CHALMERS

Life Cycle Impact Assessment – a study of the EPS method for use within SCA

Master of Science thesis

JENNY MATTSSON

Department of Energy and Environment
Division of Environmental System Analysis
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2012
Report No: 2012:26
ISSN No: 1404-8167

REPORT NO. 2012:26
ISSN NO. 1404-8167

Life Cycle Impact Assessment
–a study of the EPS method for use within SCA

JENNY MATTSSON

Master of Science thesis in the Master's programme
Industrial Ecology - for a Sustainable Society

Department of Energy and Environment
Division of Environmental System Analysis
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2012

Life Cycle Impact Assessment – a study of the EPS method for use within SCA
JENNY MATTSSON

Examiner: ANNE-MARIE TILLMAN
Supervisor: CHRISTIN LIPTOW
Supervisor at SCA Global Hygiene Category: ELLEN RIISE

Diploma thesis 2011- 2012:
Department of Energy and Environment
Division of Environmental System Analysis

Chalmers University of Technology

SE – 412 96 Göteborg

Sweden

Telephone: + 46 (0)31 – 772 1000

Online publication in Chalmers Publication Library

http://publications.lib.chalmers.se/cpl/

Abstract

Industry in today's society is becoming more and more aware of the importance of having a good environmental work. As part of this work is usually a Life Cycle Assessment (LCA) performed on a company's products. SCA (Svenska Cellulosa Aktiebolaget) has used LCA for environmental evaluation of their hygiene products since the early nineties. Performing LCA's supports SCA in identifying the areas of a product's life cycle that could potentially be improved. There are several different Life Cycle Impact Assessment (LCIA) methods; currently SCA uses the impact categories of CML2002 methodology. The company has an interest of evaluating a LCIA method that provides a weighted value. Therefore is the Environmental Priority Strategies (EPS) method described in this master thesis report. Further were the EPS method implemented in a software program and used to perform results on SCA products. The result, by using the EPS method and the impact categories from the CML2000 methodology, were presented and discussed.

The conclusions from the result were that the EPS method should be used communicating the one weighted value presented in Environmental Load Unit (ELU). The benefits with using the CML2000 impact categories used at SCA today, is that it is a known concept, which makes it easier to communicate since more people know how they are interpreted. This is one of the largest differences by using the EPS method and CML2000 impact categories. Therefore, I recommend both approaches as they present the results in different way. Thus, one cannot get the same kind of information from the impact categories that SCA currently use and the EPS-method since EPS measures further out in the cause-effect chain. With EPS, all the results from the impact categories are weighted to one single score. This value is quite easy to communicate and can be used in an early product development process, for example quickly see how different materials effect the outcome. It is also very convenient to have a method that presents one weighted value, which can be used to see if the product has improved or deteriorated its environmental performance or compared with another product.

Keywords: Environmental Priority Strategies (EPS), Life Cycle Impact Assessment (LCIA), SCA

Abbreviations

AiO	All-in-One
AP	Acidification Potential
BOD	Biochemical Oxygen Demand
CPM	Centre for Environmental Assessment of Products and Material Systems
COD	Chemical Oxygen Demand
DALY	Disability Adjusted Life Years
EI'99	ECO- indicator 99
ELU	Environmental Load Unit
EP	Eutrophication Potential
EPA	United States Environmental Protection Agency
EPD	Environmental Product Declaration
EPS	Environmental Priority Strategies
EU	European Union
FSC	Forest Stewardship Council
GHG	Green House Gas emission
GWP	Global Warming Potential
IA	Impact Assessment
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
NEX	Normalized extinction of species
NPIC	National Pesticide Information Center
OECD	Organization for Economic Co-operation and Development
PCR	Product Category Rules
PEFC	The Programme for the Endorsement of Forest Certification
RMS	Resource Management System
SAP	Super Absorbents
SCA	Svenska Cellulosa Aktiebolaget
SCA GHC	SCA Global Hygiene Category
SCA PC	SCA Personal Care
SEMC	Swedish Environmental Management Council
SQL	Structured Query Language
UN	United Nation
UNEP	United Nations Environment Programme
WTP	Willingness to pay
YOLL	Years of Lost Life

Table of Content

1. Introduction

This introductory chapter intends to give a background and insight into the subject of the thesis.

All activities that occur in society affect the environment to some extent, whereas the largest impact comes from the industrial sector. This is because it has a rapid development with rapid changes that are not always linked to a low environmental impact, for example, emissions of different kinds and in different quantities are released, waste is produced, and resources are depleted. The awareness that industrial activities create environmental impacts that affect the climate, have increased in the last decade. However, some important historical events started the debate about environmental issues and the importance of sustainable development (Carlson & Pålsson 2008).

- The starting point is very often seen as the release of mercury in the fishing community Minamata Japan, in 1959. The consequences were devastating for the local population and surrounding environment.
- In 1962 was the book "Silent Spring" published, written by Rachel Carson. The book discussed the fact that industrial products could have serious consequences on the environment.
- The UN conferences in 1972 and 1992 have been very important, particularly as United Nations Environment Programme (UNEP) was established in 1972. In 1987, UNEP published the Brundtland report, which discussed sustainable development. It defined sustainable development, as *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."* In other words, sustainable development represents the awareness of the global environment today and tomorrow. Sustainable development is often referred to as the cooperation of social development, environmental protection and the economic development, see Figure 1 (Carlson & Pålsson 2008).

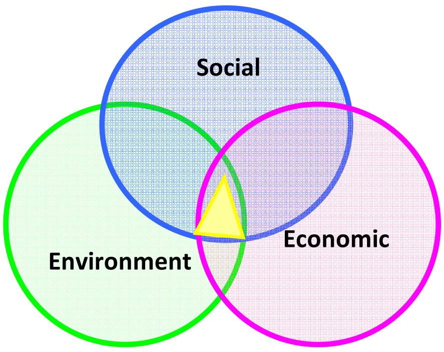


Figure 1 The circles illustrate how the cooperation between social, environment, and economic system can reach sustainable development (yellow area).

In order to reach sustainable development, it is among others things important to have a good overview of environmental issue. The tool Life Cycle Assessment (LCA) can be used to get an overview since LCA answers questions such as how large the impact is or will be due to e.g. a change or investment (Riise 2011).

1.1 Background for the thesis

SCA has used LCA for environmental evaluation of their hygiene products since the early nineties. Performing LCAs supports SCA in identifying the areas of a product's life cycle that could potentially be improved, while improvement means (Riise 2010):

- Making the best possible decisions in terms of sustainable solutions
- Choosing suppliers that offer environmentally sound materials
- Carrying out product development in a sustainable manner
- Improving the logistics chain

As part of revising and updating the way of working with LCA's within the company, there is a need to also review how the impact assessments of the LCA is performed. So far, SCA's focus has been on using three of the most common impact categories within LCA; Global Warming Potential, Acidification Potential, and

Eutrophication Potential. However, there is an interest to investigate other Life Cycle Impact Assessment (LCIA) methods and evaluate which additional environmental information they could provide (Riise 2010). LCA usage at SCA is described further in chapter 3.3. SCA's way of working with LCA.

1.2. Purpose

The aim is to:

- Investigate the different options of methods that exist today on environmental impact assessment that are of interest for SCA, but with a focus on the EPS (Environmental Priority Strategies) 2000 method
- Identify which additional environmental information the EPS method will provide (at impact category level) compared to the characterizations factors in CML2000. This will be done by analyzing the result at impact category level and the weighting result between the products.
- Update SCA's database with impact assessment data from the EPS method. Design a software model of the EPS method in the software program GaBi.
- Identify how well SCA's sustainability policy and targets can be followed up by using the EPS method.

1.3. Limitations

Total working time is 20 weeks and the focus of the project will be on integrating EPS in the company's LCA work, other LCIA methods will be presented but not integrated. Uncertainty analysis and the usage of Monte Carlo simulation are a part of the EPS method but are not included in the thesis due to time restriction.

1.4. Facts about SCA

This section provides a short introduction of SCA; all information is based on the company's website (www.sca.com) and from communication with SCA employees.

SCA is a global hygiene and paper company and operates in over 100 countries whereas Europe and North America are the main markets. In 2010 the company had about 45 000 employees worldwide and the annual sales amounted to approximately SEK 107 billion.

The company is divided into four different areas, packaging, personal care, tissue, and forest products. For the personal care products focus is on developing and manufacturing absorbent hygiene products such as feminine products (Libresse); baby diapers (Libero) and incontinence products (TENA). This master thesis is performed at the department for Environment and Product safety that is organized under Research and Innovation Support. Research and innovation Support supports personal care and tissue on a global level.

SCA has received a number of different awards for their work towards a sustainable society and ethical responsibility, see Figure 2. The past six years, SCA has been ranked as one of the world's most sustainable companies by the responsible business magazine Canadian Corporate Knights. In 2011, SCA was named one of the world's most ethical companies by the Ethisphere Institute in New York, US for the fourth consecutive year. SCA has also been awarded the New Economy Carbon Leadership Award, which companies who have reached higher levels of carbon reduction and carbon reporting than required by regulatory and voluntary frameworks receive.

Figure 2 In recent years SCA has received several awards, including Corporate Knights most sustainable companies, world's most ethical companies by Ethisphere and The New Economy Carbon Leadership Award.

2. Methodology

This chapter provides the working process, see Figure 3, and the methodology approach.

This report consists of three parts: one introductory theory part, a second part, which handles the data documentation and implementation of the EPS method into the software program GaBi, and the last part, which presents the results, moreover, the study is discussed, conclusions and recommendations are drawn, see Figure 3.

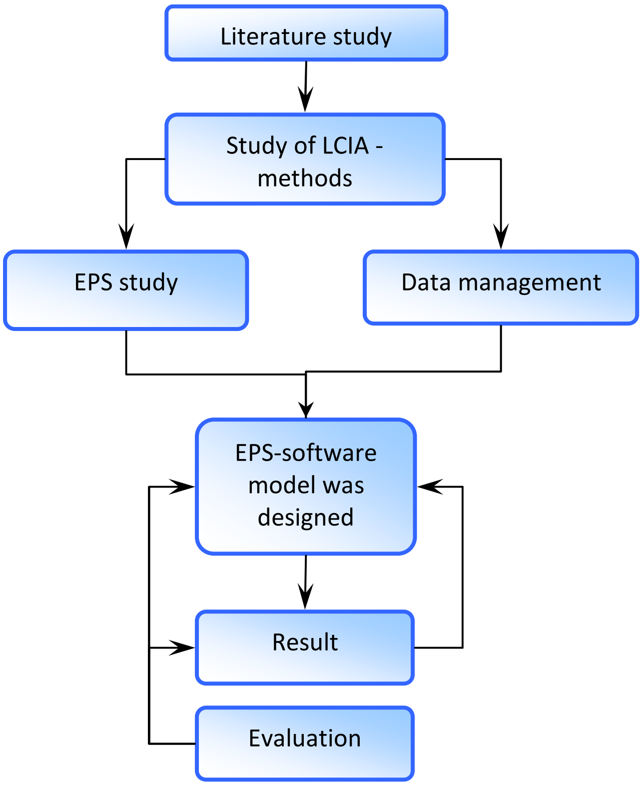


Figure 3 The working process used in the master thesis.

2.1. Procedure for theoretical background

The working process started with a literature study to get familiar with and to gain an understanding of the topic. Key words used for the search were different combinations of sustainable development, LCA, LCIA, EPS, and Environmental assessment methods. Literature from previous courses within the field was used, and the search was carried out through different search engines and through Chalmers library catalogue. Moreover, personal contacts with colleagues at SCA and Bengt Steen (Chalmers University…) have been used as references.

2.2. Analysis and Results

Once the theoretical part was finalized, the data management and implementation of the EPS method started. First, the EPS-method characterization factors (indexes) was transferred from Centre for Environmental Assessment of Products and Material Systems (CPM's) database and the printed report "A systematic approach to EPS in…..- Models and data of the Default method" (Steen 1999a) in to an Excel sheet. The relevant EPS data in CPM's database (Microsoft Access) was found by using Structured Query Language (SQL). Then, the data were sorted in different groups according to impact category, indicators, and in the pathways global warming, acidification and eutrophication. Finally, the flows were renamed according to their names in the LCA software program GaBi.

The EPS-method was implemented in the LCA software GaBi 4.4, which is currently used for performing LCA's at SCA. The substances/flows were connected to the corresponding impact categories and these were connected to their weighting factors. The results were transferred to an Excel document.

Test runs with the newly implemented EPS-method, were performed on pant diapers, open diapers, incontinence products, and tissue products. The results were compared and analysed in four different combinations:

1. First a comparison of the EPS method and the impact categories results were done, with the aim to evaluate the methods similarities and differences. For EPS the weighted value for the so-called pathways for global warming, acidification and eutrophication were used, for the impact categories Global Warming Potential (GWP), Acidification Potential (AP) and Eutrophication Potential (EP) were used. For results and analyses, see section *5.2.1. Comparison of the EPS method and the impact categories used at SCA.*

2. In the early product development new products' LCA result (GWP, AP, and EP) are compared with a corresponding reference products results'. Since there is an interest of comparison between products, it was evaluated if the EPS method and the impact categories indicated the same pattern for the results or not. EPS result presented in Environmental Load Unit (ELU) and characterized results for the impact categories were used. Further, the EPS values for the products were compared, since this might be the future usage of a weighting method at SCA. For results and analyses, see section *5.2.2. Comparison of new and reference product.*

3. Two incontinence products, which provide the same service but are designed and use different material (one was much lighter), were compared. This was done in order to evaluate if EPS method could give results that indicate that the lighter product (using less material) had a lower environmental impact or not. EPS results presented in ELU were used for the comparison. For results and analyses, see section *5.2.3. Same service with different products.*

4. A tissue product (paper towel) was used with the aim to investigate if the EPS method would give the same outcome for the results as the impact categories had done. The tissue product was modified with regard to the type of steam supplied to the mill and type of electricity supplied to the pulp production. The impact categories gave best results for geothermal steam to the mill and a combination of geothermal and bio energy electricity to the pulp production. Will the EPS result give the same recommendations? EPS results presented in ELU were used for the comparison. For results and analyses, see section *5.2.4. Tissue product with four options.*

Further, analyses of SCA's sustainability policy and the environmental strategy were made to see if it was possible to follow up the policy and its targets by using the EPS method. How suitable is the EPS approach for use within SCA? For example, is the weighting method within EPS the most suitable in order follow up the company's sustainability policy and future visions? For results and analyses, see section *5.2.5. Is it possible to follow up SCA's policy and targets with the EPS method?*

2.3 Discussion, Conclusion & Future Work

As the analyses were finalized, the results were discussed and the author gave recommendations based on these. Further, the EPS method was discussed and conclusions were drawn with respect to the tested products' LCA results, see chapter *6. Discussion.* It was also discussed if it is possible with the EPS method to follow up SCA's environmental policy and environmental strategy or not. Finally, recommendations on future work were suggested, see chapter *7. Future Work*.

