

Information system supporting a web based screening life cycle assessment tool

A procedure for constructing the information content and structure relevant for environmental life cycle inventories and impact assessments for printed circuit boards

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Summary

This report describes the methods applied when constructing the life cycle inventory and impact assessment information content and structure relevant for a web based screening life cycle assessment tool. The information content and structure is created by the Industrial environmental Informatics group (IMI) at the Center for environmental assessment of Product and Material systems (CPM) in the project "strategy of Life Cycle Assessment in the Electronics industry – inventory (LCAE)". The project is managed by the industrial research and development corporation IVF. The web-based tool mainly turns to product developers in the electronics industry who want to make environmental screening LCA on printed circuit board.

The aim of the project collaboration with IVF is to rise an interest in the environmental life cycle approach among all parties in the electronic industry, by providing an interactive web site containing quality conscious and intelligible environmental information and tools.

A pre-study was made by IMI during a few weeks, in order to make a survey of available LCI models and data, the impact assessment model in SPINE and the impact assessment design tool prototype Industrial Environmental Impact Assessment (IEIA), and related tools and ISO-standards. During the following weeks IMI designed a dummy database, i.e. a temporary short version information platform in order for the programmer to get started on the job, parallel to the real information platform design.

The life cycle inventory (LCI) system and the impact assessment system was built in about three month. Then the systems were connected, which involved a specification of the interface between the LCI and impact assessment system.

The report was written continuously during the project and were formatted and concluded during the last weeks of the project time.

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1 Introduction

The aim of this report is to document the work performed by the Industrial environmental Informatics group (IMI) at the Center for environmental assessment of Product and Material systems (CPM) in the project "strategy of Life Cycle Assessment in the Electronics industry - inventory" (LCAE). In the LCAE project IMI produced the life cycle information content and structure supporting the web based screening LCA software for printed circuit boards.

Parts of the report will be published as background information on the web site where the LCA tool is available. Another objective of this project work and report is to contribute to a general methodology report that will give guidance to any practitioner constructing an LCA information content and structure based on the SPINE model.

This report has a certain focus on the impact assessment information part. The documentation of this part involve some suggestion for improvements of the software tool design and the implementation of the impact assessment methods; Eco-indicator '99, EDIP, and the EPS system. However, the report will not summarise general recommendations on improvements of the project result. Such recommendations should be made in collaboration with all project participants, as they are totally dependent on the continuing project goals and resources.

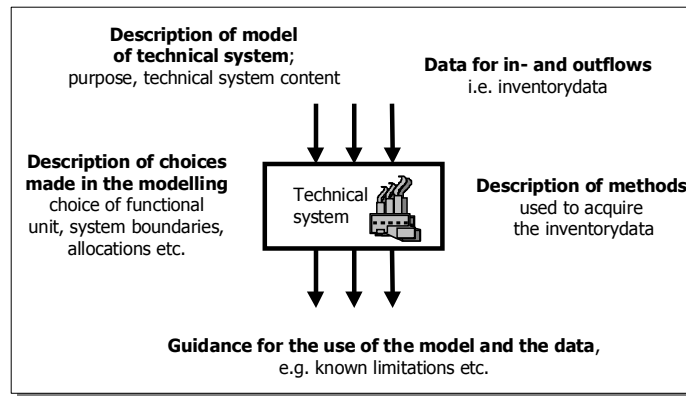
1.1 Life Cycle Assessment Information Content and Structure based on the SPINE model

CPM has worked with acquisition, documentation, and communication of environmental information in life cycle inventories performed in the industry and at universities, during several years. The development work during the period 1993 to 1995 resulted in e.g. a data quality definition, information management models and methods, and it was performed in collaborations between the industry and academic organisations. The SPINE model was one of the basic components in the development. Since then, the data documentation software SPINE@CPM Data Tool has been developed and integrated with other software tools for information management based on the SPINE model. Further, a international standardisation of a LCA data documentation format, ISO 14048, has recently been accepted as a technical specification (TS), initiated and influenced by CPM and the SPINE model.

In 1998 the research leaders at CPM, Raul Carlson and Bengt Steen, presented a detailed structure of information about models of natural and social systems. During 1999 the model for general environmental impact assessment method design was implemented in a software prototype named Industrial Environmental Impact Assessment (IEIA). The work presented in this report is the first application of IEIA. During the LCAE project the IEIA tool has been merged in to the World Wide LCA Workshop (WWLCAW) tool, which is a composite tool consisting of several separately developed tools based on the SPINE model.

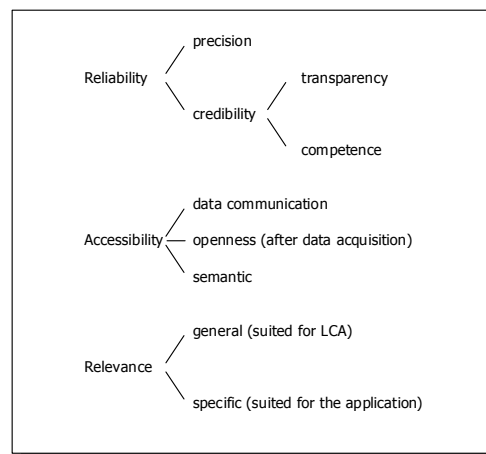
1.1.1 The Life Cycle Inventory Model in SPINE

The definition of an LCI data set, i.e. the LCI data format in the SPINE model, addresses five information parts; identification of the technical system, methods used to obtain the data set, details on data acquisition, flows of material and energy, and recommendations when using the data, see figure 1.



Ann-Christin Pålsson, CPM, 1997
Figure 1 The scope of a life cycle inventory in SPINE.

The CPM data documentation criteria are applied in the LCAE project. The criteria are based on the SPINE data format and the CPM data quality definition. The data quality dimensions are reliability, accessibility, and relevance, see figure 2.



Ann-Christin Pålsson, Raul Carlson, CPM, 1998
Figure 2 The CPM data quality definition.

The SPINE format specifies the documentation of data describing all different types of technical systems, independent of whether it is large or small, real or hypothetical. Examples of real systems are individual processes, entire plants, or large complex composite systems e.g. a complete cradle to grave system for a specific product. Unit processes and systems are both treated as technical systems in the SPINE model. That is, a technical system may have an internal structure involving several activities. The SPINE format enables transparent documentation of complete life cycle inventories as each included activity that is described separately, as a technical system, may easily be identified. In conformity with the ISO/TS 14048, the SPINE format generally contains more text fields, compared to many other LCI data documentation formats that utilises e.g. limited pre-defined text options.

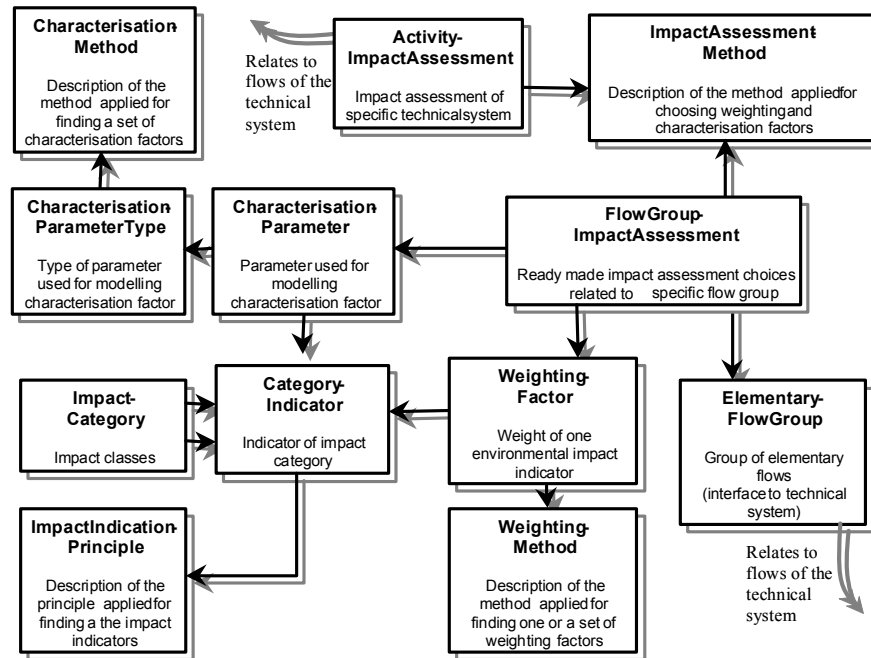
For more information regarding the LCI model in SPINE, see *"Introduction and guide to LCA data documentation using the CPM data documentation criteria and the SPINE format"* (Pålsson 1999).

1.1.2 The Impact Assessment Model in SPINE

The impact assessment part of the SPINE model, see figure 3, is designed to generally handle

environmental impact assessment. The model supports e.g. a transparent way to document all indicators selected for measurement of design performances (*impact indication principle, category indicator*), as well as weighting between them (*weighting method, weighting/actor*), and environmental characterisation factors (*characterization method, characterisation parameter*). It is a general model, enabling the design of any impact assessment method (*impact assessment method*), by relating substances and flows with environmental impacts (*flow group impact assessment*).

See "*A Data Model for LCA Impact Assessment*" (Carlson and Steen 1998), for further information on the impact assessment model in SPINE.



Raul Carlson Bengt Steen, CPM, 1998 - Chalmers, University of Technology, Gothenburg, Sweder

Figure 3 A detailed SPINE structure of information about models of natural and social systems.

The IEIA (Industrial Environmental Impact Assessment) tool is software prototype based on the impact assessment model in SPINE where the impact assessment part of LCA can be designed, documented, and calculated. The IEIA tool is used for this purpose for the first time in this LCAE project. During the LCAE project the IEIA tool has been integrated in to the World Wide LCA Workshop (WWLCAW) tool, which is a composite tool consisting of several separately developed tools based on the SPINE model.

1.2 Application in the Project "Strategy of Life Cycle Assessment in the Electronics Industry - Inventory (LCAE)"

The project "Strategy of Life Cycle Assessment in the Electronics Industry - Inventory" (LCAE) is a collaboration between the Centre for environmental assessment of Product and Material systems (CPM) at Chalmers University of Technology and IVF, during the year 2001.

The main project objective is to bring about a broad industrial application of LCA in the Swedish electronics industry. This is done e.g. by supporting the public environmental information access and providing interesting and pedagogic information material in the area of LCA and Design for environment (DFE), specifically an interactive web site containing quality conscious and intelligible environmental information and a simple screening LCA tool. The web-based tool will be freely accessible from the project web site, linked to from the IVF web site.

The web-based tool mainly turns to product developers who want to make environmental screening LCA on printed circuit board. By choosing among several predefined electronic components in the web tool, adding the number of times each component appears on the board, the user may assess the output of environmental concern from the production of a printed circuit board. It should be emphasised that the life cycle perspective is not completely fulfilled in the tool, e.g. as the waste handling part is excluded, due to lack of data and project resources. However, the “screening” part of the web tool name indicates that it does not perform a thorough assessment.

The impact assessment part consists of three impact assessment methods designed within the project, based on the three original methods, Eco-indicator, EDIP, and the EPS System. These methods were used as a base for impact assessment because they were already implemented in the IEIA tool. The original methods are re-designed according to the project requirements, see chapter about the impact assessment system for further information.

1.3 Disposition of Report

The summary provides an abstract, describing the procedure for the IMI work in the LCAE project. The following chapters are incorporated in a similar consecutive order. Below, there is a brief description of the contents of each chapter in order to facilitate the reading of the report. The aim is to make it possible for the reader to find the area of interest from the brief descriptions.

Chapter one describes the aim of the report, the history of IMI, the SPINE concept, and the objectives of the LCAE project. Further it provides the reader with reading instructions and a short SPINE concept dictionary.

In chapter two the practical procedure for designing the LCI system is described, addressing requirements from the project, the data acquisition, and presenting the final LCI system design.

In chapter three the practical procedure for designing the impact assessment system is described, addressing requirements from the project, details regarding the impact assessment methods and their construction, and general conclusions regarding the impact assessment method design, adding some improvement ideas for the impact assessment tool and the implementation.

Chapter four includes aspects on the system connection procedure, designing the flow interface, addressing flow aspects and substance nomenclature.

Chapter five give some information on the technical aspects when building and updating the database supporting the screening LCA web tool.

1.4 Report Terminology

To the greatest possible extent this report use the terminology according to the models in SPINE. These terms are written in *italic* throughout the report. Below, there is a limited dictionary presenting short explanations and/or examples of the terms in the SPINE model. For further information regarding the SPINE model terminology please see

“SPINE – A relation database structure for life cycle assessments” (Carlson, Löfgren et al. 1995)

“Introduction and guide to LCA data documentation using the CPM data documentation criteria and the SPINE format” (Pålsson 1999) (regarding the LCI part)

“A Data Model for LCA Impact Assessment” (Carlson and Steen 1998) (regarding the impact assessment part)

Short Dictionary

<i>Activity</i>	e.g. manufacturing, incineration, transports, raw material extraction, fuel combustion, use of a product, and waste deposition or treatment
<i>Category indicator</i>	an indicator of an <i>impact category</i> (e.g. years of lost life, crop production capacity, global warming potential) in mid- or endpoints
<i>Characterisation factor</i>	transfer factor, degree of impact from a substance on a <i>category indicator</i>
<i>Characterisation method</i>	description of the method applied for finding a set of <i>characterisation factors</i>
<i>Direction</i>	... of physical flow (input or output)
<i>Environment</i>	... to receive or emit the <i>flow</i> (e.g. air, water, ground technosphere)
<i>Flow</i>	inputs and outputs of matter and energy in and out of the activity
<i>Flows interface</i>	the interface between the technical and natural (environmental) system
<i>Flow type</i>	e.g. natural or refined resource, emission, product, or residue
<i>Geography</i>	e.g. Europe and Asia, North America, Goteborg, Kapellgangen 5
<i>Impact assessment method</i>	description of the method applied for choosing <i>weighting</i> and <i>characterisation factors</i>
<i>Impact category</i>	impact classes
<i>Substance</i>	e.g. limestone, crude oil, ethanol, VOC
<i>Technical system</i>	the system that delivers the functional unit
<i>Weighting Factor</i>	weight of one environmental <i>impact indicator</i>

2 The Practical Procedure for Designing the Life Cycle Inventory System by means of SPINE@CPM Data Tool

The procedure for designing the LCI system involves delimitation according to the project objectives and resources. Further, the key activities are data acquisition, and practical documentation, calculation and connection of sub-systems in order to complete the LCI database.

