high quality. It will increase the access of life cycle inventory data so that the companies can get in control of the environmental performances of their products or processes

The most important advice to everyone working with data acquisition is to put a lot of effort in the documentation so that the data is made accessible, that is, can be reused, partly and as a whole. The documentation is an investment that no one can afford to neglect.

11.1 Strategy

The most important question to ask when deciding on a strategy for LCI data acquisition is
– How is the data used today and how will it be used in the future?

LCI data can, for example, be used in life cycle assessments performed to state a market position, or in certified environmental product declarations (EPD) to communicate the results to customers and be comparable with other products. LCI data can also coincide with information that is asked for by customers, that is used in environmental reports, or public environmental statements etc. The company has to make an inventory of all (important) application areas of use for the information, and compile the requirements related to those.

The second important question to ask is
– How low data quality can be afforded?

There is a direct relation between cost and quality in data acquisition and each company needs to find a balance that suits their individual situation and goal. Often, there is a discussion about how much money that can be spent on data quality, but it is seldom considered what the actual cost may be in the long run, e.g. if an environmental scandal would occur due to unreliable information. However, a company that is making a serious investment, and wants to appear credible to their customers, should include such a calculation in the decision on strategy.

If the company finds it difficult to set the ambition level, the data quality requirement in the standard ISO 14041 [ISO 14041, 1998] is a natural common target for the ambition level of documentation and handling of data. There are also data documentation formats, e.g. SPINE [CPM, 1999], which includes the requirements in ISO and thereby simplifies the interpretation and structuring of the requirements in practice.

11.2 Methods

There are two methods very well suited for LCI data acquisition, the "LCI inquiry in the supply chain" and "LCI modelling", because they can both provide data for the whole life cycle of a product or process. Other methods, e.g. dismantling the product, are only capable of providing LCI data for parts of the life cycle and may thus lead to incomplete and expensive information systems in the long run.

11.2.1 LCI Data Inquiries in the Supply Chain

LCI data inquiry in the supply chain is the basic method for LCI data acquisition and thus, should be applied by all companies. Since it involves all the actors within the supply chain it has the capability of generating perfect LCI data. As opposed to the LCI modelling, this method enables all companies in the production chain to benefit from environmental work as each data set, i.e. environmental load, can be related to a specific site. Thus, the data set is not an average or estimation based on e.g. similar activities. The method is also used in several other environmental tools, e.g. Environmental Product Declaration (EPD) and Supply Chain Management (SCM). However, LCI data inquiry in the supply chain is extensive in time and has to be well planned, with clearly stated goals, and performed over a long time. Once the contact with the supplier has been established, one can assume that improvements of such an information system can be made faster and with less effort.

11.2.2 LCI Modelling

The LCI modelling enables simplifications of real technical systems. An LCI model can be useful as a complement to the LCI data inquiry, which can be extensive in time, but also in connection with the results from such inquiries. Models based on such inquiries can, for example, facilitate quick screening, i.e. overview, life cycle assessments in the product development phase.

The requirements for using the modelled LCI data in LCA, and further to make it feasible to develop the model, are a thorough documentation of the model, the collected data, and the assumptions involved. In addition, it is important that the model structure is based on relevant factors, i.e. factors that coincide with or affects the environmental load of the component.

It seems as if a simple, but well documented and structured model is a good starting point for a company whose LCI data acquisition strategy includes LCI modelling. After some time, one can learn from the experiences and develop the model further. The time spent in constructing the models studied in this report was approximately 180-200 hours, data acquisition excluded.

11.3 Tools to Support the Strategy Decision and Life Cycle Inventory Data Acquisition

Knowledge is the platform for making good decisions about strategies and data acquisition. Therefore companies need to know how they can organise and benefit from environmental work in general and LCA in specific, that is, learn how to utilise the business opportunities emerging from the new environmental situation on the market.