3. Theoretical overview of LCA, LCIA and LCA work at SCA

This chapter intends to give a background and insight to LCA, LCIA and the LCA work at the company. LCIA will be discussed in details since a part of the thesis is to implement a LCIA method.

3.1. The LCA concept

Life cycle assessment (LCA) is an environmental assessment tool to analyze environmental impact of products and it can be put in line with other environmental assessment tools such as environmental impact assessment, ecological risk assessment, and material flow analysis (Rydh et al 2002).

Today there is a series of international standards and guidelines for LCA. In 1997, a series of standards were published and today the revised standards ISO 14040-14044 are frequently used. In the ISO standards, the procedure of how to perform an LCA is defined as follows: "LCA is a technique for assessing the environmental aspects and potential impacts associated with a product, by

- Compiling an inventory of relevant inputs and outputs of a product system
- Evaluating the potential environmental impacts associated with those inputs and outputs
- Interpreting the results of the inventory analysis and impact assessment phases in relation to the objectives of the study" (ISO 14040:1997).

One of the benefits with LCA is that it examines the whole product system from cradle to grave. This can be done by an evaluation of a product, where the most critical and environmental harmful aspects are presented. However, it can also be a comparison of different products, as a help for decision makers (Bergendahl 2002).

3.1.1. Procedure

The LCA starts with the goal and scope definition where the purpose and product of the study is specified. The goal should be well defined including the intended application, the reason for carrying out the assessment and the commissioner of the LCA. Further, the functional unit, system boundaries, impacts to consider, and level of details should be introduced (Baumann & Tillman 2004).

After the goal and scope definition is set, data in all flows in the life cycle needs to be collected. This phase is called inventory analysis which is a system model comprising an incomplete mass and energy balance (relevant flows, scarce resources, emissions of harmful substances), and is shaped according to the requirements in the goal and scope definition. The inventory analysis consists of three steps, construction of flow model, data collection, and calculation. The flows are constructed according to the system boundaries and are usually documented as a flowchart that shows the activities and the flows between them. Data collection consists of inputs and outputs for all the activities, e.g. raw materials with energy carriers, products, waste, and emissions to air and water. The data usually comes from company documents, suppliers, databases, governments etc. The data is used to calculate the amount of resource use and pollutant emissions in relation to the functional unit (Baumann & Tillman 2004).

Impact assessment (IA) and its different steps are discussed in detail in chapter 3.2.

Interpretation is the last step of the LCA, where the result is analyzed and used to derive conclusions and recommendations. Significant issues are identified such as important environmental findings and critical methodological choices. Moreover, sensitivity and uncertainty analyses can be used in combination with data quality assessment to evaluate the robustness of the assessment (Baumann & Tillman 2004).

3.2. Life Cycle Impact Assessment (LCIA)

Life cycle impact assessment is one of the steps when performing an LCA. Its purpose is to investigate the extent to which flows in the life cycle affects the environment and how. This is done by "translating" the inventory results (environmental loads) into environmental impacts categories. This makes the result more environmentally relevant and easier to communicate e.g. acidification consequences are easier to relate to than SO_2 consequences. Often the inventory result includes 50-200 different parameters, which can be hard to handle. The LCIA reduces the number of parameters by grouping them into different impact categories and in this way dealing with 10-15 impact categories instead of 50-200 different parameters. It is also possible to receive a single number that express the overall environmental impact by weighting over the impact categories (Carlson & Pålsson 2008; Baumann & Tillman 2004).

According to ISO 14044, the impact assessment is divided into the following mandatory and optional elements see Table 1. The different elements are described further in chapter *3.2.2. Optional Elements.*

Table 1 The table presents the mandatory and optional elements in an LCIA (Baumann & Tillman 2004).

Mandatory elements	Optional elements
Impact Category definition is the step where the impact categories, category indicators and characterization models are selected. With other word, this step determines which types of environmental impacts that should be included and how the impacts should be quantified through category indicators and characterization models.	**Normalization** is the step where the characterization results are recalculated with respect to the reference information. Reference information could for example be regional or global averages of pollutants emitted or a comparison of result for a new product with the result for a reference product.
Classification means that the inventory results are divided into the selected impact categories. With other word, the inputs and outputs in the inventory are classified according to its type of environmental impact.	**Grouping** means that the indicators are sorted according to e.g. geographic relevance, a company priorities or ranking. This is done to facilitate interpretation of result.
Characterization is the step where the category indicator results are calculated. This means that the result from the inventory (environmental impact) is converted into the selected category indicators.	**Weighting** means that the indicator results are converted to a common unit using factors based on value-choices, i.e. the consequences for the different environmental impacts are prioritized and weighted against each other.
	Data quality analysis is an evaluation of the reliability of the impact assessment result. This is done by identifying major contributors, uncertainty and sensitivity.

One of the biggest challenges with impact assessment is to translate resource use and emissions into environmental impacts. The most common environmental impact categories that need consideration are *resource use*, *human health* and *ecological consequences*. Depending on the impact assessment method, these categories can for example also be referred to as safeguard subjects or areas of protection, the EPS method, described in chapter 4, referrers to safeguard subjects (Baumann & Tillman 2004).

Cause-effect chain

It is not easy to describe the environmental impacts of emission and resource use quantitatively through the three environmental categories *resource use*, *human health* and *ecological consequences*. Since environmental impacts are very complex and not always easy to understand and interpret. Figure 4 illustrates the complexity of environmental problem by a *cause-effect chain*. A cause-effect chain illustrates how the emissions of the pollutants are linked to its consequents. The pollutants give rise to a primary effect, but a primary effect can also be the reason for several secondary effects and vice versa (Baumann & Tillman 2004).

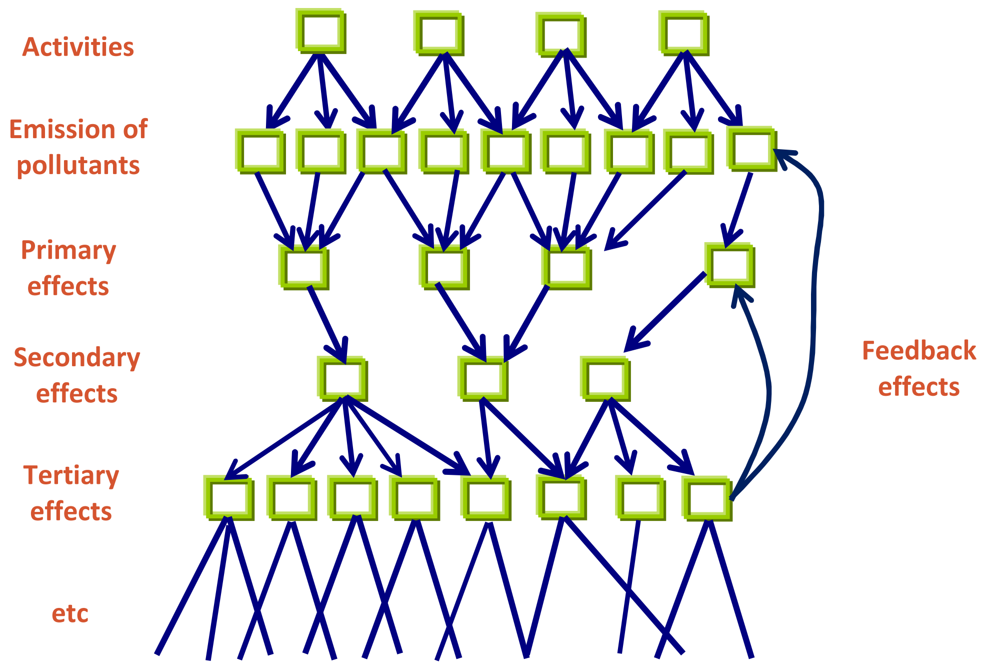


Figure 4 Cause-effect chain illustrates the complexity of emission of pollutants and their environmental impacts, primary, secondary effects etc and feedback effects.

Midpoint vs. Endpoint

With the thought on the cause-effect chain, is it possible to describe the environmental impact at different levels. Usually there are two different types of practice that are followed in LCIA: midpoint (problem oriented) and endpoint (damage-oriented). The endpoint measures the emissions one step further in the chain then the midpoint approach. Therefore have the endpoint results a higher level of uncertainty since the uncertainty are more uncertain further out in the chain. The decision whether to use midpoint or endpoint approaches, should be based on the goal of the study and to which audience the result will be communicated. In Table 2, is an example of emissions presented using midpoint and endpoint (Baumann & Tillman 2004).

Table 2 The table presents **e**xample of emissions using midpoint and endpoint measurement.

	Emission	→	Midpoint	→	Endpoint
Example	**CFC**		Destroy ozone, measured in ozone depletion potential		Less ozone allows increased radiation which leads to skin cancer, crop damage, marine life damage etc.
	NOx		Eutrophication, measured in eutrophication potential		Excessive use of e.g. fertilizers can cause unnaturally algae blooms in watercourses and seas.
			Acidification, measured in acidification potential		E.g. acid rain can cause damage to ecosystem; forests and fish kills in lakes and seas.

Impact assessment in practice

In practice, the impact assessment in LCA is usually performed using a readymade impact assessment method, where most of the choices in the impact assessment have already been made, i.e. the selection of impact categories and category indicators are set, and where classification, models for characterization and weighting sometimes have been developed (Baumann & Tillman 2004). A wide range of different impact assessment methods are available, some only includes the mandatory elements while others also includes the optional elements. The readymade impact assessment method EPS, used in this study, is described further in chapter 4.

3.2.1. Mandatory Elements

This section introduces the mandatory elements of an LCIA.

Choice of impact categories, category indicators and characterization models

Impact Category definition is the step where the impact categories, category indicators and characterization models are selected. This step is in practice mostly done by selecting which readymade impact assessment method to use in the study. It is important to evaluate that the chosen method meets the needs in the study, since every readymade method include predefined impact categories, category indicators and characterization models (Pålsson 2011).

Impact categories are types of environmental impacts such as global warming, acidification, ozone depletion etc. When a Life Cycle Impact Assessment method is developed there are a couple of important aspects to consider when deciding which impact categories to use (Baumann & Tillman 2004):

- *Completeness:* aims that the impact categories should cover as much as possible of interest for the study according to the goal and scope. In other words, the study should cover both major environmental problem as well as those of specific interest.
- *Independence:* the impacts categories used should be independent to avoid double counting.
- *Practicality*: the choice of categories must be practically feasible and should not include too many different categories.
- *Possibility to integrate:* there should be the possibility of connecting result parameters to choose impact categories and characterization methods.
- *Environmental relevance:* the chosen indicators have to be environmentally relevant to the impact categories and safeguard subjects.
- *Scientific method:* the characterization methods should be based on scientific knowledge.

The impact categories are connected to *category indicators* which quantitative measures the environmental impact from the connected category. Category indicators can also be named characterization indicator, and equivalents (Baumann & Tillman 2004).

The *characterization models* describe and quantify the environmental load for a specific substance that is presented by the category indicator. The result from the characterization models results in characterization factors, the characterization factors quantifies the contribution of an input or output flow on the category indicator (Pålsson 2011).

Classification and Characterization

Classification implies that the inventory results (input and output flows) are classified and sorted into different impact categories according to the type of environmental impact they contribute to. Therefore it is important to have knowledge in the pollutants environmental effect (Pålsson 2011).

Emissions can be assigned to one or several impacts e.g. NO_X contribute to more than one category, for example acidification and eutrophication, and should therefore be included in all they contribute to (PRé – Product Ecology Consultants 2009).

In the *characterization* phase of the LCIA, the environmental loads are translated into impacts using characterization factors. This is done by multiplying the inventory data with the characterization factor that is unique for every impact category (Rydh et al. 2002). For example, the impact category “Global Warming” has the category indicator “infrared radiative forcing”, where the characterization model is developed by the International Panel on Climate Change (IPPC). The model describes how different gases, referred to as greenhouse gases, potentially contribute to climate change. The resulting characterization factors is named “Global Warming Potential (CO_2-equivalents)”, with a 100 year time horizon the factor for e.g. emissions of methane to air is 25 kg CO_2 equivalents/kg emission of methane (IPPC 2007).

3.2.2. Optional Elements

The optional elements in impact assessment are used as an aid when interpreting, and to present the result in a more easy and understandable way.

Normalization- to compare

Normalization is the step where the characterization results are recalculated with respect to the reference value. Example of reference value can be the average environmental impact of a Swedish citizen in one year. The purpose of normalization is to get a better understanding of the results, which sometimes can be difficult to interpret since it may vary. Moreover, it helps to analyze the relevance of individual contributions but also relates them to different parts of the process (Baumann & Tillman 2004, GaBi Software).

Grouping- to create order

Grouping means that the characterization results are sorted, according to e.g. geographic relevance such as local/regional/global impacts or ranked according to e.g. low/medium/high priority. The purpose of grouping is to create a clearer overview of the environmental impact. It is very common, that studies based on the same characterization results, will give different ranking results since the ranking is based on value-choices (SS-EN ISO 14044:2006).