2.1 Requirements Regarding the Information Content

Stated in this chapter are the data quality requirements, the definition of the LCI system scope, and the accessible data sources in the project, which all have great influence on the information content supporting the screening LCA web tool.

2.1.1 System Scope

The system should be a cradle-to-gate system for the production of a printed circuit board, involving **prefabrication, manufacturing**, and, to some extent, **use**. Thus, the gate is the mounting of components on a printed circuit board or, optionally, the energy consumption in the use phase. The use phase is not regarded in any other respect than the energy consumption and the waste handling phase is excluded from the system.

The scope of electronic components included in this project system is based on 14 LCI data models developed at Ericsson in an internal LCA project between 1997 and 2000. The models were documented in the SPINE format in a co-operation with CPM during 2000 and are available in the reviewed LCI database SPINE@CPM. The models are:

1. Cable assembly
2. Capacitor for hole mounting assembly
3. Capacitor for surface mounting assembly
4. Connector assembly
5. Diode wafer production and assembly
6. Inductor assembly
7. Integrated circuit capsule assembly
8. Liquid crystal display unit assembly
9. Potentiometer assembly
10. Printed board assembly
11. Relay assembly
12. Resistor for hole mounting assembly
13. Resistor for surface mounting assembly
14. Transistor assembly

The models need to be connected to other prefabrication activities, the manufacturing activity, i.e. assembly of the printed circuit board, and the energy generation for the consumption in the use phase, see figure 4. It is decided in the project that only two stages in the prefabrication phase will be regarded, i.e. the assembly activity and one connecting refine activity. This implies e.g. that in some cases the prefabrication activity does not go all the way back to the natural system, i.e. the cradle of the technical system.

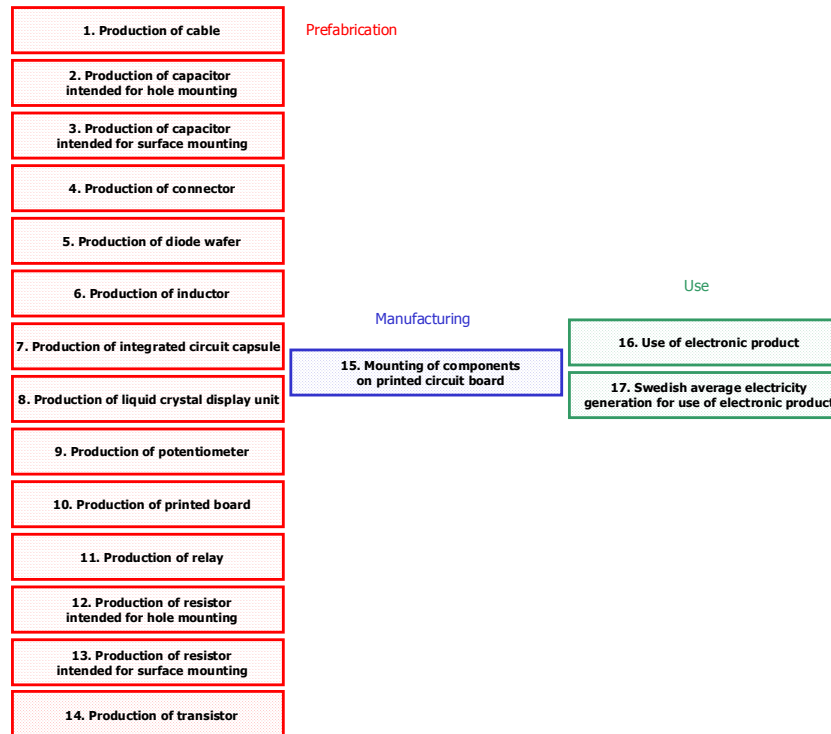


Figure 4 A schematic picture of the superior systems “Prefabrication”, “Manufacturing”, and “Use” in the LCI model. All data sets that constitute the LCI database are presented in appendix 2.

2.1.2 Data Quality

The basis for all data handling in the project is the SPINE concept. The concept is associated with a data quality definition, see figure 2, which is referred to in this quality discussion. Further, the quality dimensions is practically formalised in the CPM data documentation criteria, which set the quality standard for the data documentation throughout the project.

Reliability

The web based screening LCA tool will, as a result from this project phase, only be suited for catching attention and interest to the LCA perspective within the electronics industry and teaching the basics in the concept. The precision aspect is, in this context, not of major importance. Thus, the precision as stated in each data set, is regarded as acceptable. The credibility aspect is dealt with by applying the CPM data documentation criteria, which requires e.g. transparency. Further, all the data sets that derive from the SPINE@CPM database is reviewed according to the criteria.

Accessibility

The information platform is built electronically and will be able to be studied in the SPINE@CPM Data Tool, as HTML data reports on the web site. The tool generates the HTML reports from SPINE formatted MS Access databases. Data generated, or aggregated, in the project will be fully accessible, whereas underlying sub-systems will have the inventory profile, i.e. inventory table including numerical values, removed. The documentation language is English, and should be comprehensible for a layman in the line of business, according to the CPM data documentation criteria.

Relevance

SPINE@CPM is a LCI database and the SPINE data documentation format supports the LCI systems analysis form. Nevertheless, it is often the case that a data set is not applicable in a specific system,

due to certain restrictions in the system or limitations in the data set. In this project the boundary setting for these decisions are made quite broad, i.e. if a data set is matching the system boundaries approximately, it is included.

2.1.3 Data Sources

The only data sources used in this project are the reviewed LCI database SPINE@CPM and personal contacts within the project group.

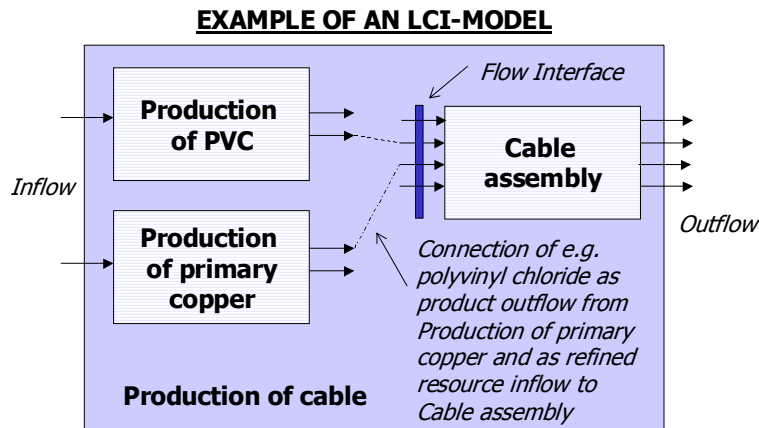
2.2 Data Acquisition

When the system scope, data quality, and data sources are identified, according to the previous chapters, the next step is the practical data acquisition. The acquisition procedure is described below.

2.2.1 SPINE@CPM Database

In order to find the relevant data in SPINE@CPM the flow interface of the inflows to the assembly models for electronic components had to be identified, see figure 5. This implied that all inflows of refined resources to the electronic component assembly models, i.e. inflows from another technical system, were compiled.

Further, these “refined resources inputs” were searched for as “product outputs” at the SPINE@CPM database web site <http://www.globalspine.com>. The result of this data search can be found in appendix 1. Totally, there are about 125 inflows of refined resources in the electric components assembly models and 45 or 36% of these are connected to an activity from SPINE@CPM. Further, the 45 connected inflows of refined resources are connected to 12 prefabrication activities deriving from SPINE@CPM.



Maria Erixon, CPM, 2001

Figure 5 The schematic picture shows how the assembly models are connected with other prefabrication models from SPINE@CPM.

2.2.2 Other Data Suppliers

A data set of main importance for the project system scope is the manufacturing process “Mounting of components on a printed circuit board”. Such information was not available in SPINE@CPM but was considered to be easily acquired from the project participants Ericsson and/or Autoliv, as they had this kind of activities within their companies.

Autoliv could only offer an environmental report (legislated report of environmental activities to Swedish authorities every year), which was quite impossible to adjust for LCA applications without an extensive investigation. Ericsson supplied some data in a PowerPoint document via e-mail, which was supplemented in a personal contact between CPM and Ericsson. This data is not very well

documented but at this time, and with available project resources, the best we could come up with.

2.3 Life Cycle Inventory System Design

The three life cycle phases prefabrication, manufacturing, and use define the model design of the LCI system, according to the requirements in the project and the SPINE inventory model. The prefabrication phase involves the production of electronic components that are possible semi-products in the manufacturing process, i.e. Mounting of components on printed circuit board.

2.3.1 Prefabrication Phase

Once the relevant connections between the electronic component assembly models and the resource refining activities were identified, 14 prefabrication systems were created. Firstly, the 14 superior systems were created in SPINE@CPM Data Tool and the sub-systems included in each superior system was imported and linked in the flow charts. Secondly, the LCI calculations were made in Excel, by exporting data in SPINE@CPM Data Tool from the sub-systems to Excel. In Excel the normalisation and unit transformation was performed and imported into the superior system in SPINE@CPM Data Tool. Finally, the documentation was completed. The result of the LCI system as a whole can be found in appendix 2.

2.3.2 Manufacturing Phase

The manufacturing phase only involves the activity “Mounting of components on printed circuit board”, which has been acquired from Ericsson and documented by CPM. The result of the LCI system as a whole can be found in appendix 2.

2.3.3 Use Phase

The use phase is represented by an electricity system that covers the energy consumption in the use phase. The result of the LCI system as a whole can be found in appendix 2.

2.3.4 Result of Total Life Cycle Inventory System

The LCI system as a whole consists of 17 data sets designed within the project, see figure 4. These superior system models are constructed from 35 data sets from the reviewed LCI database SPINE@CPM. The data set in the manufacturing phase is acquired and documented according to SPINE within the project. All data sets constituting the LCI platform are presented in a hierarchical order in appendix 2.

3 The Practical Procedure for Designing the Impact Assessment System by the means of the IEIA Tool

The procedure for designing the impact assessment system involves delimitation according to the project objectives and resources. Further, the key activities are construction of the impact assessment methods that should be used in the LCA. The method construction is basically an adaptation of the original impact assessment methods Eco-indicator '99, EDIP, and the EPS System, to the project requirements.

3.1 Requirements Regarding the Information Content

The project group set the three main requirements on the impact assessment part,

- 1) The environmental system model applied in the project constitutes the very core of the impact assessment part and should be explicit. A thorough description of the environmental system model facilitates a correct interpretation of the results and it provides the comprehension platform for any layman to catch the impact assessment concept and apply the tool.
- 2) The three impact assessment methods should be comparable in the sense that they are applied on a common environmental system model. This is a rather controversial approach, and it is

not very easy to manage. It forces the practitioner to modify the original methods in order to adapt them to the chosen environmental system model. This brings the original impact assessment methods somewhat out of context, e.g. since in this case some of the original *characterisation methods* and *flows* are excluded. However, from a scientific systems analysis point of view it is essential that the methods are addressing the same environmental system. The settings in this impact assessment part of the project should be regarded as an attempt to, within the limitations of the project resources, manage the assessment methods as consistent as possible and to document every choice and assumption along the way.

- 3) The recommendations for impact assessment in the Environmental Product Declaration (EPS) system is partially used in the description of the environmental system model in this project. The classification, which addresses five *impact categories*, is directly applied in the model. Further, the environmental system model is bounded by the pollutant emission flows included in each *impact category*. The scope of resource use flows is defined by the LCI. Nevertheless, there are several of the resource use flows that are not addressed in the impact assessment methods as well as there are several of the pollutant emission flows that are not addressed neither in the impact assessment methods nor the LCI in this specific project.

The choice of source supporting the environmental system model is made according to the plans and expectations for the next project step, where an EPD system co-ordination will be a possible task. However, the *characterisation* and *weighting methods* are used according to the three impact assessment methods Eco-indicator '99, EDIP, and the EPS system, respectively.

3.1.1 Classification According to the EPD System

The classification is common for all the three *impact assessment methods* created in this project. The six *impact categories* from the EPD system; Emission of greenhouse gases, Emissions of ozone depleting gases, Emission of acidifying gases, Emission of gases that contribute to the creation of ground-level ozone, Emission of substances to water contributing to oxygen depletion, and Resource use, are all applied. The *impact categories* in the EPD system are used as a base for selecting which *characterisation methods* to include for each *impact assessment method* and they constitute the base for identification of the environmental system model, i.e. implies which items or conditions in nature to regard in the assessment.

3.1.2 Characterisation and Weighting According to Eco-indicator '99, EDIP, and the EPS System

The methods for characterisation and weighting constitute the major difference among the three *impact assessment methods* Eco-indicator '99, EDIP, and the EPS System. They are simply modelled with different aspects in mind. It is the very purpose of the method design in this project to point out these methodological differences as a ground for having different results in the impact assessment.

The EPD system and the LCI set the common scope e.g. of flows for pollutant emissions and resource use in the new design of *impact assessment methods*. However, the original *impact assessment methods* are very different, both in structure and methodological approach, and the variation of structure among the methods makes them complex to handle stringently, in a comparative design situation as is the case in this project. For example, the indicators are of different types:

- In the EPS system (Steen 1999) the *category indicators* are YOLL (Years of Lost Life), Severe morbidity. Morbidity, Severe nuisance. Nuisance, NEX (Normalised Extinction of species). Crop (Crop production capacity). Wood (Wood production capacity). Fish and meat (Fish and meat production capacity). Drinking water (Drinking water capacity) and Base cat-ion capacity.
- In EDIP (Hauschild and Wenzel 1998) the *category indicators* are Ac (acidification potential), Etwc (chronic ecotoxicity in water), Etp (ecotoxicity to microorganisms in sewage treatment plants), Ets (chronic eco-toxicity in soil), Etw (acute ecotoxicity in water), Hta, Hts, Htw

(toxicity to humans via air, soil, water), N, P, Ne (nutrient enrichment potential, separate nitrogen or phosphorus potential, combined N-P-potential), Po (photochemical ozone formation), Gwp (global warming potential), and Odp (ozone depletion potential). In addition, there are several different *category indicators* for the resources, e.g. Wood consumption. Oil consumption, and Zinc consumption, even though they have the same *characterisation method*.