The development of an Environmental Management System (EMS), such as EMAS or ISO 14001, often constitutes a good starting point for a company in learning more about environmental information systems and related issues, as knowledge related to the specific industrial activities has to be acquired in the development process. It is also possible, although not to a satisfactory extent at present, to turn to authorities, trade organisations and other company networks to obtain information, education, and consultation regarding information systems, LCA, and related issues.

11.3.1 Standards and Data Formats

A standardised LCA data documentation format is under development [ISO 14049, 1999] and it will support the data acquisition as it gives information about the common extent of an LCA data questionnaire and provides a common language. In the meantime, in order to submit to the common language there are ISO standards available covering several connected areas, e.g. 14001-14012 regarding Environmental Management Systems (EMS), 14021-14025 regarding environmental labels and declarations and 14040-14049 regarding LCA. There are also other data documentation formats that entail this vocabulary, e.g. SPINE [CPM, 1999] and SPOLD [SPOLD, 1999].

The environmental information system should include efficient communication formats, both for internal and external use. The internal format should enable the updating of information, constitute the base for decisions on secrecy issues in the communication of data, facilitate analyses etc. One example of such a format is the software SPINE [CPM, 1999].

Finally, a prominent example of public environmental information that supplies data suitable for LCA, is the Environmental Statement catalogue from Beyschlag [Beyschlag, 1998]. It is a very comprehensive catalogue, which has a clear life cycle aim and direction, e.g. in regard of the included input-output balance of materials. It also contains a lot of quantitative environmental information for the resistors. This catalogue enables a quick and easy way to communicate environmental information to other manufacturing companies, wholesale dealers, retail chains, stores and customers.

12 Further Work

Authorities, trade institutes and other company networks have an important role in supporting the electric and electronic industries in the development of an efficient environmental information system. Since the production chains contain several different businesses, involving many small companies from all over the world, it would be favourable if one or several organisations were established in order to unify and keep a survey of the businesses. The organisations could enable environmental information flow in supply chains, co-ordinate product network databases, provide education, information, and consultation about environmental information related issues, such as secrecy issues in the communication of data etc.

Moreover, strategies for data acquisition can be further developed to give specific guidelines for different situations. There is also a need for research to support the LCI modelling.

When the standard for LCA data documentation format, ISO 14048, has been determined, it is possible to develop common and comprehensive questionnaires based on this format e.g. including predefined emission parameters for different lines of businesses. Given the standard, primary efforts should be made to facilitate the interpretation of the questionnaires e.g. by involving cognitive science etc.

12.1 Projects

Two present or soon starting environmental projects that connect to the subject for this thesis are GreenPack (Green Electronics Packaging and Environmental Data Flow Management) and GSCM (Green Supply Chain Management).

GreenPack is a recently started Nordic project, initiated and managed by IVF (Sweden) in collaboration with IPU (Denmark), SINTEF (Norway), VTT Automation (Finland) and several companies within the electric and electronic product supply chain. The overall objective is “To make Nordic electronic companies adapt environmental skills in management and product development and benefit commercially from these skills” [IVF et al, 1999]. The main focus of phase 1 (a three-year period) is “to develop a flow of environmental data in the supply chains and by that support the creation of inventory data for life cycle assessments” [IVF et al, 1999]. Thus, the main focus in the project is completely coinciding with what is considered as important further work in this study.

There is, however, an objection to the way the limitations in work in phase 1 has been planned. One limitation implies that only data regarding the material content of the product will be taken into account and that the rest of the LCA data will be included in the next project phase. Due to this limitation, the project does not seem to have the holistic approach that LCA requires. Neither is there, in the project description, any descriptions or explanations of how LCA can benefit from this limitation, or what the risks are. It may, for example, be difficult to spread knowledge about the LCA concept and, at the same time, abandon the characteristics in practice. In addition, there could be a problem in applying the tools for LCI data acquisition and information communication as they involve the LCA data set as a whole.