Weighting- to prioritize

Weighting means that the indicator results are converted to a common unit using factors based on value-choices, i.e. the consequences for the different environmental impacts are prioritized and weighted against each other. In this way, weighting can complement the study with additional information (Bengtsson 2000). Sometimes the result is then presented in an overall summarized index (Rydh et al. 2002). Usually the methods to create weighting factors are based on social science or different other principles; see below for an example (Baumann & Tillman 2004).

Monetarisation means that our values of the environment are described as the cost of different types of environmental damage. The cost or a "price" can be developed from individuals' "Willingness to pay (WTP)". WTP presents the value a person is willing to pay to avoid environmental damage (Rydh et al. 2002, Baumann & Tillman 2004).

Data quality analysis

Data quality analysis is used to further understand and test the reliability and uncertainty of the LCIA results. Preferable analyses according to ISO 14044 are uncertainty analysis, sensitivity analysis and contribution analysis (Baumann & Tillman 2004).

3.3. SCA's way of working with LCA

As mentioned in earlier chapter, SCA has worked with LCA's since the early 90's. The work with environmental issues is of high importance for SCA, since the company considers it as a necessity to create a successful business. This means that every decision should be in accordance with the highest standards and in line with all regulatory requirements. The company also uses a management tool, Resource Management System (RMS), for follow up on its environmental work. In the tool data on energy, water, transport, and raw material usage, waste and emission levels are collected and aggregated and published every year in SCA's Sustainability Report (SCA 2011).

Today, the environmental work within SCA for hygiene products is based on a life cycle approach, which is based on SCA's sustainability policy and targets. The sustainability policy considers economic, environmental, and social issues, below are a summarize of the five policy statements presented (SCA 2011);

- All activities should be in accordance with the highest standards and in line with all regulatory requirements. SCA strive for a sustainable development of its business, considering all economic, environmental, and social issues.
- SCA should have an open communication and transparency about its environmental and social practice.
- SCA evaluate the environmental impact of their products over the entire life cycle.

- SCA works ongoing with updating of their objectives and targets, in order to reduce its global impact on the environment.
- All employees should have a safe and non-discriminatory working environment.

The sustainability targets are formulated for the entire SCA group and are specific, measurable and time-limited. The four targets, listed below, are those that are of high importance for future business and that will gain the company's future sustainable environmental work (SCA 2011);

- *Carbon dioxide emissions* should be reduced with 20 % within year 2020 (2005 are used as reference year).
- *Responsible use of wood raw materials* implies that it should be a 100-% control of the usage of fiber raw material. The goal is to not use any pulp from controversial sources, such as illegal devastated timber. Since 1999 are SCA a member of Forest Stewardship Council (FSC) and all forests owned by SCA are approved by FSC or The Programme for the Endorsement of Forest Certification (PEFC).
- *Efficient use of water* implied a more efficient water usage and reduced content of BOD in wastewater. It was a short term goal that was reached in 2010, by then had the water usage reduced by 12 % and the BOD content by 35,4 %.
- *Social responsibility* implies a global code of conduct, which means that all SCA employees have a responsibility both socially but also environmentally.

LCA is very well established at SCA for its hygiene products and has been integrated as a regular part of the product development for many years (Rex & Baumann 2004). For product development projects, an LCA is performed to compare existing product's environmental performance with a newly developed corresponding product.

Today SCA is using the most commonly used impact categories global warming, eutrophication, acidification, and photochemical oxidants in its LCA studies. For recent years one of the company's focus areas has been on reduction of greenhouse gas emissions due to the increased demand and awareness from customers and consumers. The category indicators, origin from a Dutch study at the Institute of Environmental Science (CML) at University of Leiden. Nowadays this study is referred to as the CML2000 methodology (Earth shift INC 2011; ILCD Handbook 2010). Furthermore, the total energy usage is measured in the LCA studies, divided into renewable and non-renewable energy.

The LCA's at SCA are foremost performed for internal use, such as for product developers, but sometimes also for external communication. In this case the LCA's are reviewed by an independent third party. The software GaBi is used and SCA's database is updated regularly with data. The data is collected from the company's own production sites, suppliers, and well accepted sources for generic data e.g. on electricity production, fuel production, polymer production etc (Sjölin 2011, Pålsson 2011).

Parallel with the LCA studies SCA also works with the usage of chemicals and product safety. The company works systematically to ensure that it only uses chemicals that are effective, hold a high level of safety and have a small environmental footprint. The use of chemicals is an area in which legislation plays a decisive role for development. In the supply chain the suppliers are obliged to follow SCA's strict requirements on chemicals as they are stated in the SCA Global Supplier Standard. The manufacturing units have detailed procedures regarding handling of chemicals on site. Further, SCA also works regularly with product safety to guarantee that its products meet all the requirements from applicable legislation, customers and voluntary agreements in trade associations (Riise 2012).

4. Readymade Life Cycle Impact Assessment (LCIA) methods

This chapter introduces some of the current existing readymade LCIA methods that are of interest for SCA, for LCIA overview see appendix I. The main focus is on the EPS method, since it will be used in this study.

4.1. Environmental Priority Strategies (EPS)

The information about EPS is based on Bengt Steen's reports (1999) and personnel communication with him, except when stated otherwise.

EPS is a LCIA method, which uses a weighting method to present one single score. The EPS method was developed in 1989 and started out as collaboration between Volvo Car Corporation, the Swedish Environmental Research Institute (IVL), and the Swedish Federation of Industries. This cooperation started since there was a demand from product developers on a method that could supply them with one single score for environmental impact. One single score would make it easier for the decision makers e.g. product developers to take decisions on further product development. The one weighted value could indicate whether a product is better or worse compared to old reference products. Of course, this requires that an EPS is performed on the company's products in order to get an indication on what is good versus bad.

The points that made EPS so special at that time, in comparison to existing methods, were that it was the first method based on endpoint and monetarization. This means that the method measures further out in the cause effect chain and has damage cost on everything. Since then the method has been modified several times and the latest version was published in 2000 by Centre for Environmental Assessment of Products and Material Systems (CPM) at Chalmers. This version is slightly different from the previous, e.g. the overall description is updated in line with the ISO standards, and the database is extended.

The EPS method was developed in relation to the LCA concept and ISO standards. Figure 5 illustrates the relation between the LCA concept, ISO framework, EPS system, and the EPS default method, as the founder of the method; Bengt Steen sees it. The EPS system was developed according to five general principles; *the top-down principle*, *the index principle*, *the default principle, the* uncertainty principle and choice of default indices. All the principles are in line with the ISO 14040-44 for more information about the principles see the report Steen 1999. The EPS system contains a default method, which gives a starting point for LCA's within the EPS system. The default method describes the rules for the goal & scope, the inventory and the impact assessment. The impact assessment is described further in chapter *4.1.1. The impact assessment in EPS.*

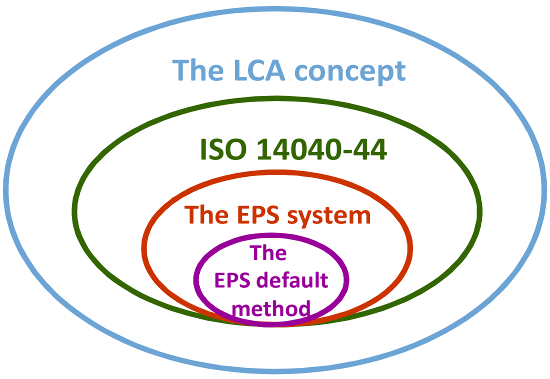


Figure 5 The figure illustrates the connections between the LCA concept, ISO framework, EPS system, and the EPS default method, as the founder of the method Bengt Steen sees it (Steen 1999).

4.1.1. The impact assessment in EPS

The impact assessment in EPS is a part of the EPS default method together with “goal & scope” and “inventory.” The “goal & scope” and “inventory” follows the requirements described in ISO 14040. Below the impact assessment in EPS is described in details.

Safeguard subjects, impact categories and category indicators

When the EPS method was revised in 2000, it was decided that the impact categories should be based on five safeguard subjects: human health, ecosystem production capacity, abiotic stock resource, bio-diversity and cultural and recreational values. The safeguard subjects used in the EPS method aims to areas and objects that generally should be protected and are as much as possible in line with the UN’s Rio declaration. Following criteria’s were also used when the impact categories and category indicators were selected (Steen 1999).

- “The impact categories shall fully cover all significant types of environmental effects due to human activities, without overlapping”.
- “The impact categories shall allow a quantitative characterization of emissions and other human activities in terms of category indicators”.
- “The impact categories and indicators shall be possible to understand for laymen”.
- “The impact categories shall allow weighting of indicators across categories”.
- “The impact categories and indicators shall be common to all types of environments. A change of a land area from forest to agriculture should be possible to evaluate” (Steen 1999).

In the safeguard subject *human health* is all physical and mental health included. Five different impact categories are used for human health effects: Life expectancy, severe morbidity & suffering, morbidity, severe nuisance and nuisance, for the different category indicators see Appendix II. The valuations of human health are done by estimating what the society is willing to pay to avoid damage on health, ranging from minor nuisance to death (Rydh et al. 2002).

The safeguard subject *ecosystem production capacity* is associated with the production of natural systems. This is related to decreased yield of the impact categories at end point effects. The impact categories used for ecosystem production capacity are crop-, wood-; fish & meat-, production capacity, base cat-ion capacity and production capacity for water (irrigation and drinking water), the category indicator are presented in Appendix II. The indicator chosen for these impact categories is a decreased production capacity of 1kg (Steen 1999). The potential effects that may occur on the ecosystems ability to produce goods, are valued in accordance with the market price that the goods have today within OECD (Rydh et al. 2002).

Abiotic stock resource means non-renewable resources e.g. crude oil, ores etc. Five different impact categories are used for Abiotic stock resource: depletion of element-, fossil (Natural gas)-, fossil (Oil)-, fossil (Coal)-, and mineral reserves. The impact categories are valued according to the cost that would appear when extracting the resources in a sustainable manner (Rydh et al. 2002).

In the safeguard subject *bio-diversity* are all species of animals, plants, organisms and their genes included. It is a quite controversial issue since it is about ethic and the balance within the biological system. Only one impact category: Extinction of species is used for bio- diversity; the category indicator is presented in Appendix II. The valuation of bio-diversity is based on the cost per person in Sweden for the efforts to protect endangered species. A global value is then achieved, through scaling Swedish results to a global level (Rydh et al. 2002).

Cultural and recreational values are very hard to describe with general impact categories and indicators, therefore they are identified only on a case study basis.

Every safeguard subjects has one or several impact categories and each impact categories are connected to its own indicator, see Appendix II. The indicator measures different flows that are called pathways. Pathways are a chain of occurrences triggered by emissions that leads to changes in the impact categories and measured by the impact indicator. With other words pathways are endpoint effects related from emissions, e.g. CO_2 emissions to air effect to global warming and global warming might effects one or several safeguard subjects. In Figure 6 this relation for human health is illustrated in a schematic figure. Human health has five impact categories each with its own indicator. The impact category life expectancy uses the indicator Years of Lost Life (YOLL) that measures several different emissions that are connected to different pathways (endpoint effects).

The pathways indicate the type of injury that occurs; examples of pathways for YOLL are cancer, global warming, and acute health effects. Emissions that are related to the pathways global warming, acidification and eutrophication, is described further in chapter 5.1.3 since they are used this study.

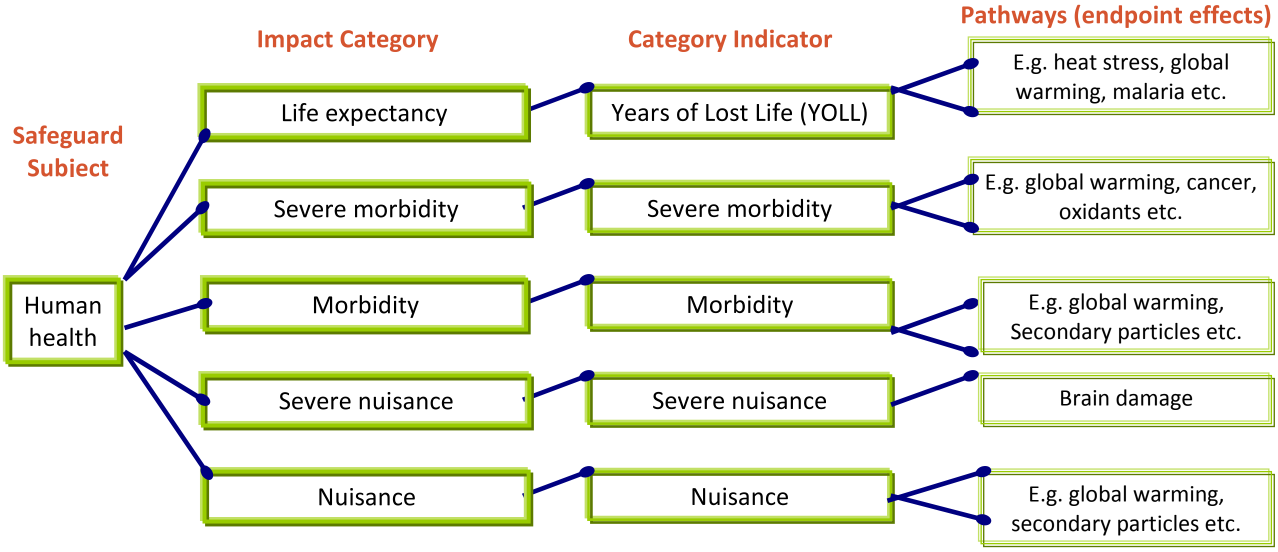


Figure 6 The schematic diagram illustrates the relationship between the safeguard subject, impact categories, category indicator and pathways for the safeguard subject human health.