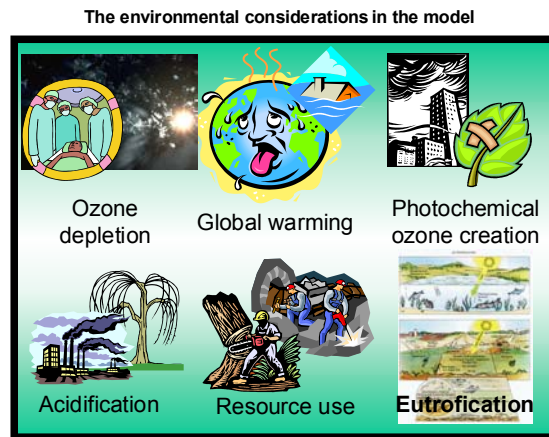
- In Eco-indicator (Goedkoop and Spriensma 2000) the *category indicators* are PDF (Potentially Disappeared Fraction) indicating the ecosystem quality, DALY (Disability Adjusted Life Years) indicating the human health, and Resource damage indicating the state of resources on earth.

The structural differences among the methods forces the practitioner to have different approaches when designing the three new methods. There is not one obvious common way of identifying the *impact categories* defined in the EPD system for all methods. The mapping to the environmental system model becomes complicated and somewhat random. Nevertheless, it is argued that such an approach is favourable as long as the procedure is well documented, i.e. the procedure is reproducible and the *impact assessment methods* possible to improve.

3.1.3 Definition of the Environmental System Model

The *impact assessment method* applied in the EPD system is not properly described, i.e. there are no explanations of why the sets of *impact categories*, *category indicators* and *characterisation factors* are chosen. In addition, the environmental system model regarded in the EPD system is not explicit, but has to be interpreted by the user. These facts make it very difficult for the impact assessment practitioner to apply the classification and characterisation correctly and further for the practitioner or interpreter to compare the *impact assessment method* in the EPD system, with other *impact assessment methods*.

However, the practical approach for defining the environmental system in the LCAE project is to identify the environmental system on the base of the stated *impact categories* in the EPD system. The *category indicators* are, in line with the *impact categories* in the EPD system, Global warming, Ozone depletion, Acidification, Photochemical ozone creation, Eutrofication, and Resources use, see figure 6. The corresponding flows relevant for this project are stated in appendix 3. Thus, these indicators and flows describe the environment and the system boundaries in this project.



Maria Erixon, CPM, 2001

Figure 6 The impact categories stated in the EPD system are the environmental considerations in the model applied in this project.

Further, the assumption is made that the environmental goal (or reference) in the EPD system is to keep the present state in the nature. This assumption is made in order for the EPD system to be in line

with the other three *impact assessment methods* included in this project study, i.e. Ecoindicator '99, EDIP, and the EPS system. It is based on the summary of impact assessment methods in the report "Systematic Approach to Environmental Priority Strategies in Product Development (EPS). Version 2000 - General System Characteristics" (Steen 1999).

3.2 Design of an Impact Assessment Method based on Eco-indicator '99

Information about Eco-indicator '99 can be found in the following report:

"The Eco-indicator 99, A damage oriented method for Life Cycle Impact Assessment" (Goedkoop and Spriensma 2000)

3.2.1 Identifying the Characterisation Methods and Relevant Flows Related to the Impact table 3.1, p22Categories

When creating the impact assessment method LCAE (ECOI/EPD) in the IEIA tool, we started from the *impact category* tables in the EPD system, e.g. "Emission of green-house gases". The question was how to find indicators and emissions corresponding to the *impact categories* in Eco-indicator?

By experience we knew that all *characterisation methods* regarding Eco-indicator were implemented in the IEIA tool having names involving the *category indicators* "DALY", "PDF", or "resource damage". Thus it was fairly easy for us to list all these *characterisation methods* in the tool and study them one by one, in order to include them in or exclude them from the new LCAE /ECIO/EPD) method.

After listing the *characterisation methods*, the documentation in the fields "Principal method name" and/or "Method description" for each method was studied, to see whether the *characterisation method* was relevant or not for the indicator, e.g. GWP.

In Eco-indicator there are several similar models included for the natural resource group fossil fuels. The different fossil fuels regarding e.g. oil (in Eco-indicator named Crude oil (feedstock), Crude oil (resource), Crude oil ETH, Crude oil IDEMAT, Energy from oil, Oil, and Crude oil) represents different heat values (energy content). The choice of energy content of coal, natural gas, and crude oil chosen for this impact assessment method are for Coal 29.3 MJ/ kg, Natural gas 30.3 MJ/ kg, and Crude oil 41 MJ/ kg. There was no background information in the Eco-indicator report regarding the different heat values, neither any recommendation on how to apply them. The choice in this study is therefor based on the fact that the other representation of fossil fuels seems to originate from other contexts than Eco-indicator '99, or they simply do not match the substance name in the LCI system model scope properly.

When creating the impact assessment method LCAE (ECOI/EPD) in the IEIA tool, the relevant EPD and LCI system flows found in each *characterisation method* were added. However, not all *flows* relevant for the environmental system model, were found in Eco-indicator. See appendix 4 to get the result of the selection procedure for *characterisation methods* and the documentation of the *impact assessment method* LCAE (ECIO/EPD) in IEIA.

3.2.2 Comments on Identification and Design Procedure

In order to list all Eco-indicator based *characterisation methods* in the IEIA tool the practitioner needs to have knowledge regarding the naming structure of the *characterisation methods*. The tool can not list these other than by searching for certain names or words. The method design also requires some knowledge regarding environmental mechanisms in nature, environmental qualities of substances etc. because these things are generally not very well described in the methods. One example of this is the existence of several fossil fuel heat values, where the practitioner is forced to choose one or several of them, or could even make different kinds of averages. However, there are basically no background information about the different figures, thus, a well-founded choice is difficult to make.

The excluded *characterisation methods* were Eco-toxic substance emission impact on PDF, Carcinogenic substance emission impact on DALYs, and Ionising radiation emission on DALYs.

3.3 Design of an Impact Assessment Method based on EDIP

Information about EDIP can be found in the following reports:

- "Environmental Assessment of Products. Methodology, tools and case studies in product development" (Alting, Hauschild et al. 1997)
- "Environmental Assessment of Products. Scientific Background" (Hauschild and Wenzel 1998)

3.3.1 Identifying the Characterisation Methods and Relevant Flows Related to the Impact Categories

When creating the impact assessment method LCAE (EDIP/EPD) in the IEIA tool, we started from the *impact category* table e.g. for "Emission of green-house gases" in the EPD system. The question was how to find the indicator for global warming and the corresponding emissions in the EDIP system?

Firstly, we listed all *characterisation methods* in EDIP. By experience we knew that all *characterisation methods* regarding EDIP were implemented in the IEIA tool having a name starting with the word "Contribution". Thus, it was fairly easy to list all these 25 *characterisation methods* in the tool and study them one by one, in order to include them in or exclude them from the new LCAE (EDIP/EPD) method. Finally five *characterisation methods* were applied, each one including several flows. See appendix 5 to get the result of the selection procedure for *characterisation methods* and the *impact assessment method* documentation in IEIA.

There are three *characterisation methods* available for nitrogen and phosphorus emissions contributing to eutrofication in EDIP. One model should be used if N is the limiting nutrient element for primary production in the environment, the other if it is P, and the last model should be used if the environment could have both N and P limiting the production. (This interpretation of EDIP was made in a dialogue with Adj. Professor Bengt Steen, Environmental Systems Analysis, Chalmers University of Technology, as the methodology report for EDIP did not give satisfying information in this matter.) Since the environmental system model in this study not defines this quality of the environment, the LCAE (EDIP/EPD) impact assessment model applies the last *characterisation method*, where both N and P is limiting factors for the production. It is most likely that this is the case for a big geographical area, such as e.g. Europe.

When creating the impact assessment method "LCAE (EDIP/EPD)" in the IEIA tool, the relevant EPD and LCI system flows found in each *characterisation method* were added. However, not all flows relevant for the environmental system model, were found in EDIP.

3.3.2 Comments on Identification and Design Procedure

As well as for the Eco-indicator based method, the procedure of listing *characterisation methods* for EDIP is difficult if the naming structure is not known. The method design also requires some knowledge regarding environmental mechanisms in nature, environmental qualities of substances etc. One example of this is the existence of three *characterisation methods* for nitrogen and phosphorus emissions contributing to eutrofication. The practitioner does not get any help from the method description in order to choose one or several of the characterisation methods. However, this is not a shortage in the SPINE model or the IEIA tool, but a failing in the documentation of EDIP. However, it is the SPINE model and tools that points out the fact that the method is insufficiently documented.

The *characterisation methods* in EDIP that are excluded from LCAE (EDIP/EPD) are related to the *category indicators* chronic ecotoxicity in water, ecotoxicity to micro organisms in sewage treatment

plants, chronic ecotoxicity in soil, acute ecotoxicity in water, and toxicity to humans via air, soil, water.

3.4 Design of an Impact Assessment Method based on the EPS System

Information about the EPS system can be found in the following reports:

- “A Systematic Approach to Environmental Priority Strategies in Product Development (EPS). Version 2000 - General System Characteristics” (Steen 1999)
- “A Systematic Approach to Environmental Priority Strategies in Product Development (EPS). Version 2000 - Models and data of the default method” (Steen 1999)

3.4.1 Identifying the Characterisation Methods and Relevant Flows Related to the Impact Categories

When designing the impact assessment method LCAE (EPS/EPD) in the IEIA tool, we started from the *impact category* table, e.g. for "Emission of green-house gases" in the EPD system. The question was how do we find the indicator for e.g. global warming and the corresponding emissions in the EPS system?

Due to our experience, it was quite easy to list all EPS system based *characterisation methods* of interest in the IEIA tool. By entering a substance from the project scope, e.g. N₂O, or the generic term for a group of substances, e.g. COD or NO_x, in the field "Restrict list to names involving" the tool listed the *characterisation methods* that could be relevant.

Secondly, after listing the *characterisation methods* involving a specific or generic flow name in the title, we studied the documentation in the fields "Principal method name" and/or "Method description" for each method, to see whether the *characterisation method* was relevant or not for the indicator, e.g. GWP. In the EPS system the "pathways", i.e. the ways for a potential pollutant emission or resource use to result in the effect of indicator, implied whether the method was relevant or not for the indicator. However, it was not always so easy to determine if the *characterisation methods* should be regarded or not, from the names of the pathways. Baoren Wei, who had experience working with the EPS system and the IEIA tool, knew all the pathways and sub-pathways and he had a key role in this part of the work. The result from this identification procedure was documented and used as a base in the next design step.

When finally creating the impact assessment method "LCAE (EPS/EPD)" in the IEIA tool, the identified EPD and LCI system flows found in each *characterisation method* were added to the new method by going through long lists of characterisation methods and flows, marking the relevant ones. However, not all flows relevant for the environmental system model in this project, were found in the EPS system.

In some cases there were several pathways involved in a *characterisation method*, but only one of them were relevant for the *impact categories*, e.g. Emission of greenhouse gases, in the LCAE (EPS/EPD) method. However, all information needed for separating the *characterisation/actor* was available in the documentation field "Method description", so in those cases it was separated, i.e. re-defined and re-calculated. Sometimes all the pathways were included in the *impact assessment method*, but for different *impact categories*, e.g. regarding ozone depletion and acidification. Then the information could be used in the aggregated state. See appendix 6 to get the result of the selection procedure for *characterisation methods* and the *impact assessment method* documentation in IEIA.

3.4.2 Comments on Identification and Design Procedure

In order to list all *characterisation methods* in the IEIA tool the practitioner needs to have certain knowledge. The naming structure of the *characterisation methods* in the EPS system has to be known to take all relevant *characterisation methods* in to consideration in the modelling. Further, knowledge

about the environmental quality and impact of emissions is a necessity since some of the *characterisation methods* are represented by a generic flow group name, e.g. VOC as in the name "Other VOC impact on crop". In order to decide which *characterisation methods* to include in a new *impact assessment method*, the names of the pathways could be a support, presupposed that these names have a meaning to the practitioner and is interpreted correctly. Baoren Wei, who had experience working with the EPS system and the IEIA tool, knew all pathways and sub- pathways or where to find them in the EPS system report "A Systematic Approach to Environmental Priority Strategies in Product Development (EPS). Version 2000 - Models and data of the default method". All the pathways are not compiled in one place in the report, but they are stated in separated tables given for each emission e.g. in chapter 3.1 "Emissions of Carbon dioxide anywhere in the world", table 3.1 at page 57, all pathways for CO₂ are listed, together with related *impact categories* and *category indicators*. After the table the pathways, or models, are described so that the practitioner can conclude e.g. which *impact category* it connects to.

In some cases there were several pathways involved in a *characterisation method*, but only one of them were relevant for the *impact categories*, e.g. Emission of greenhouse gases, in the LCAE (EPS/EPD) method. However, all information needed for separating the *characterisation factor* was available in the documentation field "Method description", so in those cases it was separated, i.e. re-defined and re-calculated. Nevertheless, it is a time consuming operation to re-define the *characterisation methods* and re-calculate the *characterisation factory*. As a total, there were about 30 (40%) of the *characterisation methods* and related *factors* that needed to be re-defined and re-calculated. It was about two days of work. Sometimes all the pathways were included in the impact assessment method, but for different impact categories, e.g. regarding ozone depletion and acidification. Then the information could be used in the aggregated state, e.g. the characterisation method "CFC-I I impact on YOLL" is an aggregated factor regarding both global warming and stratospheric ozone depletion pathway.

Another issue that we came across in the design was the fact that some flows in the environmental system model in the project not were regarded in the EPS system. However, we learned that if a flow did not exist, having a characterisation and weighting factor in the EPS system report, it could mean that indexes should be equal to zero. This has not been regarded in the method design, thus, no zero values that were not included in the EPS reports has been included.