GSCM is an EC project that will start during the year 2000. Involved parts are IKP (at the University of Stuttgart), GreenPak (see project description above), IVF, University of Thesssaloniki, Motorola, Nokia, and other companies. The aim is to support the industry in "improving efficiency" and "creating new opportunities" by initiating Supply Chain Management (SCM) [University of Stuttgart et al, 1999]. This is a very interesting initiative, which supports not only an environmental information system and LCA as described in this study, but also unifies the environmental efforts with ways to improve the response to all kinds of changes in the market. This project can become very valuable for all involved and, in addition, bring about improvements for industries in general.

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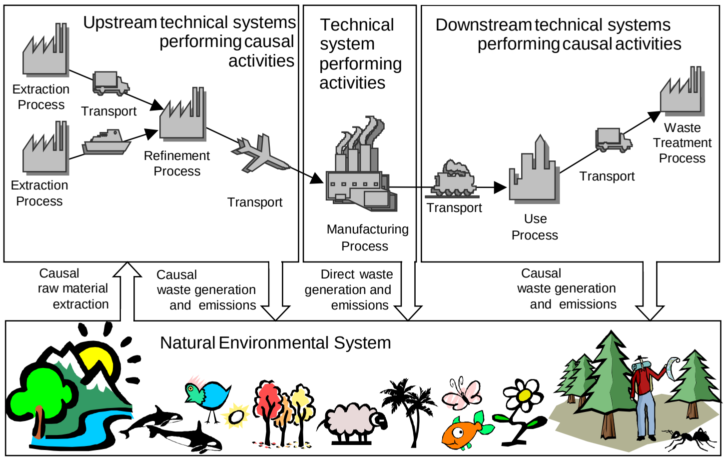
Tillman Ann-Marie, 1999, Chalmers University of Technology (CTH), Göteborg
Weidema Bo, 1999, Technical University of Denmark, Lyngby

Appendix 1: Environmental Performance Questionnaire

regarding, product name, ___________________________

1. Supply the technical description of the manufacturing process of the product.

2. Give a description of the energy source for, and quantity of energy use in, the manufacturing process described in (1).
3. What is the raw material input for the product (substance and quantity)?
4. List the emissions to air and water (substance and quantity) from the manufacturing process described in (1).
5. List the material content in the product (substance and quantity).
6. List or otherwise describe the waste from the manufacturing process.



We also need to know something about how you have acquired the data.

7. Describe the state of the manufacturing process when the quantity was measured or calculated (the factor of production).
8. Describe the type of data given (mean value measured during 24 h; calculated from similar manufacturing process etc).
9. If any allocation method have been used, please try to describe it (that is, when many products are manufactured from one line, a method for separating the load from each product has to be used).
10. How did you treat the data before entering it to this sheet, in other words the method used for acquiring the data (measuring, calculating etc).
11. Who obtains the data (someone inside the company or did you consult an expert)?
12. When did you obtain the data?

If you have any questions, you are welcome to contact us:

Maria Erixon at CPM/TEP, Chalmers University of Technology, Göteborg, Sweden
Phone +46-31-7728608, E-mail m_erixon@yahoo.com

Appendix 2: A Detailed Description of the Contacts with Each Supplier Included in Case Study 1

ACTE NC Sweden AB

ACTE NC Sweden was contacted on the third of May and sent a reminder on the ninth of June. No reply of any kind has been received.

ELFA AB

ELFA AB was contacted on the twentieth of April and sent a reminder on the eighth of June. One week later they replied that the reminder had been received, notified, and forwarded to their supplier in Taiwan. Two weeks later the questionnaire and a General Process Information paper arrived in the mail.

The questionnaire was answered on the very same sheet as the questions, with only a few words. Mostly qualitative information was given. The manufacturing process was generally described on an attached document.

My contact with ELFA was fairly good and it seems, from the Taiwanese letter, that a further contact with Megery could be possible.

IE Komponenter AB

IE Komponenter was contacted on the twentyseventh of April and sent a reminder on the ninth of June. No reply of any kind has been received.