Classification & Characterization

Classification is the step where emissions and resources are assigned to the impact categories. The classification step in EPS differs in one major respect compared with ISO 14042. The difference is that a flow is classified into a category when an affect has emerged or is likely too. This means that emissions are not only depended of a substance in the flow but are also due to the exposure situation. Exposure situation refers to the conditions that existed in 1998 on a global basis.

Characterization is the step where the inventory result is converted and aggregated to category indicator results by using characterization factors. Characterization factors express quantitative impacts on category indicators from elementary flows. Characterization factors are therefore often a sum of several pathway specific characterization factors and each one of these is modeled separately. There are in principle three types (empirical- , equivalency- and mechanistic method) of models used to determine pathway specific characterization indicators.

Normalization

Usually in LCIA is a separate normalization step done before weighting but with the EPS method, there are really no normalization. According to the methods founder Bengt Steen, one can possibly say that the factors are normalized to the monetary value in 1998.

Monetarisation

The weighting for EPS is made through valuation and with one weighting indicator using the unit Environmental load unit (ELU), since only one value for the total environmental impact is wanted. The weighting indicator is based on the Willingness- To- Pay (WTP) for protecting the safeguard subjects. The WTP values are based on the information from The Organization for Economic Co-operation and Development (OECD). OECD consist of 43 member countries, the majority are industrialized countries with democracy and market economies. The reason for using weighting indicator based on WTP for protecting the safeguard subjects among inhabitants in OECD countries was *"Today the OECD countries have a dominating role in the development of new technique and are beginning to adopt the ideas of sustainable development. Of course there are many other cultures that can claim to be more sustainable than those of modern OECD countries, but their limited use of tools like LCA makes it more reasonable to investigate the consequences of their attitude as options and not as a default"* (Steen 1999).

4.1.2. EPS in practice

The EPS method should be followed when the inventory analysis is done and all flows in the specific study are identified. Once this is finished, one can begin to calculate, by using the characterization factors and the inventory result. The first received result is a table with the data for the safeguard subjects over the different life cycle stages, one value for each impact category is presented. The values for each impact category are multiplied with the weighting factor; the results are presented for each safeguard subject and then summarized into one weighted value, the procedure is illustrated in Figure 7 .

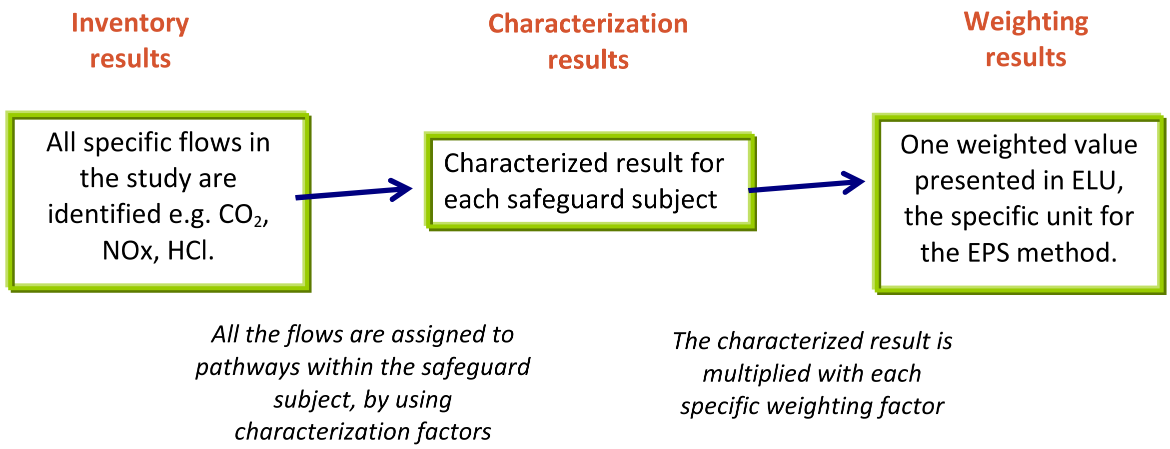


Figure 7 Illustration of the stepwise aggregation of information by using the EPS method.

4.2. Impact categories used at SCA

SCA's focus has been on using the impact categories and the categorization indicators from the method CML2000 (Earth shift INC 2011):

- Greenhouse gases
- Ozone-depleting gases,
- Acidifying compounds
- Photochemical ozone creation,
- Eutrophication compounds

SCA uses foremost the categories for global warming (greenhouse gases), acidification (acidifying compounds), eutrophication, and photochemical ozone creation. However, the company is interested in evaluating a LCIA method that provides a weighted result. The aim with this thesis is to compare the result from the impact categories used today, with the weighted result for the EPS method.

In this study only the impact categories global warming, acidification and eutrophication are used, since those are the ones of major interest for SCA. The environmental loads from the classification are translated in the characterization phase using equivalency factors as described in chapter *3.2.1*.

For greenhouse gases the indicator Global Warming Potential (GWP 100 years) is used, which measures in *CO_2-equivalents*. This means that each kilo gram CO_2, contributes with 1 kg CO_2-equivalents. Another example is methane which has a characterization factor of 25. This means that for each kg methane contributes 25 kg CO_2-equivalents to this category. The other used indicators are Acidification Potential (AP), which measures in *SO_2-equivalents* in acidifying compounds and Eutrophication Potential (EP), which measures in *O_2 or PO_4^{3-} equivalents* in eutrophicated compounds.

4.3. ECO- indicator ´99 (EI´99)

Another interesting LCIA method is EI´99, since SCA has a vision that maybe in the future be able to present weighted LCA result, this method could be an alternative. For the last couple of years has Eco-indicator 99 (EI´99) been one of the most used impact assessment method. But today it is succeeded by the new LCIA method ReCiPe. ReCiPe is a newly developed method that is a follow up of EI´99 and CML 2002 (PRé – Product Ecology Consultants). In ReCiPe the impact categories have been redeveloped and updated, and in addition it uses both midpoint and endpoint indicators (ILCD Handbook 2010). Since EI´99 is available in the software program GaBi (ReCiPe is not available), the method is described further below.

The first version of EI'99 was presented in 1995 and was intended to be used within companies for product development within Europe. In 1999 it was updated and now contains more than over two hundred indexes, which makes it one of the largest weighting methods (Rydh et al. 2002). EI'99 is based on a model that values the average damage in Europe with the help of average conditions instead of using specific conditions. The model consists of both mandatory and optional LCA steps before a result can be presented. To clarify to which extent the impact categories, see Table 3 , are affected, data on exposure are used (Baumann & Tillman 2004).

Table 3 EI'99s environmental impact categories and sub division (PRé – Product Ecology Consultants).

Human Health	Ecosystem Quality	Resources
Climate change Radiation Ozone layer depletion Cancerogenic effects Respiratory (organic) Respiratory (inorganic)	Ecotoxicity Acidification Nutrification Land use Land conversion	Minerals Fossil fuels

Human health means that all human beings, today and in the future should be free from environmental transmitted diseases, disability and premature death. This is expressed in Disability Adjusted Life Years (DALY). *Ecosystem quality* means that no species either animals or plants should suffer from environmental changes. Ecosystem quality is expressed as a percentage of a species extinct due to environmental changes. *Resources* that exist today and are essential for the human society should also be available for future generations. A resource is measured in a parameter that describes the quality of existing minerals and fossil resources in kJ excess energy divided by kg resource. Since the tree impact categories are expressed in different units, are the result weighted together in a normalization and weighting step to one indicator. This procedure is subjective and based on a European view (Wahlström & Olsson-Jonsson 2002).

The Weighting step is an important part of the EI´99 method, and is used to determine how serious the contributions to the impact categories are. This is done by using three different views based on cultural values, see Table 4. Those weighting factors were developed with help from Swiss interest groups who were asked about their views and attitudes towards environmental damage (Baumann & Tillman 2004; PRé – Product Ecology Consultants).

Table 4 The three different cultural weighting perspectives used in EI´99 (Baumann & Tillman 2004).

View	Approach
Individualistic	Short-term approach were only proven cause-effect chains are accounted
Hierarchical	Medium-term approach, which assesses in line with scientific and political bodies that reflects the environment and society today.
Egalitarian	Long-term approach together with the precautionary principle meaning "everything" is assessed; therefore, this view is the most complete but also gives the most uncertain set of indexes.

Founders of the method recommend to first use the hierarchical perspective and thereafter the egalitarian perspective. The hierarchical perspective has a medium-term approach and the founder believe that this is the most likely future scenario (Goedkopp & Spriensma 2000).

4.4 Comparison of the EPS method and EI´99

The EPS method and EI´99 are intended to be used as LCIA tool for designers and product developers. Both methods use present state as reference and endpoint effects, EPS is developed in Sweden and EI´99 in The Netherlands. The EPS method uses a global extension and EI´99 uses a European extension. Further, uses the methods different weighting principles, the EPS method uses WTP to avoid changes on safeguard subjects (human health, ecosystem production capacity, abiotic stock resource, bio diversity and cultural and recreational values) and EI´99 deals with human health, ecosystem quality and resources by using three different perspective (individualistic, hierarchical and egalitarian). Both methods account for human health, ecosystem and resources, the EPS method also account for Bio diversity and cultural and recreational values.

In order to make a fair comparison of the two LCIA methods, it is preferable to study LCA's were EI'99 and the EPS method are used. In this way it is possible to compare the methods result under same conditions with respect to e.g. boundaries and allocations. Today there are almost only studies that have focused on resources and energy usage. These studies have shown that the EPS method and EI´99 with hierarchical and egalitarian perspective give similar weighting results between minerals and fossil resources. EI´99 individual perspective considers that the extraction of fossil resources is not a problem. Moreover, consider the EPS method natural gas as a more valuable resource than oil because the method believes that is more expensive to produce biogas which is an alternative to natural gas than what it is to produce vegetable oil which is an the alternative to oil (fossil resource). EI´99 believe it will become harder to extract oil in the future compared to natural gas, therefore is the factor for oil higher than for natural gas, the EPS method has the inverse relation (Wahlström & Olsson-Jonsson 2002). In EPS, the use of metals generally gives a much higher load than the use of fossil resources. When it comes to the result for human health and ecosystem gives the EPS method slightly different result than EI´99. A major reason for this is that the EPS method focuses more on green house gases e.g. Carbon Dioxide emissions and the use of fossil energy. Therefore, when the usage of fossil fuels and green house gas emissions are relatively high, the EPS method shows a greater environmental impact than other methods (Thormark 2006). Furthermore covers the EPS method a larger area thanks to the categories bio diversity and cultural and recreational areas, which is not taken into account in EI´99.

5. Analyses and Results

This chapter provides the underlying decisions made during the development of the EPS software model and the analysis of the result. How the data collection was performed is described in chapter 2.

5.1. The development of the EPS software model

One of the purposes with the thesis was to update SCA's data base with impact assessment data from the EPS method. Currently SCA uses the LCA software GaBi 4.4 for performing LCA's. Therefore, it was natural to design the EPS software model in GaBi, since it gave access to SCA's previous inventory results.

Once the theoretical part of the thesis was finalized, the data management and the designing of the EPS software model started. First, the EPS-methods characterization factors was transferred from CPM´s database and the printed report "A systematic approach to EPS in…..- Models and data of the Default method" (Steen 1999a) in to an Excel sheet. Then, the data were sorted in different groups according to impact category, indicators, and pathways. All the flows were renamed according to the nomenclature used in GaBi and SCA's inventory data and transferred to the software model. Finally, formulas for the calculation were programmed in the model and all flows were connected.

When the EPS software model was designed in GaBi, some differences between the characterization factors in the CPM database and in the report, Steen 1999a, were discovered. Decisions on which factors to use were made after consultation with Bengt Steen (Chalmers University of technology), to be sure that the correct values were used, see section *5.1.1. Differences in characterization factors between report and database.*

Some parts of the EPS method was not included at all in the EPS software model, and has therefore not been accounted for in this study. The safeguard subject *Cultural and recreational values* is not included since it is very hard to describe with general impact categories and indicators.

The impact category severe nuisance accounts for noise and littering, noise refers to traffic noise and littering refers to waste left in the environment that provides various types of nuisance (Steen 1999a). The impact from noise and littering is very hard to identify and measure therefore was the impact category excluded from the study. Due to lack of data, were *VOC*, *Freon's* and the substances accounted for under the impact categories d*epletion of element reserves* and *depletion of mineral reserves* excluded. *Depletion of fossil reserves* such as raw coal, crude oil and natural gas are included in the study. *Land use* was excluded in the study, since the company had done a study about land use previous year. The decision to exclude *land* use was taken after discussion with Ellen Riise (SCA).

5.1.1. Differences in characterization factors between report and database

As mentioned earlier the main problem was the difference between the characterization factors in the report (Steen, 1999a) and the CPM database. After consultation with the founder of the EPS method, *Bengt Steen*, decision was taken on which characterization factors to use for the EPS software model, see Appendix III. According to Bengt Steen, is this problem (difference between the characterization factors in the report and the database) due to the human factor and appeared when the report was written and the database was developed.

For substance flow groups that were named with "soil emission impact," the same value was used for industrial and agricultural soil impact. The same principle has been used for emissions to water, in other words the same value was used for fresh & sea impact (applied for flows like N-tot, P-tot, COD, and BOD).

For substances flow groups that were identified with "emission impact," the same value was used for air emissions, soil emissions (agricultural and industrial), and water emissions (fresh and sea) e.g. for pesticides and mercury. Finally, irrigation water has been defined as fresh water when the EPS software model was designed in GaBi.

5.1.2. Substance flow groups that has been excluded in the EPS software model and the study

As mentioned previously, emissions to air from Freon's and VOC have been excluded from the study and the EPS software model, since they do not seem relevant in the view of SCA's products. Moreover, the flows were not specified with names, and a specification would have been out of the scope of this thesis.

Pesticides were included, except the ones were no pre-defined flows existed in the software program GaBi, see Table 5. They were investigated further to ensure that none of them were important for the outcome.

Table 5 Pesticides that were excluded in the study because of their application.