It is quite difficult to overview the parts of the EPS system that are excluded from LCAE (EPS/EPD). The reason is the different method design of the EPS system, involving impact categories and category indicators not consistent with the other methods. In addition, the safeguard subjects and pathways, supporting the modelling, are impossible to overview and relate to other aspects in the method. The parts of the EPS system that have been excluded from the LCAE (EPS/EPD) are related to the pathways cancer, acute health effects, inhalation, oral intake, brain damage, fishing restrictions, reproduction, and direct exposure. They are excluded because the *category indicators* and flows causing impacts in these areas are excluded.

3.5 Impact Assessment System Design

3.5.1 Result and General Conclusion of the Impact Assessment System

The impact assessment system consists of three impact assessment methods designed within the project, according to the project requirements. The impact assessment methods are based on the environmental system model explicitly defined in the project and the original methods Eco-indicator '99, EDIP, and the EPS System. Thus, a conclusion from the project work is that the SPINE model for impact assessment implemented in the IEIA tool can be used to design impact assessment methods.

3.5.2 The Practical Impact Assessment Method Design Approach

The general approach for designing *impact assessment methods* by means of the IEIA tool in this project has been to

- 1) List all *characterisation methods* of interest (for the original *impact assessment method*)
- 2) Make a selection of *characterisation methods*, relevant for the EPD system based *impact categories*, by studying the documentation in the IEIA tool and related method reports and make a note of the result
- 3) Design the new *impact assessment method* by including the relevant *aspect groups* choosing original *impact assessment method*, *category indicator*, *characterisation method*, *weighting method*, and finally documenting choices, references etc.

The practical difficulties in the design of the *impact assessment methods* are addressed in the latter chapters in this section.

3.5.3 Theoretical Design Methods Supported by the SPINE Model

The theoretical SPINE impact assessment model does not explicitly suggest any approach for the design of a new method. The selection of *category indicators*, *characterisation methods*, and *weighting methods* can be made in different ways, i.e. in different orders.

However, in the software, the only way of proceeding with the design practically is by first including the relevant *aspect groups* choosing original *impact assessment method*, *category indicator*, *characterisation method*, *weighting method*, in chronological order, and finally documenting the assumptions, choices, references etc.

When working with the method design in LCAE, the circumstances required an approach where both the *impact categories* and the *flows* where possible to regard for the new method. The practical procedure for the method design in the project became a bit complicated, partly due to the IEIA design and implementation. However, there are some possible ways of proceeding when designing a new method from another *impact assessment method*, based on *impact categories* and *flows*, and according to the theoretical SPINE model:

Procedure A

1. List all *category indicators/characterisation methods/impact categories* in a method and find out which ones that the commonly defined environmental system model (in this project *impact categories*) for the new method corresponds to,
2. List all relevant *flows* included in the identified *characterisation methods* and sort out the ones defined in the common environmental system model.

The idea is that the practitioner should be able to make some first choices, e.g. select a couple of *category indicators* included in a method, and from these choices, continue the method design with a narrowing selection scope, down to the very *flows* involved. The choice of *category indicators*, for example, would in this case generate a list of related *characterisation methods*, *flows* and *weighting methods*.

Procedure B

1. List all *flows* included in a method and select the ones that map to the environmental system model defined in the new method,
2. List all *characterisation methods/category indicators/impact categories* the flows corresponds to and find out which ones that have connection to the *impact categories* defined in the new method.

In the SPINE impact assessment model a *flow* is directly related to one or several *characterisation methods* and via each of these methods connected to one or several *category indicators* and *impact assessment methods*.

The practical procedure in LCAE is a mixture of the two procedures explained in this chapter, due to current limitations in the tool. However, there is one difficulty in both procedures that, as far as this

project study shows, not can be solved by programming; it is the difficulty to identify *category indicators* and *impact categories*. As earlier mentioned, the structure of the *impact assessment methods* can be very different, thus, the different types of e.g. *category indicators* are impossible to map directly and automatically between two or more methods. It takes a thorough documentation of the method developers and a comprehensive study of the practitioners, to deal with the mapping procedure. In addition, it will of course make demands on the practitioners' knowledge regarding scientific and environmental issues.

3.5.4 Listing and Sorting Items in the IEIA Tool

There were no impact assessment method implemented in the IEIA tool when the project started. Thus, in order to list all *characterisation methods* for a specific method in the IEIA tool, the practitioner had to have certain knowledge regarding the naming structure of the *characterisation methods*, e.g. for Eco-indicator the characterisation methods are implemented in the IEIA tool having names involving the *category indicators* "DALY", "PDF", or "resource damage".

Another approach could be to list all *flows*, with aspect properties, included in an *impact assessment method* and observe the related *characterisation method* stated next to each *flow*.

As earlier mentioned, it is not possible to list or sort the *category indicators* or the *flows* they involve for a specific *impact assessment method* in the IEIA tool due to the fact that the methods are not yet designed. It is however crucial for the practitioner to be able to overview the environmental aspects and the flows regarded in the original *impact assessment methods*, e.g. to be able to use several gateways to the selection of modules in the model, to compare one *impact assessment method* with another etc. It is a weakness in the tool that the *impact category* part not yet is implemented.

Thus, there are some ways of simplifying the *impact assessment method* design as requested in this project by giving the practitioner the possibility to make some more sophisticated searches, sorting and choices among the model modules. However, the software development is not dealt with further in this project report.

3.5.5 Knowledge About the Methods and General Environmental Concerns

In order to find relations between the *impact category* from the common environmental system model defined for the new methods and the accessible *characterisation methods*, the practitioner has to have good knowledge in environmental science. For Eco-indicator and EDIP this identification is mainly based on the *characterisation method* name and description and for the EPS system it is also very much based on the name and description of the pathways. The description of the pathways is not documented in the IEIA tool and must be known or found in the EPS system reports.

Further, some knowledge regarding the environmentally important quality and impact of a substance is necessary to have when using the tool, e.g. some of the *characterisation methods* e.g. in the EPS system are represented by a generic flow group name, such as VOC as in "Other VOC impact on crop".

The modelling also requires some knowledge regarding environmental mechanisms in nature because these things are generally not very well described in the methods. One example of this is the existence of several fossil fuel heat values in Eco-indicator, where the practitioner is forced to choose one or several of them, or could make an average. However, there is basically no background information accessible regarding the different figures, supporting any choice. Another example is the three *characterisation methods* available for nitrogen and phosphorus emissions in EDIP. In order to choose one or several of these methods, the practitioner needs background information supporting the choice. This information is not accessible in the method description.

3.5.6 Aggregated Characterisation Factors

In some cases there were several pathways in EPS involved in one *characterisation method*, but only

one of them were relevant for the *impact categories* in this project, e.g. Emission of greenhouse gases. However, all information needed for separating the *characterisation factor* was available in the documentation field "Method description". About 40% of the *characterisation factors* in the EPS system based method are separated, i.e. re-defined and re-calculated. It was about two days' work. Nevertheless, it is a time consuming operation to re-define the *characterisation methods* and re-calculate the *characterisation factors*. Sometimes all the pathways were included in the *impact assessment method*, but for different *impact categories* e.g. regarding ozone depletion and acidification, then the information could be used in the aggregated state.

3.5.7 Excluded Parts of the Methods

In Eco-indicator '99 and EDIP it is quite easy to overview the *characterisation methods* not included in the new methods. This is due to that the number of the *characterisation methods* is fairly small, none of the *characterisation factors* are aggregated, and the names are informative in regard of how it connects to environmental indicators and impact. Eco-indicator has 17 *characterisation methods*, EDIP 25, and the EPS system about 200.

The excluded *characterisation methods* in Eco-indicator and EDIP can be summarised as regarding chronic and acute eco-toxicity in water and soil, toxicity to humans via air, soil, and water i.e. carcinogenic and ionising radiation emissions. The excluded parts of the EPS system concerns toxic metals, pesticides etc. There are also *flows* in the EPS system that has several specific *characterisation methods* and some of these *flows* are not included in the project environmental system model, even though they are covered by the *impact categories*.

4 Connecting the Life Cycle Inventory and Impact Assessment Systems

When the LCI profile is to be analysed in the impact assessment step, each and every *flow* from the technical system is mapped to the *flows* included in the impact assessment method. This gave rise to two practical problems in the connecting of the systems. The first problem was the identification of the impact assessment flow qualities and the second regarded the need to unify the different *substance* nomenclatures.

4.1 Flows' Interface

In order to connect the technical system, i.e. the life cycle inventory, and the natural system, i.e. the impact assessment part in the LCA, the flows' interface has to be clearly defined. This implies that the flows are described with qualities like *direction* (inflow or outflow), *type* (e.g. natural or refined resource, emission), *substance* (e.g. limestone, crude oil, ethanol, VOC), *environment* to receive or emit the flow (e.g. air, water, ground, technosphere), *geography* (Europe, Göteborg, Kapellgängen 5 etc).

The technical system is based on the inventories documented according to the SPINE concept. The inventory model in SPINE requires a thorough description of the flows, involving qualities like the ones stated above. Thus, the relevant flows in the technical system are defined properly.

However, the environmental system model is based on the EPD system, which not involves this kind of information about the flows. Thus, in this project, assumptions have been made regarding the qualities of the relevant flows in the natural system. The flows in the impact categories Greenhouse gases, Ozone depleting gases, Acidifying gases, and Gases that contribute to the creation of ground-level ozone are all assumed to be emissions to air. Some of the flows in the impact category Substances to water contributing to oxygen depletion have indications in the substance name regarding the emission media, e.g. N to air and NH₃ to water. However, the flows PO₄³⁻ and COD do not have such indications in the name. They are assumed to be emissions to water.

The section "Flows Interface" in WWLCAW is developed in order to support the design of the flows' interface between the LCI and the impact assessment phase in a study. Here you can easily assign one or several substances one or several different qualities, and add them to the project scope.

4.2 Substance Nomenclature

As discussed above, the definition of the flows' interface is crucial when connecting the systems. One of the qualities describing a flow is the substance name, i.e. the name of the molecule, chemical substance, supply material, component, product, waste type etc., that the flow consist of. The substance naming is preferably done based on one defined nomenclature setting and according to some rules and recommendations regarding how the nomenclature should be extended. This chapter deals with the problems related to the fact that there are several nomenclatures involved in the project.

4.2.1 Mapping Substance Nomenclatures

There were six nomenclatures to take into consideration in the project:

LCI	regarding the connection to the technical system and the scope of natural resources
The EPD system	regarding the scope of pollutant emissions
SPINE 2000	which is the reference nomenclature in SPINE
Eco-indicator	regarding the impact assessment applying the method
EDIP	regarding the impact assessment applying the method
The EPS system	regarding the impact assessment applying the method

In this project the default substance nomenclature was set to SPINE 2000, see "Facilitating Data Exchange between LCA Software involving the Data Documentation System SPINE" (CPM Report

2000:2, Chalmers University of Technology, Göteborg) for further information.

All nomenclatures are mapped within the project scope and can be studied in appendix 3. The mapping table was established mainly with support from Gunnar Mattsson, a chemist at ABB Corporate research, which is a member company within CPM. It also required some web browsing and literature studies.

In the project it was important to clean up in the substance nomenclature in order to facilitate the mapping of the *flows* in the different impact assessment methods to the flows included in the environmental system model. For example, the emission "sulphurhexafluoride" is a *flow* that falls under the *impact category* "greenhouse gases". This emission is regarded in two of the *impact assessment methods*, but is stated with different default names, "sulphurhexafluoride" in Eco-indicator '99 and "SF6" in the EPS system. Thus, the mapping becomes a very difficult task if the practitioner is not familiar with the substance and its synonyms. In addition, it simplifies an automatic mapping if the substances are spelled likewise, e.g. H-1211 should be Halon-1211 and Methyl ethyl ketone should be Methyl ethyl ketone etc.

One thing to emphasise regarding the nomenclature work is the importance of starting with the mapping of the substance nomenclature early in the project, in fact as soon as the environmental system model is set, the LCI scope defined, and the *impact assessment methods* chosen. In this project then the *impact assessment method* design was performed parallel with the substance nomenclature mapping. It led to that the method designed had to be reviewed after the substance nomenclature mapping was finalised and in this phase there were quite a lot of new substances found in the methods, i.e. several *characterisation methods* were added.

4.2.2 Implementing SPINE 2000

Another reason for mapping the substance nomenclatures was to facilitate the implementation of the new SPINE 2000 nomenclature in the WWLCAW tool. However, the implementation was not performed in the project due to limited time and resources.

In the nomenclature database there are sometimes several identical substance names, i.e. it contains three items named "coal". In addition, some available substance names refer to the same substance, e.g. "carbon dioxide" and "CO₂" or "sulphurhexafluoride" and "SF₆". This makes the tool difficult to work with and it may in some cases lead to errors in the assessments.

It is necessary to prevent inconsistency in the substance nomenclature and it should be thought of early in the project. Later it is complicated to put things straight since the substances has connections in the database and therefor are difficult to rename or delete.

It is suggested that a tool is developed to take care of these kinds of user problems. Such a tool should be able to facilitate the clean up in the nomenclature database. It is desirable that synonyms and other valuable information can be stored in the database and that the information is searchable.

4.2.3 Introduce New Substance Names

The calculation program presented an error message when one or more similar substances with different units were added. This was the fact with the energy substances that had units both in kg and in kWh. To avoid this error message some of the substances were renamed. For example, the substance "Coal" was only presented in "kg" while the new substance "Energy coal" was presented in "kWh". In this way the presentation did not presented substances with mixed units.

5 Technical Aspects when Building and Updating the Information Platform

The LCI system was built in SPINE@CPM Data Tool and the impact assessment system in the IEIA tool. The LCI and impact assessment systems were both stored separately in SPINE formatted MS Access databases during the first construction phase and were merged to one dummy database for the programmer to start working with. Before the connecting of the systems was started, designing the flows interface, the dummy database was replaced with a complete, merged database. The LCI systems were moved to the impact assessment database in SPINE@CPM Data Tool when updating the merged database. After connecting the systems, the programmer adapted the database to the project LCA web tool and the composite IMI web tool World Wide LCA Workshop (WWLCAW).