Jakob Hatteland Electronics AB

Jakob Hatteland Electronics was contacted the on third of May and sent a reminder on the ninth of June. No reply of any kind has been received.

Modern Elteknik AB

Modern Elteknik was contacted on the twenty-seventh of April and sent a reminder on the eighth of June. The first of July Ericsson Components, suppliers of Modern Elteknik, called and left the message that their suppliers in England (an American company) did not have time to answer the questionnaire.

OEM-Component AB

OEM-Component was contacted on the seventh of May and on the twentieth a reply was received. It consisted of the Environmental Statement of their supplier, Beyschlag.

The 1998 Environmental Statement was an impressive thirty-page catalogue that gave both comprehensible and accessible environmental information about the company and its products.

Some references are made to the 1997 Annual Environmental Report and the Raw Materials section of the 1997 Materials Budget, which can be ordered from the company. One can also order a complete material balance for each product.

Pelcon Electronics AB

Pelcon Electronics was contacted the seventh of May. On the thirty-first they sent an e-mail and excused their supplier, who did not have time to answer the questionnaire in time. When a reminder was sent, on the ninth of June, Pelcon Electronics suggested that a contact would be established directly with their supplier Ixys in Germany.

No direct contact with Ixys was established and no LCI data was received.

Rune Ohlsson Electronics AB

Rune Ohlsson Electronics was contacted in the beginning of April and on the seventh a reply was received. It consisted of technical report from their supplier, BHC Aerovox.

The catalogue did not contain much environmental information usable for answering the questionnaire. Rune Ohlsson referred directly to their supplier, BHC Aerovox, for more information, but no answer was received after several e-mails to United Kingdom.

Universal Import Elektronik AB

Universal Import Elektronik was contacted in the beginning of April and on the nineteenth of May a letter was received from their supplier, Hi-Tech Resistors, in India. The letter contained a few comments to the questionnaire.

A new request, in shape of a letter, was sent to Hi-Tech Resistors in order to get a more extensive answer. No reply has been received

Appendix 3 Interviews with Five LCA Practitioners and Reviewers Regarding Cost and Data Quality in Practice

The interviewed LCA practitioners and examiners are: Ann-Marie Tillman and Bengt Steen from Technical Environmental Planning at Chalmers University of Technology, Tomas Ekvall at Chalmers Industriteknik (CIT), Lars-Gunnar Lindfors at the Swedish Environmental Research Institute (IVL), and Bo Weidema from the Department of Manufacturing Engineering at the Technical University of Denmark.

The five interviews are based on the following questions:

- What time/financial means has to be spent to make a good LCA?
- What are the characteristics of an LCA? What has to be included?
- What is the common/your data quality requirement today for an LCA?

Ann-Marie Tillman

Technical Environmental Planning at Chalmers University of Technology, Sweden

Of course the time required to make an LCA depends on the complexity of the product, material, or process in question. For example, some life cycle assessments have been performed as diploma thesis at this institution. A diploma thesis extends over 20 weeks. These life cycle assessments have been performed on moderatly complex products/materials and sometimes with two or three similar alternatives, such as: aluminium, copper, and steel [Sunér, 1996]; 2-etylhexyl-polyglukosid [Hultén, 1997] and printed and CD-stored information [Beckman, 1997]. These are all good life cycle assessments. One must keep in mind that if an expert would perform the same LCA it might only take half the time.

If an LCA already is performed and there only are some changes to be made, one week may be enough.

It is important not to get lost in details when performing an LCA, but to identify the dominating activities or factors that leads to impact.

When it comes to data quality requirements for an LCA, the most important principals is
to present the data source and
to interpret the results of the LCA correctly, that is, to put the results in perspective to the quality of data used when making the conclusions. The quality requirements concerning the relevance of the data should be expressed in the goal and scope definition.

Bengt Steen

Technical Environmental Planning at Chalmers University of Technology, Sweden

It would take about 5 minutes for an expert to perform a good survey LCA in the construction phase. The purpose of this kind of LCA is to reach environmental improvement through environmental adapted construction. In this case a “good LCA” implies that it is performed fast and gives the constructor a hint about in what direction he should develop the product.