Pesticide	Usage
Fenamiphos	Nematicide used to control nematodes living outside or inside a plant (e.g. tobacco, bananas) (NPIC 1996).
Hexachlorbenzene (perchlorobenzene)	Fungicide, formerly used as a seed treatment (wheat control). Since 1966 are the product banned (Electronic Recyclers International 2008-2011).
Methoxychlor	Insecticide to protect crops and pets against fleas, mosquitoes, cockroaches, and other insects (EPA 2011).
Phosphine	Fumigant, foremost farm use (EPA 1999).
Resmethrin	Insecticide for pest controls (mosquitoes, gnats and flying insects) (NPIC 1996).
Sodium fluoracetate	Farmers and glaziers use the poison to protect pastures and crops from various herbivorous mammals (EPA 1995).
Thallium sulphate	Many countries banned the substance in the '70, were back then used as rat poison and ant killer (PAN Pesticide Database 2000-2010).
Warfarin	Foremost used as a pesticide against rats and mice (PAN Pesticide Database 2000-2010).
Zinc phosphide	Is used as a rodenticide to kill gophers, moles, rats and squirrels (EPA 1996).

5.1.3. Pathways used in the study

The safeguard subjects in the EPS method are divided into several impact categories, see Appendix II - EPS safeguard subjects. Various substances; carbon dioxide, methane, benzene etc. are connected to these impact categories. The substance is then connected to different pathways (endpoint effects); depending on the impact they cause e.g. global warming, malaria, brain damage etc. Table 6 illustrates an example; the relation between CO_2 emissions to air and the safeguard subjects and endpoint effects that are related from CO_2 emissions to air. For example CO_2 emission to air can lead to the pathway (endpoint effect) starvation connected to the safeguard subject human health. This is possible since CO_2 emissions are related to climate changes such as dry weather conditions. If the opportunities for cultivation changes to the worse, it is very likely that lack of food occur and people will starving. This scenario and pathway (starvation) might lead to an early death which is measured by the category indicator YOLL.

Table 6 Illustration of CO_2 emissions to air and its effect on the safeguard subjects and the endpoint effects that are related from CO_2 emissions to air.

Substance	Safeguard subject	Impact category	Category indicator	Pathway (endpoint effects)
CO_2	Human Health	Life expectancy	YOLL	Heat stress Starvation Flooding Malaria

CO_2	Human Health	Severe morbidity & suffering	Severe morbidity	Starvation Malaria
CO_2	Human Health	Morbidity	Morbidity	Starvation Malaria
CO_2	Ecosystem production capacity	Crop production capacity	Crop	Desertification
CO_2	Ecosystem production capacity	Wood production capacity	Wood	Global warming CO_2 fertilization
CO_2	Bio-diversity	Extinction of a species	NEX	Climate change

In this study four results from the EPS method has been used. First the one weighted value presented in ELU, but also three other weighted results based on pathways in the EPS method. The weighted result for the pathways global warming, acidification and eutrophication are used, since those are the categories of interest for SCA.

5.2. Result

Inventory results from different SCA products were used to calculate results with the newly implemented EPS software model and the impact categories that SCA usually use on global warming, eutrophication and acidification. The calculations were performed on different products; incontinence products, open diapers, pant diapers and tissue products. The incontinence product and open baby diaper were chosen since they contain a large amount of material and usually show a larger impact/share on upstream manufacturing and waste. The pant diaper is a product that SCA sells in large quantities. The tissue product (paper towel) in this study uses electricity with large amount of environmental impact, therefore it was compared with three other options that was modified with regard to the type of steam supplied to the mill and type of electricity supplied to the pulp production which should give different results.

The calculations were compared and analyzed in four different combinations; the results are presented in this chapter.

5.2.1. Comparison of the EPS method and the impact categories used at SCA

A comparison of the EPS method and the impact categories was done, with the aim to evaluate the methods similarities and differences in the result. For the EPS method results the weighted values for the pathways global warming, acidification and eutrophication were used, for the impact categories were the characterized results for GWP, AP and EP used. The results for the two methods are presented in % as relative contribution of the total impact from the pathway, the total impact from the pathway is set to 100%.

Global Warming

The EPS values are based on the weighted global warming pathways and the values for the impact categories are measured in characterized results for Global Warming Potential (GWP). All three products, with both methods, show the same pattern for the distribution over the life cycle stages except for the pant diaper, see Figure 8- 10. The pant diaper has a larger % difference on factory and upstream manufacturing between the methods see Figure 9.

Another interesting aspect is that the methods include different numbers of substances depending how they count for effects. For example, the EPS method includes only real and likely effects, compared with other methods, which usually also includes potential effects. For upstream manufacturing (investigated since it's here the largest impact lies), the EPS method has 10 different substances that are contributing to global warming compared to the impact categories, which has 79 flows contributing. Of those cover nine of the EPS method and 27 of the impact categories the substance contents in SCA products. The substances that both methods include are nitrous oxide (laughing gas), carbon dioxide (inorganic emissions to air), and methane (organic emissions to air). The pant diaper had a larger % difference compared to the open diaper and the incontinence product on factory and upstream manufacturing. Probably are the differences in the result between the methods due to which substances they include. In Appendix IV is a complete list of the flows that contribute to global warming presented.

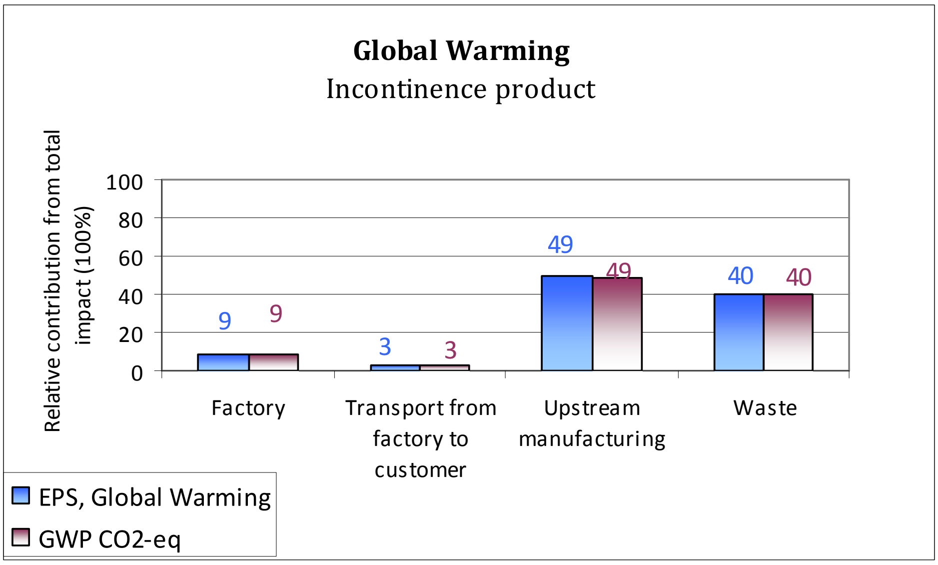


Figure 8 The distribution of global warming for EPS and the impact categories used at SCA over the life cycle stages for the incontinence product.

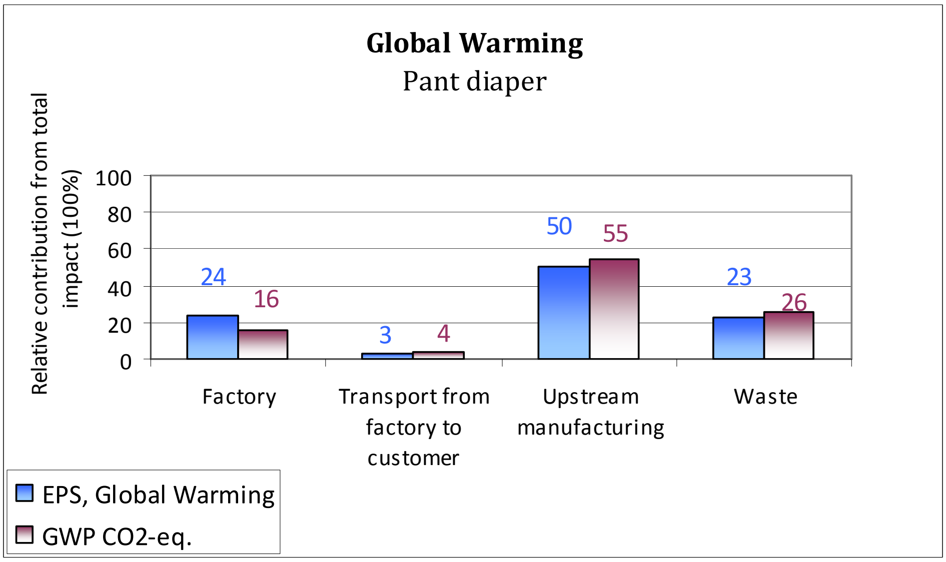


Figure 9 The distribution of global warming for EPS and the impact categories used at SCA over the life cycle stages for the pant diaper.

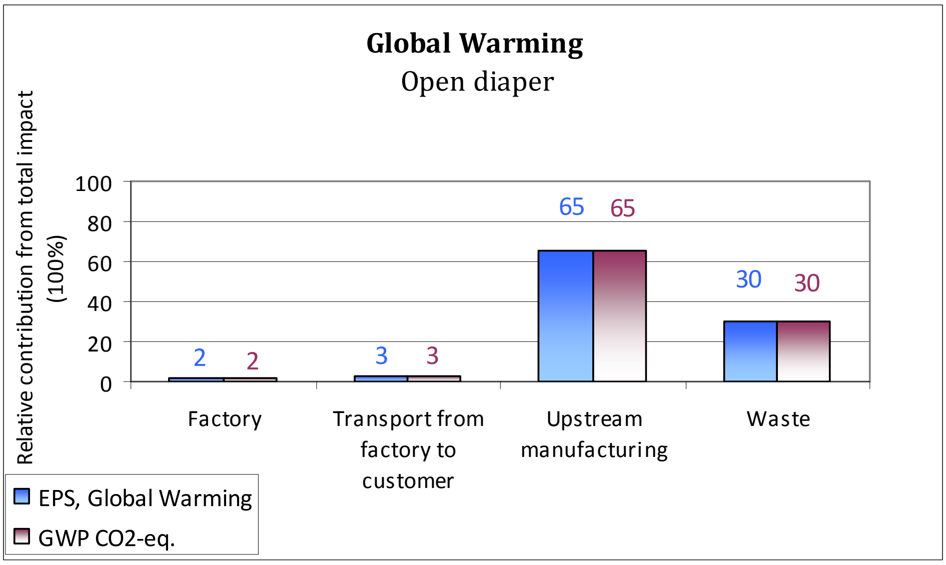


Figure 10 The distribution of global warming for EPS and the impact categories used at SCA over the life cycle stages for the open diaper.

Acidification

The EPS values are based on the weighted acidification pathways and the values for the impact categories are measured in Acidification Potential (AP).

The results for acidification are in the same range for the two methods; all differences are within 6 %. Both methods indicate the same pattern and the same distribution within the product. However, it is not the same distribution between the life cycle stages when comparing the three products; this is due to different manufacturing sites and usage of different material. The incontinence product and the open diaper show results that are within 1 % or less different. This lies within the uncertainty marginal, which makes it difficult to draw any conclusions, except that both methods give very similar result. The pant diaper indicates a slightly higher difference, 5-6 % difference for factory and upstream manufacturing. For diagrams, see Appendix V.

The reason for the similarity in the results might be that both methods cover almost the same substances with respect to upstream manufacturing (investigated since it's here the largest impact lies). The EPS method has seven different substances that contribute to acidification compared to the impact categories, which only has five substances contributing. The SCA products covers six substances stated under the EPS method and four stated under the impact categories. The only substance not occurring is sulphur trioxide. Both methods include ammonia (inorganic emissions to air), nitrogen oxides, and sulphur dioxide. In Appendix VI, a complete list of the flows that contribute to acidification is presented.

Eutrophication

The EPS values are based on the weighted eutrophication pathways and the values for the impact categories are measured in eutrophication potential (EP).

The result for eutrophication shows a consistent trend; see Figure 11- Figure 13. EPS indicate a higher % share on factory, transport from factory to costumer and on waste. The impact categories show higher distribution on upstream manufacturing with approximately 11%. The pant diaper shows a deviation on the % difference between the methods compared to the other two products see Figure 12 .

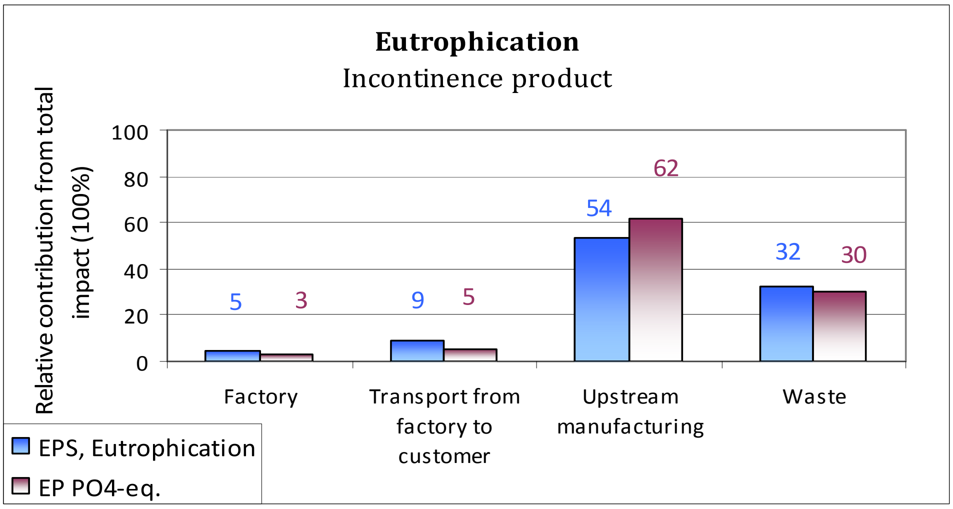


Figure 11 The distribution of eutrophication for EPS and the impact categories used at SCA over the life cycle stages for the incontinence product.