Step-by-step procedures for creating a composite database, i.e. merging the first two separate LCI and impact assessment databases, see also figure 7:

1. Make sure no one works with the databases involved and make a backup of the latest LCI database (give the copy a unique name e.g. involving the date),
2. Make a backup of the latest impact assessment database (give the copy a unique name e.g. involving the date),
3. Move the LCI data to the impact assessment database by using the SPINE@CPM Data Tool and rename the new, merged LCA database (if there already exists a web database, use the same name, presupposed that they are in different folders),
4. Make a backup of the new, merged LCA database, and finally,
5. Publish the new, merged LCA database on the web (possibly by replacing the original web publishing database connected to the web based LCA tool)

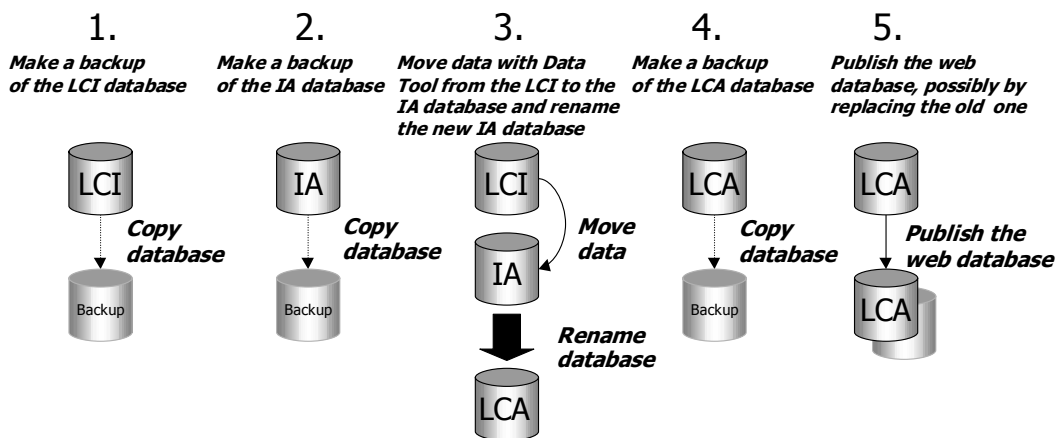


Figure 7 Step-by-step procedures for creating a composite database from the two separate databases for life cycle inventories and impact assessment methods.

6 Appendix 1: Refined Resources in the Original Electronic Component Models and Connected Activities in SPINE@CPM

Refined Resources	Connecting Activities in SPINE@CPM	Related Component Model
Acetone	-	Capacitor for hole mounting
Acetone	-	Liquid crystal display unit
Acetone	-	Potentiometer
Air	-	Relay
Al	Virgin aluminium production	Capacitor for hole mounting
Al	Virgin aluminium production	Printed board
Al	Virgin aluminium production	Transistor
Al2O3	-	Resistor for hole mounting
Al2O3	-	Resistor for surface mounting
Au	-	Connector
Cardboard	-	Integrated circuit capsule
Cardboard	-	Liquid crystal display unit
Ceramic	-	Capacitor for surface mounting
Copper	Production of primary copper	Cable
Copper	Production of primary copper	Capacitor for hole mounting
Copper	Production of primary copper	Diode wafer
Copper	Production of primary copper	Integrated circuit capsule
Copper	Production of primary copper	Printed board
Cu	Production of primary copper	Inductor
Cu	Production of primary copper	Relay
Cu	Production of primary copper	Resistor for hole mounting
Cu	Production of primary copper	Connector
Electricity	Swedish average electricity	Cable
Electricity	Swedish average electricity	Capacitor for hole mounting
Electricity	Swedish average electricity	Capacitor for surface mounting
Electricity	Swedish average electricity	Diode wafer
Electricity	Swedish average electricity	Inductor
Electricity	Swedish average electricity	Integrated circuit capsule
Electricity	Swedish average electricity	Liquid crystal display unit
Electricity	Swedish average electricity	Potentiometer
Electricity	Swedish average electricity	Printed board
Electricity	Swedish average electricity	Relay
Electricity	Swedish average electricity	Resistor for hole mounting
Electricity	Swedish average electricity	Resistor for surface mounting
Electricity	Swedish average electricity	Transistor
Electricity	Swedish average electricity	Connector
Epoxy	-	Capacitor for hole mounting
Epoxy	-	Diode wafer
Epoxy	-	Inductor
Epoxy	-	Integrated circuit capsule
Epoxy	-	Liquid crystal display unit
Epoxy	-	Relay
Epoxy	-	Resistor for hole mounting
Epoxy	-	Resistor for surface mounting
Epoxy	-	Transistor
Ethyl acetate	-	Capacitor for surface mounting
Fe3O4	Production of iron oxide	Inductor
Film (acrylate)	-	Printed board
FR4 laminate	-	Printed board
Gamma-butyrolacetone	-	Printed board
Glass	Glassworks	Liquid crystal display unit
Gold plated board	-	Liquid crystal display unit
H2SO4	Production of sulphuric acid by roasting of py...	Diode wafer

H2SO4	Production of sulphuric acid by roasting of py...	Printed board
Hard metal	-	Printed board
Hardener	-	Capacitor for hole mounting
Hardener	-	Resistor for hole mounting
Hydrochloric acid	Production of PVC	Diode wafer
Hydrochloric acid	Production of PVC	Liquid crystal display unit
Hydrochloric acid	Production of PVC	Printed board
Isopropanol	-	Diode wafer
Isopropanol	-	Liquid crystal display unit
Isopropanol	-	Relay
Lead frame	-	Transistor
Methanol	-	Capacitor for hole mounting
Methanol	-	Diode wafer
Methanol	-	Potentiometer
N2	-	Diode wafer
N2	-	Integrated circuit capsule
N2	-	Liquid crystal display unit
N2	-	Relay
N2	-	Transistor
NaOH	Production of PVC	Liquid crystal display unit
NaOH	Production of PVC	Printed board
Natural gas	-	Capacitor for surface mounting
Natural gas	-	Diode wafer
Ni	-	Connector
Oil	-	Diode wafer
Oil	-	Potentiometer
Oil	Extraction of crude oil	Relay
Oil	-	Resistor for hole mounting
Oil (MJ)	-	Relay
Oil, lubricant	-	Capacitor for hole mounting
P	-	Connector
Pb	-	Capacitor for hole mounting
Pb	-	Printed board
Pb	-	Resistor for hole mounting
Pb	-	Resistor for surface mounting
Phenolic laminated sheet	-	Potentiometer
Poly(butylene terephthalate)	-	Capacitor for hole mounting
Poly(butylene terephthalate)	-	Potentiometer
Polyacetal	-	Potentiometer
Polyester	-	Cable
Polyester	-	Printed board
Polyester	-	Connector
Polyethylene	Extraction to polyethylene all grades APME	Liquid crystal display unit
Polyphenyl oxide	-	Inductor
Polyvinyl Chloride	Production of PVC	Cable
Polyvinyl Chloride	Production of PVC	Diode wafer
Silicon wafer	Si wafer production and Si wafer processing...	Integrated circuit capsule
Silicon wafer	Si wafer production and Si wafer processing...	Transistor
SiO2	-	Integrated circuit capsule
SiO2	-	Resistor for hole mounting
SiO2	-	Resistor for surface mounting
Sn	-	Cable
Sn	-	Capacitor for hole mounting
Sn	-	Capacitor for surface mounting
Sn	-	Diode wafer
Sn	-	Inductor
Sn	-	Integrated circuit capsule
Sn	-	Liquid crystal display unit
Sn	-	Printed board
Sn	-	Resistor for hole mounting

Sn	-	Resistor for surface mounting
Sn	-	Connector
SnPb30 plating	-	Connector
Stainless steel	Virgin steel production	Liquid crystal display unit
Steel	Virgin steel production	Capacitor for hole mounting
Steel	Virgin steel production	Potentiometer
TiO2	Production of titanium dioxid	Resistor for hole mounting
Water	-	Integrated circuit capsule
Water	-	Resistor for hole mounting
Water	-	Transistor
Zn	-	Capacitor for hole mounting

7 Appendix 2: All Sub-Systems Included in the LCI System Model Subdivided in the Phases Prefabrication, Manufacturing, and Use

7.1 Prefabrication

7.1.1 Production of cable

- Production of primary copper
- Production of PVC
- Swedish average electricity
 - Combined heat and power plant with support systems
 - Gas-turbine power plant with support systems
 - Hydro-electric power plant with support systems
 - Nuclear power plant with support systems
 - Oil condensing power plant with support systems
 - Swedish electricity production system
 - Wind power plant with support systems
- Cable assembly

7.1.2 Production of capacitor intended for hole mounting

- Production of primary copper
- Swedish average electricity
 - Combined heat and power plant with support systems
 - Gas-turbine power plant with support systems
 - Hydro-electric power plant with support systems
 - Nuclear power plant with support systems
 - Oil condensing power plant with support systems
 - Swedish electricity production system
 - Wind power plant with support systems
- Virgin aluminium production
- Virgin steel production
- Capacitor for hole mounting assembly

7.1.3 Production of capacitor intended for surface mounting

- Swedish average electricity
 - Combined heat and power plant with support systems
 - Gas-turbine power plant with support systems
 - Hydro-electric power plant with support systems
 - Nuclear power plant with support systems
 - Oil condensing power plant with support systems
 - Swedish electricity production system
 - Wind power plant with support systems
- Capacitor for surface mounting assembly

7.1.4 Production of connector

- Production of primary copper
- Swedish average electricity
 - Combined heat and power plant with support systems
 - Gas-turbine power plant with support systems
 - Hydro-electric power plant with support systems
 - Nuclear power plant with support systems
 - Oil condensing power plant with support systems
 - Swedish electricity production system
 - Wind power plant with support systems
- Connector assembly

7.1.5 Production of diode wafer

- Production of primary copper
- Production of PVC
- Production of sulphuric acid by roasting of pyrite
- Swedish average electricity
 - Combined heat and power plant with support systems
 - Gas-turbine power plant with support systems
 - Hydro-electric power plant with support systems
 - Nuclear power plant with support systems
 - Oil condensing power plant with support systems
 - Swedish electricity production system
 - Wind power plant with support systems
- Diode wafer production and assembly

7.1.6 Production of inductor

- Production of iron oxide
- Production of primary copper
- Swedish average electricity
 - Combined heat and power plant with support systems
 - Gas-turbine power plant with support systems
 - Hydro-electric power plant with support systems
 - Nuclear power plant with support systems
 - Oil condensing power plant with support systems
 - Swedish electricity production system
 - Wind power plant with support systems
- Inductor assembly

7.1.7 Production of integrated circuit capsule

- Production of primary copper
- Si wafer production and Si wafer processing for integrated circuits
- Swedish average electricity
 - Combined heat and power plant with support systems
 - Gas-turbine power plant with support systems
 - Hydro-electric power plant with support systems
 - Nuclear power plant with support systems
 - Oil condensing power plant with support systems
 - Swedish electricity production system
 - Wind power plant with support systems
- Integrated circuit capsule assembly

7.1.8 Production of liquid crystal display unit

- Extraction to polyethylene all grades APME
- Glassworks
- Production of PVC
- Swedish average electricity
 - Combined heat and power plant with support systems
 - Gas-turbine power plant with support systems
 - Hydro-electric power plant with support systems
 - Nuclear power plant with support systems
 - Oil condensing power plant with support systems
 - Swedish electricity production system
 - Wind power plant with support systems
- Virgin steel production
- Liquid crystal display unit assembly

7.1.9 Production of potentiometer

- Swedish average electricity
 - Combined heat and power plant with support systems

- Gas-turbine power plant with support systems
- Hydro-electric power plant with support systems
- Nuclear power plant with support systems
- Oil condensing power plant with support systems
- Swedish electricity production system
- Wind power plant with support systems
- Virgin steel production
- Potentiometer assembly

7.1.10 Production of printed board

- Production of primary copper
- Production of PVC
- Production of sulphuric acid by roasting of pyrite
- Swedish average electricity
 - Combined heat and power plant with support systems
 - Gas-turbine power plant with support systems
 - Hydro-electric power plant with support systems
 - Nuclear power plant with support systems
 - Oil condensing power plant with support systems
 - Swedish electricity production system
 - Wind power plant with support systems
- Virgin aluminium production
- Printed board assembly

7.1.11 Production of relay

- Extraction of crude oil
- Production of primary copper
- Swedish average electricity
 - Combined heat and power plant with support systems
 - Gas-turbine power plant with support systems
 - Hydro-electric power plant with support systems
 - Nuclear power plant with support systems
 - Oil condensing power plant with support systems
 - Swedish electricity production system
 - Wind power plant with support systems
- Relay assembly

7.1.12 Production of resistor intended for hole mounting

- Production of primary copper
- Production of titanium dioxide
- Swedish average electricity
 - Combined heat and power plant with support systems
 - Gas-turbine power plant with support systems
 - Hydro-electric power plant with support systems
 - Nuclear power plant with support systems
 - Oil condensing power plant with support systems
 - Swedish electricity production system
 - Wind power plant with support systems
- Resistor for hole mounting assembly

7.1.13 Production of resistor intended for surface mounting

- Swedish average electricity
 - Combined heat and power plant with support systems
 - Gas-turbine power plant with support systems
 - Hydro-electric power plant with support systems
 - Nuclear power plant with support systems
 - Oil condensing power plant with support systems
 - Swedish electricity production system
 - Wind power plant with support systems

Resistor for surface mounting assembly

7.1.14 Production of transistor

Si wafer production and Si wafer processing for transistors

Swedish average electricity

Combined heat and power plant with support systems

Gas-turbine power plant with support systems

Hydro-electric power plant with support systems

Nuclear power plant with support systems

Oil condensing power plant with support systems

Swedish electricity production system

Wind power plant with support systems

Virgin aluminium production

Transistor assembly

7.2 Manufacturing

7.2.1 Mounting of components on printed circuit board

7.3 Use

7.3.1 Use of electronic product

7.3.2 Swedish average electricity generation for use of electronic product (re-named)

Combined heat and power plant with support systems

Gas-turbine power plant with support systems

Hydro-electric power plant with support systems

Nuclear power plant with support systems

Oil condensing power plant with support systems

Swedish electricity production system

Wind power plant with support system

8 Appendix 3: Scope of Flows Regarded in the LCA

8.1 Pollutant Emissions

Table 1 The table shows the nomenclature for pollutant emissions for the six systems involved in the impact assessment in the LCAE project. The EPD system constitutes the scope of the included impact categories and flows. The LCI column shows the connection to the technical system, i.e. the flows that were registered in the inventory. The three following columns shows the existence and naming of pollutant emissions in the different impact assessment methods Eco-indicator '99, EDIP, and the EPS system. The last column shows the reference nomenclature at CPM, SPINE 2000, which is the default nomenclature in the project. The shaded area in the table shows the pollutant emissions that are included in the LCI and represented in all the impact assessment methods. In addition, the impact categories Greenhouse Gases etc. are shaded.