The main reason to use LCA is to widen the perspectives and give a survey of the impacts. Further, it is important that all environmental impacts are included in the assessment so that the result gives a complete picture of these. This it what most people expect when they use the results and misinterpretations are decreased.

The traditional quality conception includes reliability, relevance and accessibility. They are unfortunately often in conflict with each other. However, the reliability should always be presented by assigning the data two measures, the calculated or measured number and the standard deviation. The accuracy should be considered in the result discussion. This data quality requirement is difficult to achieve today, but it is simply a matter of structuring the data collection and documentation procedures.

Tomas Ekvall

Chalmers Industriteknik (CIT), Sweden

According to my experience, it takes about one year to make a good traditional LCA. This estimate is relatively independent of how many practitioners that are involved. It is relevant in most projects because of the time it takes to identify activities and companies, make connections, find data, and interpret it etc. For example, at CIT we have done life cycle assessments for laminate flooring and soda packaging, which both took about one year each to perform. In the first case, two versions of the flooring were investigated. The case study involved two LCA practitioners at CIT, and the total cost was a couple of ten thousands US$ (a few hundred thousand SEK). In the latter case, six different types of packaging and a total of twelve different systems were assessed. The case study involved approximately fifteen LCA practitioners at CIT and Instituttet for Produktudvikling (IPU). The cost for this LCA was a few hundred thousand US$ (a few million SEK).

On the other hand there are other types of life cycle assessments, screening and simplified assessments. In a screening LCA one has the holistic approach to the system, but use easily accessible data. In a simplified LCA, on the other hand, one does more daring assumptions concerning the cut-offs, based on what is considered to be of importance for the purpose of the LCA. A simplified LCA takes only a few weeks and can cost less than 12 000 US$ (100 000 SEK).

When using the word LCA for a study, it implies that the whole life cycle is considered in the study as well as an impact assessment. Otherwise it could be, e.g., a cradle to gate study or an LCI.

The data quality requirements in an LCA depend on how the results and conclusions are going to be used. For example, if the LCA aim at establishing a policy, as in the case of the LCA on soda packages, the assessment will be subject to extensive reviews and examinations and must therefore have high data quality requirements to be solid.

Sometimes the data quality requirement from ISO has to be stressed in the LCA. In that case one has to address issues as uncertainty, completeness and representativeness, but also define the meaning of the words oneself. Such a data quality assessment was carried through in the LCA on soda packaging, which also included a qualitative sensitivity analysis. If the LCA is not carried out in accordance with any specific guidelines, it may be sufficient that the data sources are stated in the report.

Lars-Gunnar Lindfors

Swedish Environmental Research Institute (IVL)

The life cycle assessments that are performed at IVL cost between 12 000 and 85 000 US$ (100 000 and 700 000 SEK). The most time consuming phases in an assessment are to agree up on a goal and scope definition together with the client, and to collect the data. In conventional life cycle assessments, usually specific data for one or two lines of activities are obtained. The rest of the activities and flows in the system are represented by literature data.

Often a data collection is performed with one purpose solely, namely to fit the goal and scope definition in a specific LCA. However, some companies make advanced collections to map and describe their product system in detail. This collection can be regarded as an investment to get an LCA model or database to support many different environmental related assessments etc. within the company.

The fundamental element in an LCA is to address all human activities within the system. If there are lack of data or other limitations regarding the width of the assessment, they have to be compensated for and considered in the interpretation of the result. However, there are no demands regarding the depth of the assessment, as long as the result is interpreted from these facts. A common mistake in life cycle assessments is too superficial uncertainty and sensibility analyses. The most serious mistake in life cycle assessments is that only one ready-made impact assessment is performed in the weighting phase. The characterisation is often overlooked, though it probably is the most important step in an LCA. According to Nordic Guidelines one should use two or three weighting methods and discuss the results.