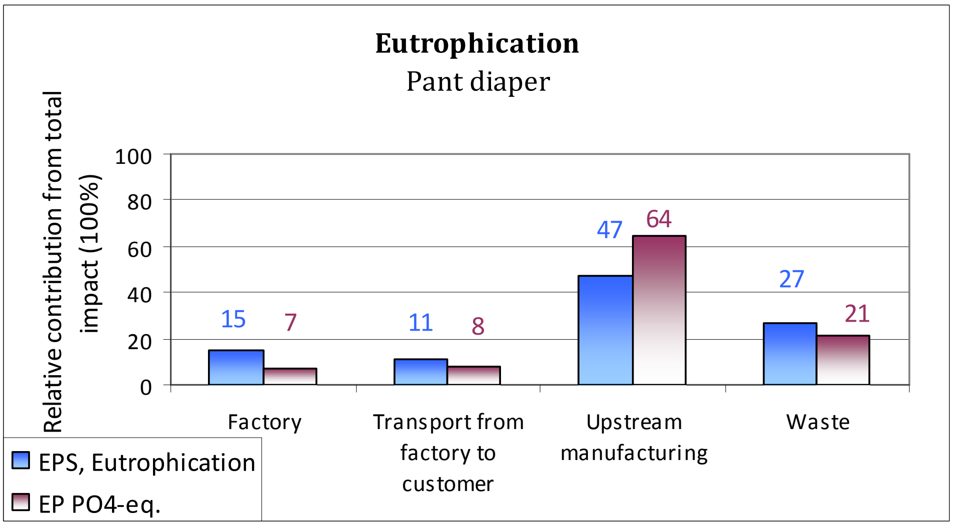


Figure 12 The distribution of eutrophication for EPS and the impact categories used at SCA over the life cycle stages for the pant diaper.

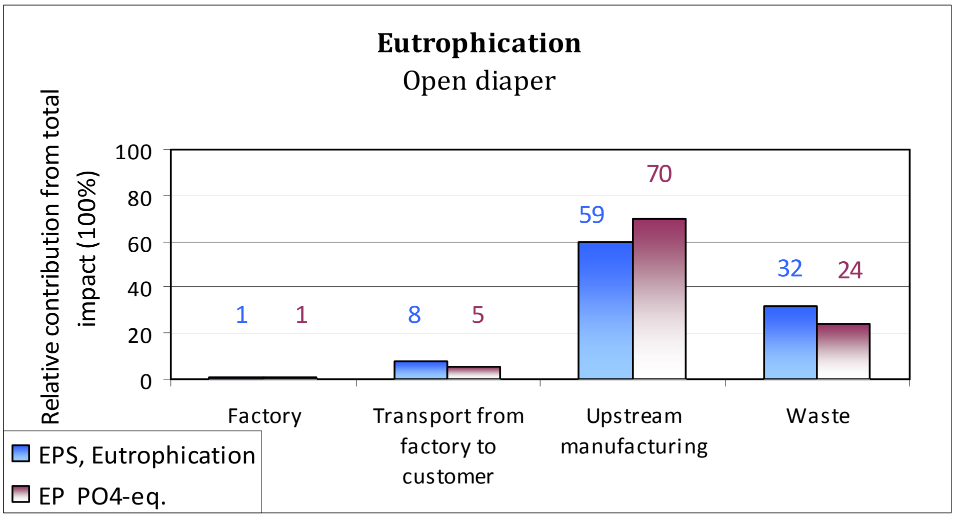


Figure 13 The distribution of eutrophication for EPS and the impact categories used at SCA over the life cycle stages for the open diaper.

The reason for a distribution difference, about 20-36% on upstream manufacturing, is that the methods cover different substances. Upstream manufacturing and the EPS method has 10 substances that contribute to eutrophication compared to the impact categories that has 61 substances contributing. The SCA products covers 8-9 substances stated under the EPS method and 31-32 stated under the impact categories. This might be the reason why the impact categories used at SCA indicate a higher % share on upstream manufacturing compared to EPS, since the impact categories (CML2000) are more complete then the EPS. However, both methods include ammonia (inorganic emissions to air), COD (analytical measures to sea and fresh water), nitrogen oxides (inorganic emissions to sea and fresh water), nitrogen (as total N, inorganic emissions to sea and fresh water) and phosphorus (inorganic emissions to sea and fresh water). EPS also include BOD (analytical measures to sea and fresh water), which is excluded in the impact categories. The impact categories includes for example Nitrogen dioxide, Nitrogen monoxide and Sulphur trioxide. In Appendix VII is a complete list of the flows that contribute to eutrophication presented.

5.2.2. Comparison of new and reference product

In the early product development phase at SCA, new products' LCA result (GWP, AP, and EP) are compared with a corresponding reference products results'. This helps to evaluate if a product's environmental performance has improved or not. With focus on reduction of Green House Gas emissions (GHG), based on the company's targets, it was of interest to compare new and reference products with only weighted EPS results (ELU), but also a comparison of the EPS method and the impact categories. This was done to evaluate if the methods would show the same distribution differences or not for the results, but also to see if a product had improved its performance or not.

Weighted EPS results presented in ELU

One of the advantages with the EPS method and its final weighted value is that it is easy to communicate and gives a good overview whether a product has improved its environmental performance or not. Three (incontinence product, pant diaper, open diaper) different new products have been compared with its reference product using the one weighted value ELU, see Figure 14. According to the result the incontinence product and open diaper has improved its performance with 8 respectively 16 %. On the other hand, has the pant diaper deteriorated with 3 %.

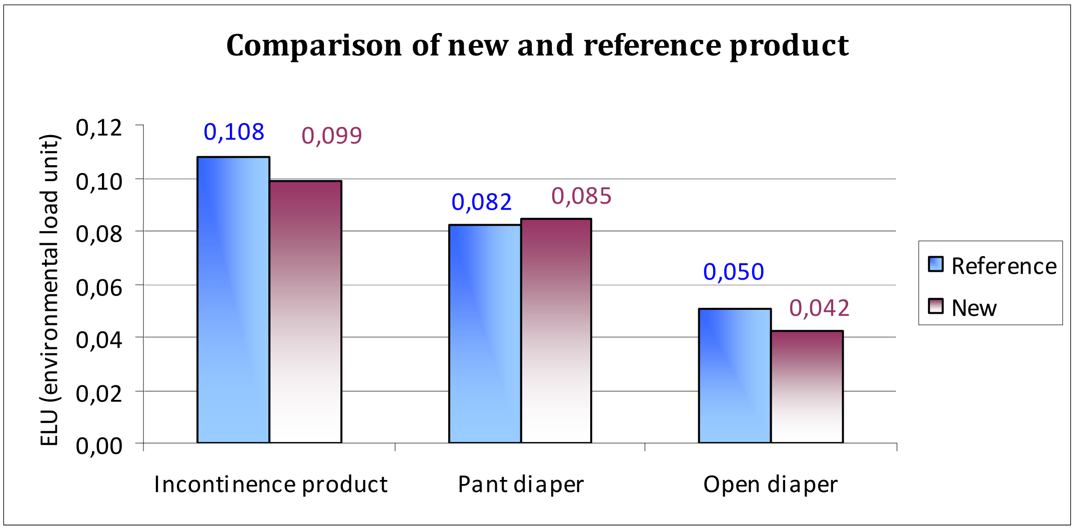


Figure 14 The diagram illustrates the weighted EPS value (Absolute values) for the new and reference products. Reference flow: New- incontinence (1 piece 91g), Reference- Incontinence (1 piece 95g), New Pant diaper (1 piece 46.6g), Reference pant diaper (1 piece 50g), New open diaper (1 piece 34g) and Reference open diaper (1 piece 42g).

Weighted EPS results compared to estimated weighting values for the impact categories at SCA

To be able to compare the weighted EPS result presented in ELU, with the characterized result (absolute values) for the impact categories used at SCA, estimated weighting factors[1] for GWP, AP and EP was used. GWP were set to 0.5, AP and EP were set to 0.25 each, see Table 7. When using the estimated weighting factors, the result shows that all three products have improved their performance. The incontinence product has improved its performance with 15 %, the pant diaper with 13 % and the open diaper has improved its performance with 32 %. Depending on using the result for the EPS method or the impact categories used at SCA the improvement/deterioration is different. The EPS method shows much lower % improvement compared to the impact categories used at SCA. This result is probably due to the resource consumption and since the EPS method account for resource usage, the improvement is lower compared to the impact categories used at SCA.

1 The estimated weighting factors are used unofficial at SCA and are developed by the employees who works with LCA's at SCA in Gothenburg.

Table 7 The absolute values and % improvement for the products when using the Impact categories used at SCA. The right column shows the improvement when using the estimated weighting factors.

Incontinence product	New	Reference	Improvement	Improvement after weighting
GWP	326	357	9%	
AP	1.0	1.3	24%	15%
EP	0.18	0.23	20%	
Pant diaper	New	Reference	Improvement	Improvement after weighting
GWP	203	221	8%	
AP	0.6	0.8	20%	13%
EP	0.10	0.12	14%	
Open diaper	New	Reference	Improvement	Improvement after weighting
GWP	114	147	23%	
AP	0.4	0.6	42%	32%
EP	0.06	0.09	39%	

5.2.3. Same service with different products

Two incontinence products, All-in-One (AiO) and belted see Figure 15, which provide the same service but are designed and use different material, were compared. This was done in order to evaluate if the EPS method could give results that indicate that the lighter product (using less material) had a lower environmental impact or not. The belted product is lighter and should have a lower impact then AiO, since it is a newer and improved product. Does the EPS method provide results that are in line with this fact? The weighted EPS value (ELU) for the products was used for the comparison.

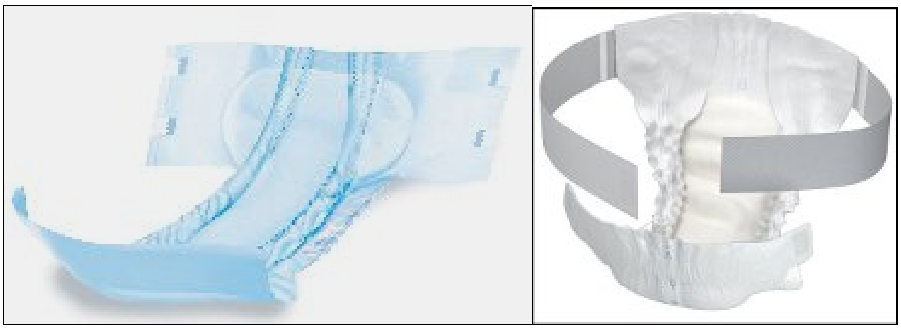


Figure 15 Illustrates the two tested incontinence products, All-in-one and belted.

The EPS method presents a 7-percent improvement between AiO and the belted product, see Figure 16. The improvements according to the weighted impact categories used at SCA (the estimated weighting factors are used) are much higher about 18 %[2].This is likely due to resource consumption, since the EPS method values the usage of resources much more compared to the impact categories. Further is the uncertainty high with the estimated weighting factors, since there is no detailed explanation available on which basis they were developed.

2 The result for each impact categories: GWP (15-% improvement), AP (15-% improvement), and EP (27 % improvement).

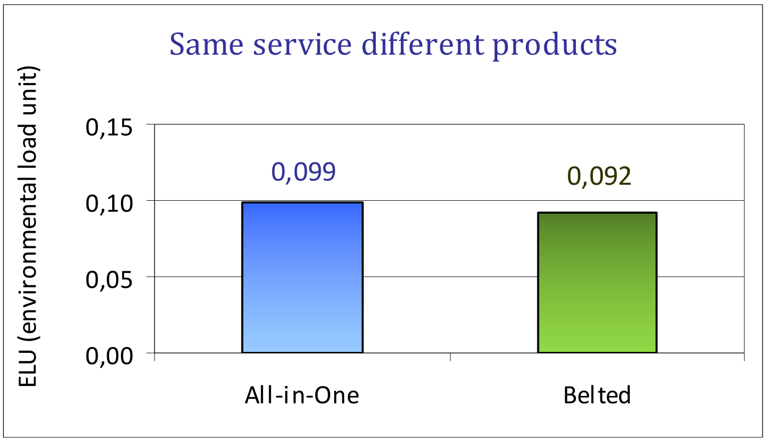


Figure 16 Illustrates the result for AiO and belted: ELU/ reference flow. Reference flow AiO: 1 piece (91g of product). Reference flow belted: 1 piece (77g of product).

The distributions between the safe guard subjects are different. AiO has 58 % impact on abiotic stock resource and 42 % impact on human health, compared to the belted that has 62 % on abiotic stock resource and 38 % on human health. Abiotic stock resource has had a 4 % increase and another distribution within the category see Table 8. The factory has improved its performance but the upstream manufacturing has instead deteriorated a bit. Human health has instead decreased with 4 %. Where upstream manufacturing have become slightly larger and waste has decreased, see Table 9 .

Table 8 Distribution within the safeguard subject abiotic stock resource for AiO and Belted. The total impact from abiotic stock resource is set to 100 %. Upstream transports are included in transport.

	Factory	Transport	Upstream	Waste
AiO	11 %	5 %	84 %	0.4 %
Belted	9 %	5 %	86 %	0.3 %

Table 9 Distribution within the safeguard subject human health for AiO and Belted. The total impact from human health is set to 100 %. Upstream transports are included in transport.

	Factory	Transport	Upstream	Waste
AiO	8 %	7 %	51%	34%
Belted	8 %	8%	54%	31%

Even though the overall result is better for the belted product compared to the AiO, it is of interest to see if the share of renewable material has decreased as well. From the product specifications are the information about the product formula taken, see Figure 17 -18. The pie diagrams show that the belted product has increased the usage of SAP (non –renewable resource) and decreased the usage of pulp (renewable resource), even though the overall performance has improved. Therefore it is not possible to say that a product that has improved its performance also uses a larger share of renewable material. The most preferable would be a lighter product with improved environmental performance but where the use of renewable material would increase and non-renewable decrease.