The EPD System 1999	LCI in LCA-E	EcoIndicator '99	EDIP	The EPS System	SPINE 2000
<i>Pollutant Emissions</i>					
Greenhouse Gases					
CO2	CO2	CO2	CO2	CO2	CO2
N2O	N2O	N2O	N2O	N2O	N2O
CH4	-	CH4	CH4	Methane	Methane
CFC-11	-	CFC-11	CFC-11	CFC-11	CFC-11
CFC-12	-	CFC-12	CFC-12	CFC-12	CFC-12
CFC-13	-	-	-	CFC-13	CFC-13
CFC-113	-	CFC-113	CFC-113	CFC-113	CFC-113
CFC-114	-	-	CFC-114	CFC-114	CFC-114
CFC-115	-	-	CFC-115	CFC-115	CFC-115
Carbon tetrachloride	-	Carbon tetrachloride	Tetrachloromethane	-	Tetrachloromethane
Methylchloroform	-	Methylchloroform	1,1,1-Trichloroethane	Methyl chloroform	1,1,1-Trichloroethane
HCFC-22	-	HCFC-22	HCFC-22	HCFC-22	HCFC-22
HCFC-141b	-	HCFC-141b	HCFC-141b	HCFC-141b	HCFC-141b
HCFC-142b	-	HCFC-142b	HCFC-142b	HCFC-142b	HCFC-142b
HCFC-123	-	HCFC-123	HCFC-123	HCFC-123	HCFC-123
HCFC-124	-	HCFC-124	HCFC-124	HCFC-124	HCFC-124
HCFC-225ca	-	-	HCFC-225ca	HCFC-225ca	HCFC-225ca
HCFC225cb	-	-	HCFC225cb	HCFC225cb	HCFC225cb
H-1301	-	H-1301	H-1301	-	Halon-1301

HFC-23	-	HFC-23	-	HFC-23	HFC-23
HFC-32	-	HFC-32	-	HFC-32	HFC-32
HFC-41	-	HFC-41	-	-	HFC-41
HFC-43-10mee	-	HFC-43-10mee	-	HFC-43-10mee	HFC-43-10mee
HFC-125	-	HFC-125	-	HFC-125	HFC-125
HFC-134	-	HFC-134	-	HFC-134	HFC-134
HFC-134a	-	HFC-134a	HFC-134a	HFC-134a	HFC-134a
HFC-152a	-	HFC-152a	HFC-152a	HFC-152a	HFC-152a
HFC-143	-	HFC-143	-	HFC-143	HFC-143
HFC-143a	-	HFC-143a	-	HFC-143a	HFC-143a
HFC-227ea	-	HFC-227ea	-	HFC-227ea	HFC-227ea
HFC-236fa	-	HFC-236fa	-	HFC-236fa	HFC-236fa
HFC-245ca	-	HFC-245ca	-	HFC-245ca	HFC-245ca
Chloroform	Chloroform	Chloroform	Chloroform	-	Trichloromethane
Methylene chloride	-	Methylene chloride	-	-	Dichloromethane
Sulphurhexafluoride	-	Sulphurhexafluoride	-	SF6	SF6
Perfluoromethane	-	Perfluoromethane	-	-	Tetrafluoromethane
Perfluoroethane	-	Perfluoroethane	-	-	Hexafluoroethane
Perfluoropropane	-	Perfluoropropane	-	-	Octafluoropropane
Perfluorobutane	-	Perfluorobutane	-	-	Decafluorobutane
Perfluoropentane	-	Perfluoropentane	-	-	Dodecafluoropentane
Perfluorohexane	-	Perfluorohexane	-	-	Tetradecafluorohexane
Perfluorocyclobutane	-	Perfluorocyclobutane	-	-	Octafluorocyclobutane
Trifluoroiodomethane	-	Trifluoroiodomethane	-	-	Trifluoroiodomethane
Ozone Depleting Gases					
CFC-11	-	CFC-11	CFC-11	CFC-11	CFC-11
CFC-113	-	CFC-113	CFC-113	CFC-113	CFC-113
CCl4	-	-	Tetrachloromethane	-	Tetrachloromethane
CH3CCI3	-	1,1,1-Trichloroethane	1,1,1-Trichloroethane	-	1,1,1-Trichloroethane
HCFC-142b	-	HCFC-142b	HCFC-142b	HCFC-142b	HCFC-142b
HCFC-22	-	HCFC-22	HCFC-22	HCFC-22	HCFC-22
HCFC-141b	-	HCFC-141b	HCFC-141b	HCFC-141b	HCFC-141b
HCFC-123	-	HCFC-123	-	HCFC-123	HCFC-123
HCFC-124	-	HCFC-124	-	HCFC-124	HCFC-124

HCFC-225ca	-	HCFC-225ca	-	HCFC-225ca	HCFC-225ca
HCFC-225cb	-	HCFC-225cb	-	HCFC-225cb	HCFC-225cb
CH3Br	-	Methyl bromide	Methyl bromide	-	Bromomethane
H-1211	-	Halon-1211	H-1211	-	Halon-1211
H-1301	-	Halon-1301 1	H-1301	H-1301	Halon-130
H-2402	-	Halon-2402	-	-	Halon-2402
Acidifying Gases					
SO2	SO2	SO2	SO2	SO2	SO2
SO3	SO3	SO3	SO3	SO3	SO3
NO2	NO2	NO2	NO2	-	NO2
NOx	NOx	NOx	NOx	NOx	NOx
NO	-	NO	NO	-	NO
HCl	HCl	-	HCl	HCl	HCl
HNO3	HNO3	-	HNO3	-	HNO3
H2SO4	-	-	H2SO4	-	H2SO4
H3PO4	H3PO4	-	H3PO4	-	H3PO4
HF	-	-	HF	HF	HF
H2S	-	-	H2S	H2S	H2S
NH3	NH3	Ammonia	NH3	NH3	NH3
Gases that Contribute to the Creation of Ground-level Ozone					
Hydrocarbons (average)	HC	-	-	-	Hydrocarbons
Non-methane hydrocarbons (average)	-	-	-	-	-
Petrol car, combustion emissions	-	-	VOC from petrol car, combustion	-	-
Petrol car, evaporation	-	-	VOC from petrol car, evaporation	-	-
Diesel car, combustion emissions	-	-	VOC from diesel car, combustion	-	-
Stationary combustion	-	-	-	-	-
Use of solvents	-	-	-	-	-
Industrial processes	-	-	-	-	-
Oil refinement and distribution	-	-	VOC from oil refining and distribution	-	-

Leakage of natural gas	-	-	VOC from natural gas leakage	-	-
Methane	CH4	Methane	Methane	CH4	Methane
Ethane	Ethane	Ethane	Ethane	Ethane	Ethane
Propane	-	Propane	Propane	Propane	Propane
n-Butane	-	Butane	n-Butane	n-Butane	Butane
i-Butane	-	i-Butane	-	i-Butane	2-Methylpropane
n-Pentane	-	Pentane	n-Pentane	n-Pentane	Pentane
i-Pentane	-	i-Pentane	-	i-Pentane	2-Methylbutane
Neopentane	-	Neopentane	-	-	2,2-Dimethylpropane
n-Hexane	-	Hexane	n-Hexane	Hexane	Hexane
2-Methylpentane	-	2-Methylpentane	2-Methylpentane	2-Methylpentane	2-Methylpentane
3-Methylpentane	-	3-Methylpentane	3-Methylpentane	3-Methylpentane	3-Methylpentane
2,2-Dimethylbutane	-	2,2-Dimethylbutane	2,2-Dimethylbutane	-	2,2-Dimethylbutane
2,3-Dimethylbutane	-	2,3-Dimethylbutane	2,3-Dimethylbutane	-	2,3-Dimethylbutane
n-Heptane	-	Heptane	n-Heptane	n-Heptane	Heptane
2-Methylhexane	-	2-Methylhexane	2-Methylhexane	-	2-Methylhexane
3-Methylhexane	-	3-Methylhexane	3-Methylhexane	-	3-Methylhexane
n-Octane	-	Octane	n-Octane	n-Oktane	Octane
n-Nonane	-	Nonane	n-Nonane	n-Nonane	Nonane
n-Decane	-	Decane	n-Decane	n-Decane	Decane
n-Undecane	-	Undecane	n-Undecane	n-Undecane	Undecane
n-Dodecane	-	Dodecane	n-Dodecane	n-Dodecane	Dodecane
Cyclohexane	-	Cyclohexane	-	-	Cyclohexane
Cyclohexanone	Cyclohexanone	Cyclohexanone	-	-	Cyclohexanone
Cyclohexanol	-	Cyclohexanol	-	-	Cyclohexanol
Ethylene	-	Ethene	Ethylene	Ethylene	Ethene
Propylene	-	Propene	Propylene	-	Propene
But-1-ene	-	1-Butene	But-1-ene	1-Butene	1-Butene
cis-But-2-ene	-	cis 2-butene	-	-	cis-2-Butene
trans-But-2-ene	-	trans 2-butene	trans-But-2-ene	-	trans-2-Butene
Methylpropene	-	Methylpropene	-	-	2-Methylpropene
cis-Pent-2-ene	-	cis-Pent-2-ene	-	-	cis-2-Pentene
trans-Pent-2-ene	-	trans-Pent-2-ene	trans-Pent-2-ene	-	trans-2-Pentene
Pent-1-ene	-	Pent-1-ene	Pent-1-ene	1-Pentene	1-Pentene

2-Methylbut-1-ene	-	2-Methylbut-1-ene	2-Methylbut-1-ene	-	2-Methyl-1-butene
3-Methylbut-1-ene	-	3-Methylbut-1-ene	3-Methylbut-1-ene	-	3-Methyl-1-butene
2-Methylbut-2-ene	-	-	2-Methylbut-2-ene	-	2-Methyl-2-butene
Hex-1-ene	-	Hex-1-ene	-	-	1-Hexene
cis-Hex-2-ene	-	cis-Hex-2-ene	-	-	cis-2-Hexene
trans-Hex-2-ene	-	trans-Hex-2-ene	-	-	trans-2-Hexene
Styrene	-	Styrene	-	-	Styrene
1,3-Butadiene	-	1,3-Butadiene	-	-	Butadiene
Isoprene	-	Isoprene	Isoprene	Isoprene	Isoprene
Acetylene	-	Acetylene	Acetylene	Acetylene	Acetylene
Benzene	-	Benzene	Benzene	-	Benzene
Toluene	-	Toluene	Toluene	Toluene	Toluene
o-Xylene	-	o-Xylene	o-Xylene	o-Xylene	o-Xylene
m-Xylene	-	m-Xylene	m-Xylene	m-Xylene	m-Xylene
p-Xylene	-	p-Xylene	p-Xylene	p-Xylene	p-Xylene
Ethylbenzene	-	Ethylbenzene	Ethylbenzene	Ethylbenzene	Ethylbenzene
Propylbenzene	-	-	-	-	Propylbenzene
i-Propylbenzene	-	i-Propylbenzene	-	i-Propylbenzene	Cumene
1,2,3-Trimethylbenzene	-	1,2,3-Trimethylbenzene	1,2,3-Trimethylbenzene	1,2,3-Trimethylbenzene	1,2,3-Trimethylbenzene
1,2,4-Trimethylbenzene	-	1,2,4-Trimethylbenzene	1,2,4-Trimethylbenzene	1,2,4-Trimethylbenzene	1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene	-	1,3,5-Trimethylbenzene	-	1,3,5-Trimethylbenzene	1,3,5-Trimethylbenzene
o-Ethyltoluene	-	o-Ethyltoluene	o-Ethyltoluene	o-Ethyltoluene	1-Ethyl-2-methylbenzene
m-Ethyltoluene	-	m-Ethyltoluene	m-Ethyltoluene	m-Ethyltoluene	1-Ethyl-3-methylbenzene
p-Ethyltoluene	-	p-Ethyltoluene	p-Ethyltoluene	p-Ethyltoluene	1-Ethyl-4-methylbenzene
3,5-Dimethylethylbenzene	-	3,5-Dimethylethylbenzene	-	3,5-Dimethylethylbenzene	3,5-Dimethylethylbenzene
3,5-Diethyltoluene	-	3,5-Diethyltoluene	-	3,5-Diethyltoluene	1,3-Diethyl-5-methylbenzene
Formaldehyde	-	Formaldehyde	Formaldehyde	Formaldehyde	Formaldehyde
Acetaldehyde	-	Acetaldehyde	Acetaldehyde	Acetaldehyde	Acetaldehyde
Propionaldehyde	-	Propionaldehyde	Propionaldehyde	Propionaldehyde	Propanal
Butyraldehyde	-	Butanal	Butyraldehyde	Butyraldehyde	Butanal
i-Butyraldehyde	-	i-Butyraldehyde	-	i-Butyraldehyde	2-Methylpropanal