The most important data quality requirement is to have information concerning the representativeness of the data, that is the boundaries of the technical system, the collection date, the geography and the type of data. However, these facts are seldom included in a LCA. Then it can help if the examiner is familiar with the data source and knows the representativeness by experience.

There are also rules of thumb for predicting the quality of data for certain flows. For example, the data representing emissions of sulphur dioxide from combustion of fuel are reliable because it is based on the consumption, which generally is well known.

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The answer to “How long time does it take to make LCA” depends on the question asked. It can be as little as a few hours and it can be several years. The guide to know when you have enough information is the uncertainty on your data. As soon as the uncertainty has been reduced to a level where you can make a conclusion, it is meaningless to go further.

But it happens that you reach a situation where uncertainty can not be further reduced (the level of inherent uncertainty in the investigated system) and still you cannot make a conclusion. In this case, you must conclude that there is no significant difference between the systems investigated.

Often, or at least with some experience, you can in advance estimate how large the inherent (irreducible) uncertainty is, and thereby in advance conclude whether it is sensible to refine the data that you already have. For example, you can use the fact that some data sets or industry activities are comparable.

80% of the life cycle assessments we make are qualitative (matrix life cycle assessments) and they are consequently based on qualitative data, that is, using few or no numbers (which is not the same as no data!).

A qualitative matrix LCA can be made within a few hours, while a well documented screening LCA, based on existing quantitative data, can be performed within a couple of weeks. If the LCA includes data collection it can take up until two years to finish it, and probably never less than four months.

The important thing to remember when performing an LCA is to ensure that all consequences, in all steps, are included in the studied system.

Any data is better than no data, and often the crucial data is qualitative data and market data, more than the quantitative environmental data. What I mean is that in qualitative and market data sets you have to make assumptions about substitutions, system expansions etc. A fault here would probably have much larger consequences than, for example, a fault in quantitative emission data for a flow. This is not to say that data quality in quantitative data is not important; I just say this to put it in the right perspective.

With regard to quality requirements, I am again guided by uncertainty: How can I reduce my uncertainty most with the least effort. Thus, knowing what is the uncertainty - and not less: what is the cause of the uncertainty - is crucial.

Practical Strategies for Acquiring Life Cycle Inventory Data in the Electronics Industry
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A supplemental paragraph to section *10.6 Quality Requirements of Life Cycle Inventory Data and Cost Issues Related to Life Cycle Assessment* in chapter *10 Final conclusions*, page 42:

An rough estimation of the time needed to make a first time life cycle inventory for the whole product in case study 1 is 30 man-weeks, that is working weeks, effective time. This estimation is based on the fact that it took about 2 weeks to make the test inventory, which involves about 6% of the whole product. This time includes telephone calls, writing and sending letters, treat the incoming answers to be able to make new inquiries if necessary, and sending out reminders. It should be noted that no complete LCI data set was achieved in this inventory and thus complementary information is required for each data set.

When the time it takes to receive the questionnaire is included, it may sum up to 3 years. This is based on the working speed in case study 1 and the fact that is took ten weeks to receive the answers in the inventory test.

The time spent on the LCI data documentation is not included in the estimations for the LCI models.

Estimation of the time spent to acquire LCI data for the different methods in the case studies:

LCI inquiries in the supply chain: 30 man-weeks effective time
(Between 40 weeks and 3 years when receiving the information is included)
Model 1: 9 man-weeks
Model 2: 15 man-weeks

According to the interviewed LCA experts an LCA may take up to 2 years to perform. The figures mentioned above might give a hint about how time-consuming and expensive an LCA may become if it is based on LCI data solely acquired for one project through inquiries in the supply chain. If this method is used to acquire LCI data within a single project it is likely that the project will become too expensive or that the data quality will be fairly low. This is why the method “LCI data inquiries in the supply chain” should become a task integrated in the every day environmental work. However, the LCI modelling seems to be a method that may be used to acquire data within a single LCA project.