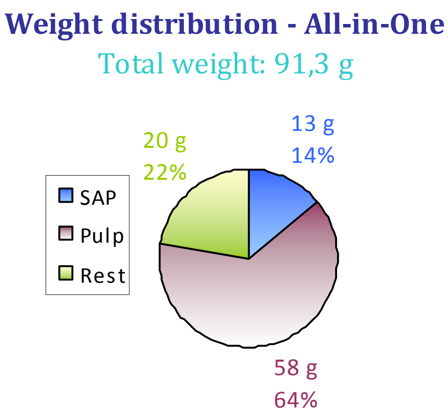


Figure 17 The diagram illustrates the weight distribution for the AiO product with a total weight of 91.3 g.

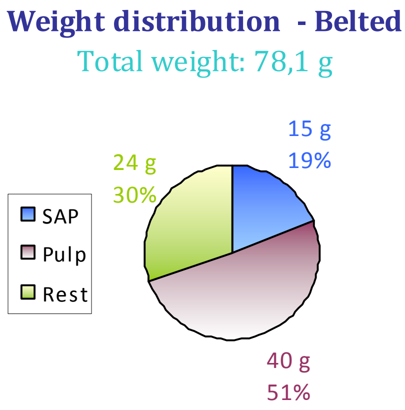


Figure 18 The diagram illustrates the weight distribution for the belted product with a total weight of 78.1 g

5.2.4. Tissue product with four options

In this study has an "Away from home" tissue product (paper towel) been used. The product has been modified with regard to the type of steam supplied to the mill and type of electricity supplied to the mechanical pulp production, see Table 10. The aim was to investigate if the EPS method would give the same outcome for the results as the impact categories used at SCA had done. The impact categories used at SCA gave best results for geothermal steam to the mill and a combination of Geothermal and bio energy electricity to the mechanical pulp production. Will the EPS result give the same recommendations? The total weighted EPS value for the products were used for the comparison.

Table 10 The different combinations of the tissue product, the options are named D1-D4.

Options	Type of steam to the mill	Type of used electricity to the mechanical pulp production
D1	Geothermal	Fossil fuel (50% coal & 50% Natural gas)
D2	Natural gas	Fossil fuel (50% coal & 50% Natural gas)
D3	Geothermal	Geothermal & Bio energy
D4	Natural Gas	Geothermal & Bio energy

The result for EPS, see Figure 19, and the impact categories are very similar and they indicate the same pattern for the different options. Both methods indicate that option D3 is the most preferable and product D2 the worst case. Option D1 and D4 is roughly equivalent. This was also the expected result, when compared the options on the paper. However, the % difference between the methods, are larger with the impact categories (approximately 31.5 %) then with EPS (approximately 22 %).

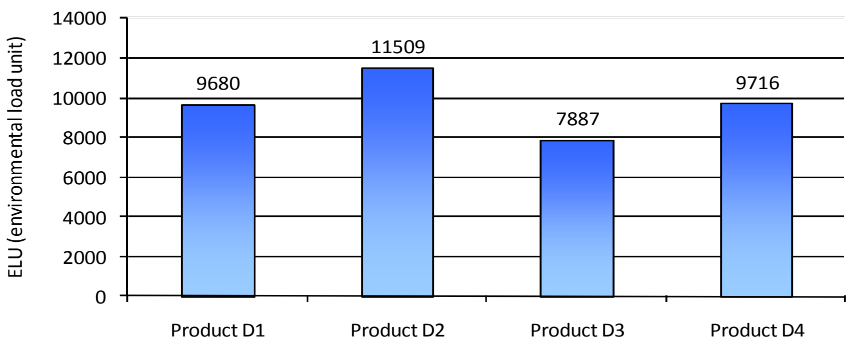


Figure 19 Presents the EPS result for product D1-D4. The reference flow is 1000 cases (3.2 million products).

5.2.5. Is it possible to follow up SCA's policy and targets with the EPS method?

In broad terms, SCA sustainability policy aims at iintegrating sustainability into all levels in the company, managing risk from an economic, environmental and social perspective, and providing business possibilities through sustainable thinking. The four sustainability targets of SCA are reduced carbon dioxide emissions, responsible use of fibre raw materials, water and a compliance with the company's code of conduct. The cornerstones of the hygiene business environmental way of working are active sourcing clean production, and sustainable solutions. The question is how well SCA´s sustainability policy and targets can be followed up by using the EPS method, the policy and targets are described in section *3.3. SCA's way of working with LCA*. The answer is both yes and no, because parts of the policy can be followed by the EPS method. For example is one of the policy statements that all activities for the company should follow the highest standards and requirements. With the EPS method, the result would probably improve if the standards improve but it is not possible to actually see if a new regulation directly will give an improvement. However, it is not possible to follow SCA's targets in a good way, described below. The aim with EPS is to evaluate the willingness to pay for the safeguard subject. SCA policy does not explicitly describe which safeguard subjects they want to protect in the environment, but they state that "SCA places strong emphasis on the renewability and recyclability of the raw materials it uses and strives to offer environmentally sound products and services, capable of continuously meeting customers' and consumers' needs with respect to functionality, economy, safety and environmental impact." (SCA 2011) This means that, depending on how you interpret that message, one can say that it is in line with the EPS method and the willingness to protect the safeguard subject. Because, to actually be able to take actions to protect the safeguard subjects, a company has to be conscious of sustainability and environmentally sound behaviour, as well as an ethical thinking when protecting the safeguard subject human health. Furthermore, it is described that the criteria for impact categories and indicators "Shall fully cover all significant types of environmental effects due to human activities" (Steen 1999) which is consistent with SCA's guidelines.

SCA's targets are not possible to be completely monitored with the EPS method. On the other, covers the EPS method the four targets much better than the impact categories that are used today at SCA. For example are the ability to monitor water consumption limited, because EPS only covers drinking and irrigation water. For the water goal, the aim was to measure overall use of water and the amount of BOD in wastewater. This is not possible with EPS since there are no indexes on total water consumption available. Likewise, it is not possible to follow these targets with the impact categories used at SCA today either.

Can the hygiene business environmental way of working be followed with EPS? To find out if a material is of good or poor environmental quality is quite difficult with EPS. However, it is possible to find out certain materials impact, especially in the early stages of product development[3]. Then this result can be used to communicate an indication if a material give lower or higher weighted value. Waste and energy consumption can be partially followed with EPS by comparing new and old products and see if their performances have improved or not.

SCA focuses on using renewable materials and energy sources as far as possible. The use of renewable energy also provides an impact which is very important for companies to measure. The ISO- standard for LCA's requires that the usage of renewable energy is included, which it is in the EPS method. Therefore, it is more appropriate to use the EPS method to monitor the use of renewable energy than the impact categories that are used today.

EPS weighting method is based on the willingness to pay for protection of the safeguard subject. The question is if the EPS weighting method is the most preferable weighting method for SCA? If not, what would the most preferable weighting method for SCA be? The willingness to pay for protecting the safeguard subjects are estimations in according to an OECD habitant. OECD consists of 34 member states where the majorities are industrial countries with democracy and market economy. Since SCA is a company that operates globally in approximately 100 countries, it may not be the most optimal to use a weighting method based on an OECD member. Maybe the most desirable would be to use a value on willingness to pay for a global population that represents the places where the company operates. However, as long as there are not any data available for a global population and SCA operates in OECD countries the weighting method within the EPS method could be applied.

3 This statement was confirmed by comparing LCA studies on one paper and one plastic bag using the EPS method. E.g. by using both recycled paper mass or new paper mass for the paper bag.

6. Discussion

This chapter contains the author's discussion and conclusions of the findings in chapter 5. Analyses and Results.

As stated in the introduction, one of the purposes of this study was to implement the EPS method for the global hygiene and paper company SCA. This has been done by gathering method specific characterization- and weighting factors from the report (Steen 1999a) and CPM´s database. The factors were organized and renamed in a Microsoft Excel sheet and transferred into the software program GaBi, were an EPS software model was designed.

There has been some scepticism about the use of weighting methods, fearing that when the environmental impact is described in "one value" the transparency will be lost. This is important to have in mind when using a weighting method. The most crucial is when people that are not directly involved in the LCA cite the result and leave out the background. Therefore, it is always important to communicate underlying information, limitations, etc. together with the weighted value.

Since EPS was developed with the intention to present one weighted value, it is recommended to especially communicate the weighted value. The weighted value is quite easy to communicate and can be used in an early product development process, for example quickly see how different materials effect the outcome. It is also very convenient to have a method that presents one weighted value, which can be used to see if the product has improved or deteriorated its environmental performance or compared with another product.

The only benefits with using the impact categories, is that it is a known concept, which makes it easier to communicate since more people know how they are interpreted. This is one of the largest differences with the methods, since the EPS method isn't widely known. Therefore, I recommend both approaches as they present the results in different way and one cannot get the same kind of information from the impact categories and the EPS- method. On the other hand correspond the impact categories poorly with the sustainability targets and it would be more preferable to use the EPS method to follow them. Actually it is only the impact category global warming that is useful for the carbon dioxide emission target. The other impact categories can not be used at all for the targets.

The largest difference between EPS and the impact categories are that they present different kind of results, one communicate a weighted value the other a characterized result. EPS puts another dimension to the use of resources, which also is reflected in the result when looking at distribution between the safeguard subjects. Because the EPS method put more emphasis on the resource use, which also is showed in the weighted result compared to a characterized result. Moreover, the EPS method and the impact categories accounts for different emissions, EPS only account for real and likely effect and the impact categories also account for potential effects. Nevertheless, was it not possible to determine whether this fact influenced the result or not. Another advantage for SCA to use the EPS method is that the safeguard subject human health also presents a social life cycle perspective, which could be very useful since SCA has a target for social responsibility.

In this study, individual pathways for EPS have been used to compare results with the characterised impact categories. The distribution of the relative contribution over the life cycle stages was compared. EPS and the impact categories showed the same pattern and similar distribution within the stages. It is important to not only compare the relative value, because to some extent it can be misleading, since it only distributes the impact over the life cycle stages and not see to the magnitude of the value. Therefore, to actually see if a product has improved its environmental performance or not it is important to compare the absolute value between the safeguard subjects and the life cycle stages. The EPS method account for resource consumption, which is reflected in the result since it consistently, gives a lower improvement compared to the impact categories.

Another very important difference between EPS and the impact categories is that they describe environmental impacts at different levels. EPS take it a step further in the cause-effect-chain than the impact categories. Take the global warming impact as an example; EPS provide information on which type of effect global warming might lead to by using the pathways e.g. flooding, starvation etc. This information is not possible to get from the impact categories. EPS is a very interesting LCIA method and its philosophy and intentions is useful when asking for a weighted result. However, it needs refinement since the last version is 12 years old. Factors need an update and there might be an interest of new factors. For example it is very likely that the willingness to pay for the safeguard subjects has changed, since people become more aware of the importance to have for example a well working ecosystem production capacity.

7. Future Work

This chapter gives suggestions on what the author believe would be interesting for future research.

When the EPS method was developed, an uncertainty factor for each index and weighting factor was created. This factor has not been considered in this work, due to time constraints. However, for future use of the EPS method, it would be very interesting to include this factor, in order to be able to present an overall uncertainty value with the weighted value. The uncertainty value would add another dimension to the result and provide a direction in how uncertain the final outcome really is.

It would have been extremely interesting to test a Nordic eco-labeled baby diaper with an old model and replacing certain components of the diaper. Components that could be interesting to model would be super absorbents, pulp fluff, nonwoven material etc. in order to find out how different materials affect the result.

During the study, some parts (e.g. land use) of the EPS method have been excluded because of various factors. For future use of EPS it is recommended to include as many parts as possible since they all accomplish the method, and might be important for the outcome.

When the first version of EPS was launched, it was ahead of its time. The last version was published in 2000 and a lot of development has occurred since then, therefore an update that reflects today's conditions would be preferable.

Appendix I- Weighting methods and their general principles

The table illustrates weighting methods and their general principles, the green ones are discussed further in chapter 4. This table is stated as found in Steen 1999 table 3.1 page 23.

Method name	Environmental goal or reference	Weighting principle	Spatial extension
EPS	Present state of environment	WTP to avoid changes	Global
ECO-indicator ´99	Present state	Two step weighting, last step of panel type	Europe
EDIP	Present state	Separate weighting of emissions (political goals), resources (supply horizon) and work environment	Global and national
Environmental themes	National critical loads	Relative reduction of distance to target	Switzerland, Netherlands, Sweden or Norway
Tellus	Zero emission (not explicitly expressed)	WTP for flue gas cleaning	USA
Eco-scarcity	National emissions	Relative reduction of distance to target	Switzerland, Netherlands, Sweden or Norway

Appendix II - EPS safeguard subjects

The impact categories in the EPS method are based on five safeguard subjects: human health, ecosystem production capacity, abiotic stock resource, bio-diversity and cultural and recreational values.

Safeguard subject: Human health		
Impact Category	**Indicator name**	**unit**
Life Expectancy	YOLL: years of lost life	person year
Severe Morbidity & suffering	Severe Morbidity	person year
Morbidity	Morbidity	person year
Severe Nuisance	Severe Nuisance	person year
Nuisance	Nuisance	person year

Safeguard subject: Ecosystem Production Capacity		
Impact Category	**Indicator name**	**unit**
Crop production capacity	Crop	kg
Wood production capacity	Wood	kg
Fish & meat production capacity	Fish & meat	kg
Soil acidification	Base cat-ion capacity	mole H+ equivalents
Production capacity of water	Irrigation water	kg
Production capacity of water	Drinking water	kg

Safeguard subject: Abiotic Stock Resource		
Impact Category	**Indicator name**	**unit**
Depletion of element reserves	"element name" reserves	Kg of element
Depletion of fossil reserves	Natural gas reserves	Kg
Depletion of fossil reserves	Oil reserves	Kg
Depletion of fossil reserves	Coal reserves	Kg
Depletion of mineral reserves	"mineral name" reserves	Kg of minerals

Safeguard subject: Bio-diversity		
Impact Category	**Indicator name**	**unit**
Extinction of a species	NEX: Normalized extinction of species	Dimension less

Cultural and recreational values are very hard to describe with general impact categories and indicators, therefore they are identified only on a case study basis.