Pentanaldehyde	-	Pentanal	-	-	Pentanal
Benzaldehyde	-	-	-	-	Benzaldehyde
Acetone	Acetone	Acetone	Acetone	Acetone	Acetone
Methylethylketone	Methyl ethyl ketone	Methylethylketone	Methylethylketone	Methylethylketone	Methyl ethyl ketone
Methyl-i-butylketone	Methyl isobutyl ketone	Methyl-i-butylketone	Methyl-i-butylketone	Methyl-i-butylketone	Methyl i-butyl ketone
Methylpropylketone	-	2-Pentanone	-	-	2-Pentanone
Diethylketone	-	3-Pentanone	-	-	3-Pentanone
Methyl-i-propylketone	-	Methyl-i-propylketone	-	-	3-Methyl-2-butanone
Hexan-2-one	-	2-Hexanone	-	-	2-Hexanone
Hexan-3-one	-	3-Hexanone	-	-	3-Hexanone
Meth-1-t-but-1-ketone	-	-	-	-	3,3-Dimethyl-2-butanone
Methanol	Methanol	Methanol	Methanol	Methanol	Methanol
Ethanol	-	Ethanol	Ethanol	Ethanol	Ethanol
n-Propanol	-	n-Propanol	-	-	Propanol
n-Butanol	-	n-Butanol	Butanol	Butanol	Butanol
i-Propanol	i-Propanol	i-Propanol	-	i-Propanol	i-Propanol
i-Butanol	-	i-Butanol	-	i-Butanol	i-Butanol
s-Butanol	-	s-Butanol	-	-	s-Butanol
t-Butanol	-	t-Butanol	-	-	t-Butanol
3-Pentanol	-	3-Pentanol	-	-	3-Pentanol
2-Methylbutan-1-ol	-	2-Methylbutan-1-ol	-	-	2-Methyl-1-butanol
3-Methylbutan-1-ol	-	3-Methylbutan-1-ol	-	-	3-Methyl-1-butanol
3-Methylbutan-2-ol	-	3-Methylbutan-2-ol	-	-	3-Methyl-2-butanol
2-Methylbutan-2-ol	-	2-Methylbutan-2-ol	-	-	2-Methyl-2-butanol
Diacetone alcohol	Diacetone alcohol	Diacetone alcohol	-	-	Diacetone alcohol
Ethylene glycol	Ethylene glycol	-	-	-	Ethylene glycol
Propylene glycol	-	-	-	-	Propylene glycol
Dimethylether	-	Dimethylether	Dimethylether	Dimethylether	Dimethyl ether
Methyl-t-butylether	-	Methyl-t-butylether	-	-	Methyl t-butyl ether
Diethylether	-	Diethylether	-	-	Diethyl ether
Diisopropylether	-	Diisopropylether	-	-	Diisopropylether
Ethyl-t-butylether	-	Ethyl-t-butylether	-	-	2-Ethoxy-2-methylpropane
2-Methoxyethanol	-	2-Methoxyethanol	-	-	2-Methoxyethanol

2-Ethoxyethanol	-	2-Ethoxyethanol	-	-	2-Ethoxyethanol
1-Butoxypropanol	-	1-Butoxypropanol	-	-	1-Butoxypropanol
2-Butoxyethanol	2-Butoxy ethanol	2-Butoxyethanol	-	-	2-Butoxyethanol
1-Methoxy-2-propanol	-		1-Methoxy-2-propanol	-	1-Methoxy-2-propanol
Formic acid	-	Formic acid	-	-	Formic acid
Acetic acid	Acetic acid	Acetic acid	-	-	Acetic acid
Propanoic acid	-	Propanoic acid	-	-	Propanoic acid
Methyl formate	-	Methyl formate	-	-	Methyl formate
Methyl acetate	-	Methyl acetate	Methyl acetate	-	Methyl acetate
Ethyl acetate	Ethyl acetate	Ethyl acetate	Ethyl acetate	-	Ethyl acetate
i-Propyl acetate	-	i-Propyl acetate	i-Propyl acetate	-	1-Methylethyl acetate
n-Propyl acetate	-	n-Propyl acetate	-	-	Propyl acetate
n-Butyl acetate	Butyl acetate	n-Butyl acetate	n-Butyl acetate	n-Butyl acetate	Butyl acetate
s-Butyl acetate	-	s-Butyl acetate	-	-	1-Methylpropyl acetate
t-Butyl acetate	-	t-Butyl acetate	-	-	1,1-Dimethylethyl acetate
Methyl chloride	Methyl chloride	Methyl chloride	-	-	Chloromethane
Methylene chloride	-	Dichloromethane	-	-	Dichloromethane
Chloroform	Chloroform	Chloroform	Chloroform	-	Trichloromethane
cis-Dichloroethylene	-	cis 1,2-Dichloroethene	-	-	cis-1,2-Dichloroethene
trans-Dichloroethylene	-	trans 1,2-Dichloroethene	-	-	trans-1,2-Dichloroethene
Tetrachloroethylene	-	-	Tetrachloroethylene	-	Dichloroethene
Trichloroethylene	Trichloroethylene	Trichloroethylene	Trichloroethylene	-	Tetrachloroethene
Methyl chloroform	-	1,1,1-Trichloroethane	Methyl chloroform	Methyl chloroform	Trichloroethene
					1,1,1-Trichloroethane
Substances to Water Contributing to Oxygen Depletion					
N to air	-	-	-	-	N total
NOx to air	NOx	Nox	Nox	NOx to air	NOx
NH3 to air	NH3	Ammonia	NH3	NH3 to air	NH3
N to water	N-tot	-	-	N-tot	N total
NO3- to water	Nitrate NO3-	-	-	-	NO3-
NH4+ to water	NH4+	Ammonium	-	-	NH4+
P to water	P-tot	-	P-tot	P-tot	P total
PO43-	PO43-	-	-	-	PO43-

8.2 Natural Resources

Table 2 The table shows the nomenclature for the natural resources in all six involved systems involved in the impact assessment in the LCAE project. The LCI column shows the scope of the natural resources. The EPD system column is left empty here since the system does not list any natural resources. The following three columns shows the nomenclature for the impact assessment methods applied, and the last column, SPINE 2000, shows the reference nomenclature in the project.

LCI in LCA-E	The EPD system 1999	Eco-indicator '99	EDIP	The EPS system	SPINE 2000
<i>Natural resources</i>					
Elements in Ore/Metals					
Cr	-	Chromium in ore	-	Cr	Chromium in ore
Lead	-	Lead in ore	Lead	Pb	Lead in ore
Uranium	-	-	-	U	Uranium in ore
Zinc	-	Zinc in ore	Zinc	Zn	Zinc in ore
Minerals - Specific Minerals					
Bauxite	-	Bauxite	-	-	Bauxite
Bentonite	-	-	-	-	Bentonite
Dolomite	-	-	-	-	Dolomite
Feldspar	-	-	-	-	Feldspar
Lime	-	-	-	-	Limestone
Limestone	-	-	-	-	Limestone
Olivine	-	-	-	-	Olivine
Sodium chloride	-	-	-	-	Sodium chloride
Minerals - Non Specific Minerals					
Copper ore	-	Copper ore	-	-	Copper ore
Iron ore	-	Iron ore	-	-	Iron ore
Lead ore	-	Lead ore	-	-	Lead ore
Uranium ore	-	-	-	-	-
Non-material Energy Resources					
Hydro	-	-	-	-	-
Hydro power	-	-	-	-	-

Nuclear power	-	-	-	-	-
Other Natural Resources					
Alloy material	-	-	-	-	-
Alloy ore	-	-	-	-	-
Area	-	Occup. as convent. arable land	-	Arable land	-
Calcium fluoride	-	-	-	-	-
Calcium sulphate	-	-	-	-	-
Chalice	-	-	-	-	-
Clay	-	-	-	-	-
Coal	-	Coal	Coal	Coal	Coal
Crude oil	-	Crude oil	Oil	Oil	Crude oil
Diesel	-	-	-	-	-
Electricity	-	-	-	-	-
Emulsifier	-	-	-	-	-
Fuel oil	-	Crude oil	Oil	Oil	Crude oil
Fuel wood	-	-	Wood	-	Wood
Gas	-	Natural gas	Natural gas	Natural gas	Natural gas
Lignite	-	-	-	-	-
Na ₂ SO ₄	-	-	-	-	-
NaCl	-	-	-	-	-
Natural gas	-	Natural gas	Natural gas	Natural gas	Natural gas
Nitrogen	-	-	-	N	Nitrogen
NO ₃ -N	-	-	-	-	-
Oil	-	Crude oil	Oil	Oil	Crude oil
Other energy	-	-	-	-	-
Peat	-	-	-	-	-
Portland soda	-	-	-	-	-
Renewable energy source	-	-	-	-	-
Sand	-	-	-	-	-
Sodium sulphate	-	-	-	-	-
Solvey soda	-	-	-	-	-
Sulphur	-	-	-	-	-
Water	-	-	-	Drinking water	Water
Wood	-	-	Wood	-	Wood

9 Appendix 4: Eco-indicator

9.1 Included Characterisation Methods

The *characterisation methods* included in the method LCA-E(ECOI/EPS) are stated in the table below, next to the *impact category* that was the base for the identification.

Impact Category	Characterisation Method
Emission of greenhouse gases	1. Climate change impact on DALYs
Emissions of ozone depleting gases	2. Ozone layer depletion impact on DALYs
Emission of acidifying gases	3. Acidification and eutrofication impact on PDF
Emission of gases that contribute to the creation of ground-level ozone	4. Respiratory effects impact on DALYs
Emission of substances to water contributing to oxygen depletion	Acidification and eutrofication impact on PDF
Resource use	5. Fossil fuels extraction impact on resource damage 6. Minerals extraction impact on resource damage 7. Land use impact on PDF

9.2 Descriptions of the impact assessment method "LCA-E (ECOI/EPD) "

Name

LCA-E (ECOI/EPD)

Version

2001

Date completed

2001-05-23

Principal Method Name

Eco-indicator based EPD adapted impact assessment

Method Description

Context

The purpose of creating this method is to support a web based tool with life cycle impact assessment information. The tool turns to product developers who want to make screening LCA on printed circuit board. The three methods LCA-E (EPS/EPD), LCA-E (EDIP/EPD), and LCA-E (EcoIndicator/EPD) are included in this tool. The tool is developed within the project "LCA Electronics - Inventory" (LCA-E) during the year 2001, in a co-operation between the competence Centre in Environmental Assessment of Product and Material Systems (CPM) at Chalmers University of Technology and Industrial Research and Development Corporation (IVF) in Sweden.

Classification and included flows

The classification and choices of included flows for each impact category is based on the

recommendations in the EPD system, except for resource use, where the scope of flows is defined by the life cycle inventory. The EPD (Environmental Product Declarations) system is an attempt to apply ISO TR 14025 (a normative technical report for provisional use in the field of Type III environmental declarations) in practice. See Literature reference to find further information about the EPD system. information in the LCI about the metal content in included ores (e.g. Copper, Iron, Lead and Uranium ore) these mineral resources have not been included as pure metals in the impact assessment methods.

The included natural resource "Area" is assumed to be arable land. Further, there are almost no minerals relevant for the LCI addressed in the impact assessment methods. The exception is "Bauxite" in the EPS system. Due to lack of information in the LCI about the metal content in included ores (e.g. Copper, Iron, Lead and Uranium ore) these mineral resources have not been included as pure metals in the impact assessment methods.

Characterisation and weighting factors

The characterisation and weighting factors derive from the EPS system for impact assessment, see Literature reference to find further information about this system.

Environmental goal/reference

The assumption is made that the environmental goal (or reference) in the environmental system model in this project study, is to keep the present state in the nature. The assumption supplements the definition of the environmental system model, which is based on the choices of *impact categories* and the scope of *flows* to and from the studied system.

The EPD system has not defined such a goal or reference and this assumption is made in order for this method to be in line with the other three impact assessment methods included in this project study, i.e. Eco-indicator '99, EDIP, and the EPS system. The assumption is based on the summary of impact assessment methods in the report "Systematic Approach to Environmental Priority Strategies in Product Development (EPS). Version 2000 - General System Characteristics", see Literature reference.

Practical approach when creating the method

The creation of the impact assessment method LCA-E (ECOI/EPD) in the IEIA tool, started from the *impact category* tables in the EPD system, e.g. "Emission of green-house gases". The question was how to find indicators for the *impact categories* and the corresponding emissions in Eco-indicator?

By experience we knew that all *characterisation methods* regarding Eco-indicator were implemented in the IEIA tool having names involving the *category indicators* "DALY", "PDF", or "resource damage". Thus, it was fairly easy to list all these *characterisation methods* in the tool and study them one by one, in order to include them in or exclude them from the new LCA-E (ECOI/EPD) method.

After listing the *characterisation methods*, the documentation in the fields "Principal method name" and/or "Method description" for each method was studied, to see whether the *characterisation method* was relevant or not for the indicator, e.g. GWP.

In EDIP there are several similar models included the natural resource group fossil fuels. The different fossil fUels regarding e.g. oil (in Eco-indicator named Crude oil (feedstock). Crude oil (resource). Crude oil ETH, Crude oil IDEMAT, Energy from oil. Oil, and Crude oil) represents different heat values (energy content). The choice of energy content of coal, natural gas, and crude oil in this impact assessment method are:

Coal 29.3 MJ/kg

Natural gas 30.3 MJ / kg

Crude oil 41 MJ/kg

There were no background information in the Eco-indicator report (see Literature reference) regarding the different heat values neither any recommendations on how to apply them. The choice in this study is therefor based on the fact that the other representation of fossil fuels seems to originate from other contexts than Eco-indicator '99, or they simply do not match the substance name in the LCI system model scope properly.

When creating the impact assessment method "LCA-E (ECOI/EPD)" in the IEIA tool, the relevant EPD and LCI system flows found in each *characterisation method* were added. However, not all flows relevant for the environmental system model, were found in Eco-indicator.

Literature reference

Requirements for Environmental Product Declarations, EPD; An Application of ISO TR 14025 Typ III Environmental Declarations; MSR 1999:2; Swedish Environmental Management Council; 2000-03-27; English Translation - Draft version 1

"The Eco-indicator 99, A damage oriented method for Life Cycle Impact Assessment", Goedkoop M, Spriensma R, Methodology Report, 17 April 2000, Second Edition, Product Ecology (Pre) Consultants

Methodological Range

Geographical Boundary (from Eco-indicator)

All emissions and all forms of land-use are assumed to occur within Europe. The damages for most impact categories are also assumed to occur in Europe, with the following exceptions:

- The damages from ozone layer depletion and greenhouse effects are occurring on a global scale, as European emissions are influencing the global problem and not just the European.
- The damages to resources are occurring on a global scale.

Time Boundary (from Eco-indicator)

The method models emissions as if they are emitted during 1999.

Boundaries to Natural and Technical System

The values in the environmental system model are defined as global temperature, stratospheric ozone concentration, acidity in ground and water, concentration of oxygen in water and ground-level ozone. The occurrence of e.g. heavy metals, PCBs, or dioxins and the environmental and human health effects from exposition, is not regarded in this study.

Further, the flows regarded in this study are natural resources used in, and pollutant emissions emitted from, the life cycle of a printed circuit board, from the resource extraction, through refining and processing, to the final manufacturing and use phase.

Notes

This method is created by Maria Erixon at CPM, Chalmers University of Technology, in Goteborg, Sweden.

10 Appendix 5: EDIP

10.1 Included characterisation methods for the EDIP based IA method

Impact Category	Characterisation Method
Emission of greenhouse gases	1. Contributions to GWP
Emissions of ozone depleting gases	2. Contributions to ODP
Emission of acidifying gases	3. Contributions to EF(ac)
Emission of gases that contribute to the creation of ground-level ozone	4. Contributions to EF (po)
Emission of substances to water contributing to oxygen depletion	5. Contributions to EF (ne)
Resource use	6. Contributions to resource consumption

10.2 Descriptions of the Impact Assessment Method "LCA-E (EDIP/EPD)" in IEIA

Name

LCA-E (EDIP/EPD)

Version

2001

Date completed

2001-05-23

Principal Method Name

EDIP based EPD adapted impact assessment

Method Description**Context**

The purpose of creating this method is to support a web based tool with life cycle impact assessment information. The tool turns to product developers who want to make screening LCA on printed circuit board. The three methods LCA-E(EPS/EPD), LCA-E (EDIP/EPD), and LCA-E (EcoIndicator/EPD) are included in this tool. The tool is developed within the project "LCA Electronics - Inventory"(LCA-E) during the year 2001, in a co-operation between the competence Centre in Environmental Assessment of Product and Material Systems (CPM) at Chalmers University of Technology and Industrial Research and Development Corporation (IVF) in Sweden.

Classification and included flows

The classification and choices of included flows for each impact category is based on the recommendations in the EPD system, except for resource use, where the scope of flows is defined by the life cycle inventory. The EPD (Environmental Product Declarations) system is an attempt to apply ISO TR 14025 (a normative technical report for provisional use in the field of Type III environmental declarations) in practice. See Literature reference to find

further information about the EPD system.

The included natural resource "Area" is assumed to be arable land. Further, there are almost no minerals relevant for the LCI addressed in the impact assessment methods. The exception is "Bauxite" in the EPS system. Due to lack of information in the LCI about the metal content in included ores (e.g. Copper, Iron, Lead and Uranium ore) these mineral resources have not been included as pure metals in the impact assessment methods.

Characterisation and weighting factors

The characterisation and weighting factors derive from the EPS system for impact assessment, see Literature reference to find farther information about this system.

Environmental goal/reference

The assumption is made that the environmental goal (or reference) in the environmental system model in this project study, is to keep the present state in the nature. The assumption supplements the definition of the environmental system model, which is based on the choices of *impact categories* and the scope *Of flows* to and from the studied system.

The EPD system has not defined such a goal or reference and this assumption is made in order for this method to be in line with the other three impact assessment methods included in this project study, i.e. Eco-indicator '99, EDIP, and the EPS system. The assumption is based on the summary of impact assessment methods in the report "Systematic Approach to Environmental Priority Strategies in Product Development (EPS). Version 2000 - General System Characteristics", see Literature reference.

Practical approach when creating the method

The creation of the EDIP based EPD adapted impact assessment method LCA-E (EDIP/EPD) in the IEIA tool, started from the *impact category* table e.g. for "Emission of green-house gases" in the EPD system. The question was how to find the indicator for global warming and the corresponding emissions in the EDIP system?

All *characterisation methods* regarding EDIP were implemented in the IEIA tool having a name starting with the word "Contribution". Thus, all these 25 *characterisation methods* were listed in the tool and studied one by one, in order to include them in or exclude them from the new LCA-E (EDIP/EPD) method.

There are three *characterisation methods* available for nitrogen and phosphorus emissions in EDIP. One model should be used if N limits the eutrofication in the environment, the other if it is P, and the last model should be used if the environment could have both N and P limiting the eutrofication. (This interpretation of EDIP was made in a dialogue with Adj. Professor Bengt Steen, Environmental Systems Analysis, Chalmers University of Technology, as the methodology report for EDIP did not give satisfying information in this matter.) Since the environmental system model in this study not defines this quality of the environment, the LCA-E (EDIP/EPD) impact assessment model applies the last *characterisation method*, where both N and P is limiting the eutrofication.

When creating the impact assessment method "LCA-E (EDIP/EPD)" in the IEIA tool, the relevant EPD and LCI system flows found in each *characterisation method* were added. However, not all flows relevant for the environmental system model, were found in EDIP.

Literature reference

Requirements for Environmental Product Declarations, EPD; An Application of ISO TR 14025 Typ III Environmental Declarations; MSR 1999:2; Swedish Environmental Management Council; 2000-03-27; English Translation - Draft version 1

"Environmental Assessment of Products", Alting L., Hauschild M., and Wenzel H., Volume 1: Methodology, tools, and case studies in product development, 1998, Institute for Product Development, Cambridge

"Environmental Assessment of Products", Hauschild M., Wenzel H., Volume 2: Scientific Background, 1998, Institute for Product Development, Cambridge

Methodological Range

Geographical Boundary (from EDIP): Europe

Time Boundary (from EDIP): The method is created during 1990.

Boundaries to Natural and Technical System

The values in the environmental system model are defined as global temperature, stratospheric ozone concentration, acidity in ground and water, concentration of oxygen in water and ground-level ozone. The occurrence of e.g. heavy metals, PCBs, or dioxins and the environmental and human health effects from exposition, is not regarded in this study.

Further, the flows regarded in this study are natural resources used in, and pollutant emissions emitted from, the life cycle of a printed circuit board, from the resource extraction, through refining and processing, to the final manufacturing and use phase.

Notes

This method is created by Maria Erixon at CPM, Chalmers University of Technology, in Goteborg, Sweden.

11 Appendix 6: EPS System

11.1 Included characterisation methods for the EPS System based IA method

The *characterisation methods* included in the method LCA-E (EPS/EPS) are stated in the table below, next to the *impact category* that was the base for the identification.

Impact Category	Characterisation Method
Emission of greenhouse gases	<ol style="list-style-type: none"> 1. CFC-11 impact on crop 2. CFC-11 impact on morbidity 3. CFC-11 impact on NEX 4. CFC-11 impact on wood 5. CO2 impact on crop 6. CO2 impact on morbidity 7. CO2 impact on NEX 8. CO2 impact on severe morbidity 9. CO2 impact on wood by elevated temperature 10. CO2 impact on YOLL 11. Freons impact on crop 12. Freons impact on morbidity 13. Freons impact on NEX 14. Freons impact on severe morbidity by global warming 15. Freons impact on wood 16. Freons impact on YOLL by global warming 17. Methane impact on crop by global warming 18. Methane impact on morbidity 19. Methane impact on NEX 20. Methane impact on severe morbidity by global warming 21. Methane impact on wood by global warming 22. Methane impact on YOLL by global warming 23. N2O impact on crop by global warming 24. N2O impact on morbidity by global warming 25. N2O impact on NEX by global warming 26. N2O impact on severe morbidity by global warming 27. N2O impact on wood by global warming 28. N2O impact on YOLL by global warming 29. Other VOC impact on crop
Emissions of ozone depleting gases	<ol style="list-style-type: none"> 30. CFC-11 impact on severe morbidity 31. CFC-11 impact on YOLL 32. Freons impact on severe morbidity 33. Freons impact on YOLL
Emission of acidifying gases	<ol style="list-style-type: none"> 34. H2S impact on base-cat ions 35. H2S impact on crop 36. H2S impact on fish & meat 37. H2S impact on morbidity 38. H2S impact on NEX 39. H2S impact on severe morbidity 40. H2S impact on YOLL 41. HCl impact on base cat-ion capacity 42. HCl impact on fish & meat 43. HCl impact on NEX by acidification

	44. NH3 impact on base cat-ion capacity 45. NH3 impact on fish & meat by acidification 46. NH3 impact on NEX by acidification 47. NOx impact on base cat-ion capacity 48. SO2 impact on base cat-ion capacity 49. SO2 impact on fish & meat 50. SO2 impact on NEX by acidification 51. SO3 impact on NEX by acidification
Emission of gases that contribute to the creation of ground-level ozone	52. Ethylene impact on crop by oxidant 53. Ethylene impact on severe morbidity by oxidant 54. Ethylene impact on YOLL by oxidant 55. Formaldehyd impact on crop by oxidant 56. Formaldehyde impact on severe morbidity by oxidant 57. Formaldehyde impact on YOLL by oxidant Other VOC impact on crop 58. Other VOC impact on severe morbidity by oxidante 59. Other VOC impact on YOLL by oxidant
Emission of substances to water contributing to oxygen depletion	60. COD impact on NEX 61. N-tot impact on fish & meat 62. N-tot impact on NEX 63. NH3 impact on fish & meat 64. NH3 impact on NEX by eutrofication 65. NH3 impact on wood by eutrofication 66. NOx impact on fish and meat 67. NOx impact on NEX by eutrofication 68. NOx impact on wood by eutrofication 69. P-tot impact on NEX
Resource use	70. Arable land use impact on NEX 71. Resource consumption impact on resource reserves

11.2 Documentation of the impact assessment method "LCA-E (EPS/EPD)" in IEIA

This description of the impact assessment method "LCA-E (EPS/EPD)" is designed in line with the SPINE data format for impact assessment, applied in the IEIA tool.

Name

LCA-E (EPS/EPD)

Version

2001

Date completed

2001-05-23

Principal Method Name

EPS based EPD adapted impact assessment

Method Description

Context

The purpose of creating this method is to support a web based tool with life cycle impact

assessment information. The tool turns to product developers who want to make screening LCA on printed circuit board. The three methods LCA-E(EPS/EPD), LCA-E (EDIP/EPD), and LCA-E (ECOI/EPD) are included in this tool. The tool is developed within the project "LCA Electronics - Inventory" (LCA-E) during the year 2001, in a co-operation between the competence Centre in Environmental Assessment of Product and Material Systems (CPM) at Chalmers University of Technology and Industrial Research and Development Corporation (IVF) in Sweden.

Classification and included flows

The classification and choices of included flows for each impact category is based on the recommendations in the EPD system, except for resource use, where the scope of flows is defined by the life cycle inventory. The EPD (Environmental Product Declarations) system is an attempt to apply ISO TR 14025 (a normative technical report for provisional use in the field of Type III environmental declarations) in practice. See Literature reference to find farther information about the EPD system.

The included natural resource "Area" is assumed to be arable land. Further, there are almost no minerals relevant for the LCI addressed in the impact assessment methods. The exception is "Bauxite" in the EPS system. Due to lack of information in the LCI about the metal content in included ores (e.g. Copper, Iron, Lead and Uranium ore) these mineral resources have not been included as pure metals in the impact assessment methods.

Characterisation and weighting factors

The characterisation and weighting factors derive from the EPS system for impact assessment, see Literature reference to find further information about this system.

Environmental goal/reference

The assumption is made that the environmental goal (or reference) in the environmental system model in this project study, is to keep the present state in the nature. The assumption supplements the definition of the environmental system model, which is based on the choices of *impact categories* and the scope of *flows* to and from the studied system.

The EPD system has not defined such a goal or reference and this assumption is made in order for this method to be in line with the other three impact assessment methods included in this project study, i.e. Eco-indicator '99, EDIP, and the EPS system. The assumption is based on the summary of impact assessment methods in the report "Systematic Approach to Environmental Priority Strategies in Product Development (EPS). Version 2000 - General System Characteristics", see Literature reference.

Practical approach when creating the method

The creation of the impact assessment method LCA-E (EPS/EPD) in the IEIA tool, started from the *impact category* tables in the EPD system, e.g. "Emission of green-house gases". The question was how to find the indicator for global warming and the corresponding emissions in the EPS system?

In the field "Restrict list to names containing" in the IEIA tool, we searched for the relevant flows from the table "Emission of greenhouse gases". Since the *characterisation method* is EPS involves the flow name, or the generic term for a group of flows, it was quite easy to list all *characterisation methods* of interest in the tool.

After listing the *characterisation methods* involving a specific flow in the name, the documentation in the fields "Principal method name" and/or "Method description" for each method was studied, to see whether the *characterisation method* was relevant or not for the indicator, e.g. GWP. In the EPS system the "pathways", i.e. the ways for a potential pollutant emission or resource use to result in the effect of indicator, implied whether the method was

relevant or not for the indicator.

When creating the impact assessment method "LCA-E (EPS/EPD)" in the IEIA tool, the relevant EPD and LCI system flows found in each *characterisation method* were added. However, not all flows relevant for the environmental system model, were found in the EPS system.

In some cases there were several pathways involved in a *characterisation method* but only one of them were relevant for the *impact categories*, e.g. Emission of, greenhouse gases, in the LCA-E (EPS/EPD) method. However, all information needed for separating the *characterisation factor* was available in the documentation field "Method description", so in those cases it was separated, i.e. re-defined and re-calculated. Sometimes all the pathways were included in the impact assessment method, but for different impact categories, e.g. regarding ozone depletion and acidification. Then the information could be used in the aggregated state.

Literature reference

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A Systematic Approach to Environmental Priority Strategies in Product Development (EPS). Version 2000 - Models and data of the default method, Steen B., CPM Report 1999:5, Chalmers University of Technology, Goteborg

Methodological Range

Geographical Boundary (from the EPS system): Europe

Time Boundary (from the EPS system): The method is created during 1990-1999

Boundaries to Natural and Technical System

The values in the environmental system model are defined as global temperature, stratospheric ozone concentration, acidity in ground and water, concentration of oxygen in water and ground-level ozone. Hence, the occurrence of e.g. heavy metals, PCBs, or dioxins and the environmental and human health effects from exposition, is not regarded in this study.

Further, the flows regarded in this study are natural resources used in, and pollutant emissions emitted from, the life cycle of a printed circuit board, from the resource extraction, through refining and processing, to the final manufacturing and use phase.

Notes

This method is created by Maria Erixon at CPM, Chalmers University of Technology, in Goteborg, Sweden.

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