Appendix III - Differences in characterization factors between report and database

In the table below are the characterization factors, which differed between the report (Steen, 1999a) and the CPM database for emissions to air presented. The characterization factors that were used in the EPS software model are highlighted in purple.

Impact category	Flow	Characterization factor from the report	Characterization factor from CPM database
Life expectancy	Ethane (Ethylene)	2.60E-05	2.27E-05
Severe Morbidity	Formaldehyde	7.69E-06	1.01E-05
Severe Morbidity	Ethane (Ethylene)	5.18E-06	4.50E-06
Morbidity	Cadmium	1.92E-04	0.512E-04
Nuisance	Hydrogen sulphide	1.06E-02	9.16E-03
Crop	Butadiene	4.87	4.78
Wood	Hydrogen chloride	6.37E-01	0.0182
Normalized extinction of species	Hydrogen fluoride	-1.75E-13	1.92E-10
Normalized extinction of species	Ammonia	2.91E-13	2.78E-13

The values below for emissions to air were missing in the report but have been included in the EPS software model, since they are correct according to Bengt Steen and should be used within the EPS method (2011-03-23).

- Ammonia (impact category: wood, pathway: global warming) -0.0282
- Sulphur trioxide (impact category: normalized extinction of species, pathway: acidification) 0.944E-14

The following values for emissions to air were missing in the report and should not be used, since the values in the CPM database are wrong according to Bengt Steen (2011-03-23, 2011-03-29).

- Cadmium (life expectancy, water emission) 2E-11
- Copper (life expectancy, water emission) 1.11E-10
- Lead (severe nuisance, air emission) 1.58E-4
- Lead (severe nuisance, water emission) 1.58E-4

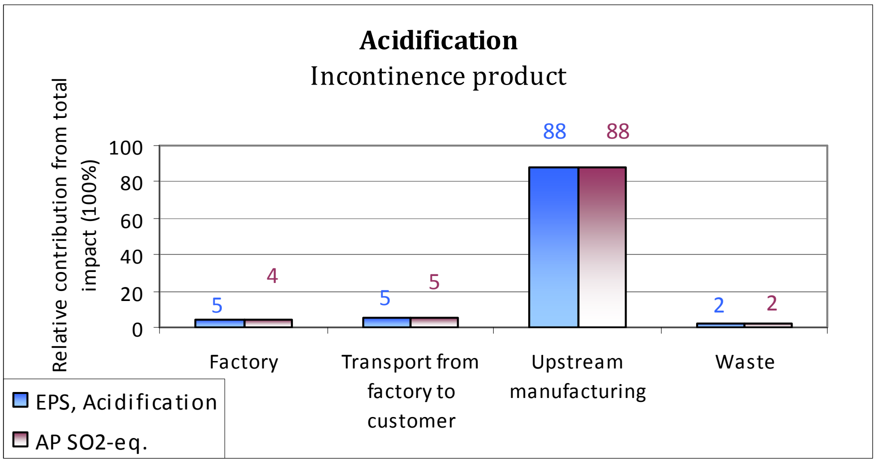
Appendix IV- The flows contributing to global warming

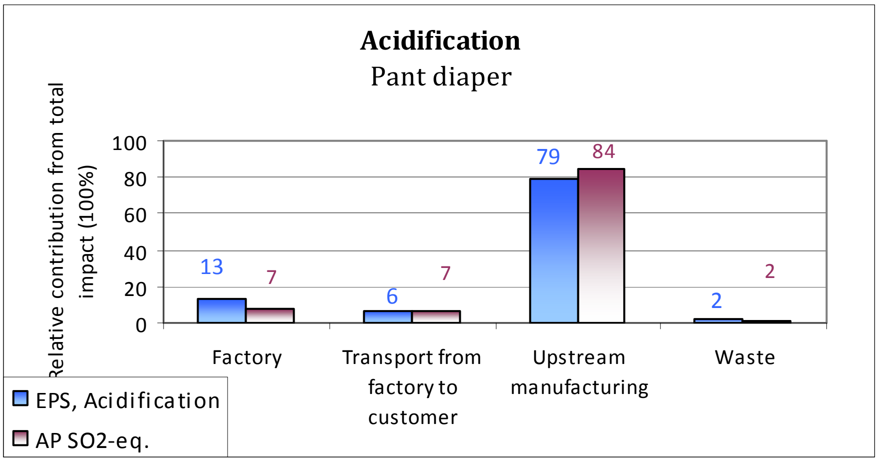
Global Warming Potential (GWP 100 years)	
1,1,1-Trichloroethane [Halogenated organic emissions to air]	R 134a (tetrafluoroethane) [Halogenated organic emissions to air]
2,2,2-Trifluoroethanol [Halogenated organic emissions to air]	R 141b (dichloro-1-fluoroethane) [Halogenated organic emissions to air]
2,2,3,3,3-Pentafluoro-1-propanol [Halogenated organic emissions to air]	R 142b (chlorodifluoroethane) [Halogenated organic emissions to air]
Bromodichloromethane [Halogenated organic emissions to air]	R 143 (trifluoroethane) [Halogenated organic emissions to air]
Carbon dioxide [Renewable resources]	R 143a (trifluoroethane) [Halogenated organic emissions to air]
Carbon dioxide [Inorganic emissions to air]	R 152a (difluoroethane) [Halogenated organic emissions to air]
Carbon dioxide, land transformation [Inorganic emissions to air]	R 161 [Halogenated organic emissions to air]
Carbon tetrachloride (tetrachloromethane) [Halogenated organic emissions to air]	R 21 (Dichlorofluoromethane) [Halogenated organic emissions to air]
Chloromethane (methyl chloride) [Halogenated organic emissions to air]	R 22 (chlorodifluoromethane) [Halogenated organic emissions to air]
Dibromomethane [Halogenated organic emissions to air]	R 225ca (dichloropentafluoropropane) [Halogenated organic emissions to air]
Dichloromethane (methylene chloride) [Halogenated organic emissions to air]	R 225cb (dichloropentafluoropentane) [Halogenated organic emissions to air]
Dimethyl ether [Hydrocarbons to fresh water]	R 227ea (septifluoropropane) [Halogenated organic emissions to air]
Halon (1211) [Halogenated organic emissions to air]	R 23 (trifluoromethane) [Halogenated organic emissions to air]
Halon (1301) [Halogenated organic emissions to air]	R 23cb [Halogentaed organic emissions to air]
Hexafluoroisopropanole [Group NMVOC to air]	R 236ea [Halogenated organic emissions to air]
HFE 7100 [Halogenated organic emissions to air]	R 236fa (hexafluoropropane) [Halogenated organic emissions to air]
HFE 7200 [Halogenated organic emissions to air]	R 245ca (pentafluoropropane) [Halogenated organic emissions to air]
Methane [Organic emissions to air (group VOC)]	R 245fa [Halogenated organic emissions to air]
Methane (biotic) [Organic emissions to air (group VOC)]	R 365mfc [Halogenated organic emissions to air]
Methane emission remaining in landfill gas [Organic emissions to air (group VOC)]	R 41 [Halogenated organic emissions to air]
Methyl bromide [Halogenated organic emissions to air]	R 43-10 (decafluoropentane) [Halogenated organic emissions to air]
Nitrous oxide (laughing gas) [Inorganic emissions to air]	R E125 [Halogenated organic emissions to air]
Perfluorobutane [Halogenated organic emissions to air]	R E134 [Halogenated organic emissions to air]
Perfluorocyclobutane [Halogenated organic emissions to air]	R E143a [Halogenated organic emissions to air]
Perfluorohexane [Halogenated organic emissions to air]	R E235da2 [Halogenated organic emissions to air]
Perfluoropentane [Halogenated organic emissions to air]	R E236ca12 (HG-10) [Halogenated organic emissions to air]
Perfluoropropane [Halogenated organic emissions to air]	R E245cb2 [Halogenated organic emissions to air]
R 11 (trichlorofluoromethane) [Halogenated organic emissions to air]	R E245fa2 [Halogenated organic emissions to air]
R 113 (trichlorofluoroethane) [Halogenated organic emissions to air]	R E254cb2 [Halogenated organic emissions to air]
R 114 (dichlorotetrafluoroethane) [Halogenated organic emissions to air]	R E338pcc13 (HG-01) [Halogenated organic emissions to air]
R 115 (chloropentafluoroethane) [Halogenated organic emissions to air]	R E347mcc3 [Halogenated organic emissions to air]
R 116 (hexafluoroethane) [Halogenated organic emissions to air]	R E356pcf3 [Halogenated organic emissions to air]

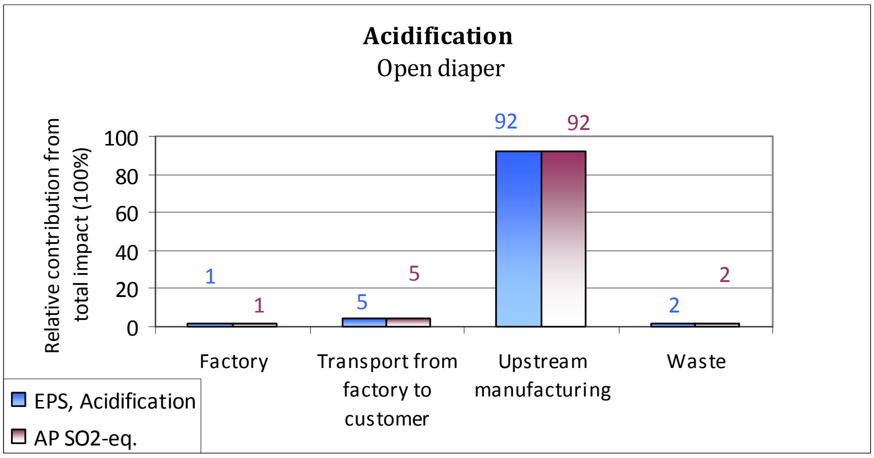
R 12 (dichlorodifluoromethane) [Halogenated organic emissions to air]	R E374pc2 [Halogenated organic emissions to air]
R 12 (dichlorodifluoromethane) [Halogenated organic emissions to sea water]	R E43-10pccc124 (H-Galden1040x) [Halogenated organic emissions to air]
R 12 (dichlorodifluoromethane) [Halogenated organic emissions to fresh water]	R32 (difluoromethane) [Halogenated organic emissions to air]
R 123 (dichlorotrifluoroethane) [Halogenated organic emissions to air]	Sulphur hexafluoride [Inorganic emissions to air]
R 124 (chlorotetrafluoroethane) [Halogenated organic emissions to air]	Tetrafluoromethane [Halogenated organic emissions to air]
R 125 (pentafluoroethane) [Halogenated organic emissions to air]	Trichloromethane (chloroform) [Halogenated organic emissions to air]
R 13 (chlorotrifluoromethane) [Halogenated organic emissions to air]	Trifluoroiodomethane [Halogenated organic emissions to air]
R 134 [Halogenated organic emissions to air]	
EPS, Global Warming	
EPS, Human health, Nuisance, Global Warming	Propene (propylene) [Group NMVOC to air]
Nitrous oxide (laughing gas) [Inorganic emissions to air]	EPS, Ecosystem production capacity, Crop, Global Warming
EPS, Human health, Morbidity, Global Warming	Benzene [Group NMVOC to air]
Benzene [Group NMVOC to air]	Butadiene [Group NMVOC to air]
Butadiene [Group NMVOC to air]	Carbon dioxide [Inorganic emissions to air]
Carbon monoxide [Inorganic emissions to air]	Carbon monoxide [Inorganic emissions to air]
Dust (PM10) [Particles to air]	Dust (PM10) [Particles to air]
Ethene (ethylene) [Organic intermediate products]	Ethene (ethylene) [Organic intermediate products]
Formaldehyde (methanal) [Group NMVOC to air]	Formaldehyde (methanal) [Group NMVOC to air]
Methane [Organic emissions to air (group VOC)]	Methane [Organic emissions to air (group VOC)]
Nitrous oxide (laughing gas) [Inorganic emissions to air]	Nitrous oxide (laughing gas) [Inorganic emissions to air]
Propene (propylene) [Group NMVOC to air]	Propene (propylene) [Group NMVOC to air]
EPS, Human health, Severe morbidity, Global Warming	EPS, Ecosystem production capacity, Wood, Global Warming
Benzene [Group NMVOC to air]	Carbon dioxide [Inorganic emissions to air]
Butadiene [Group NMVOC to air]	Carbon monoxide [Inorganic emissions to air]
Carbon monoxide [Inorganic emissions to air]	Dust (PM10) [Particles to air]
Dust (PM10) [Particles to air]	Methane [Organic emissions to air (group VOC)]
Formaldehyde (methanal) [Group NMVOC to air]	Nitrous oxide (laughing gas) [Inorganic emissions to air]
Methane [Organic emissions to air (group VOC)]	EPS, Bio-diversity, Extinction of a species, Global Warming
Nitrous oxide (laughing gas) [Inorganic emissions to air]	Benzene [Group NMVOC to air]
EPS, Human health, Life expectancy, Global Warming	Butadiene [Group NMVOC to air]
Benzene [Group NMVOC to air]	Carbon dioxide [Inorganic emissions to air]
Butadiene [Group NMVOC to air]	Carbon monoxide [Inorganic emissions to air]
Carbon monoxide [Inorganic emissions to air]	Dust (PM10) [Particles to air]
Dust (PM10) [Particles to air]	Ethene (ethylene) [Organic intermediate products]
Ethene (ethylene) [Organic intermediate products]	Formaldehyde (methanal) [Group NMVOC to air]
Formaldehyde (methanal) [Group NMVOC to air]	Methane [Organic emissions to air (group VOC)]
Methane [Organic emissions to air (group VOC)]	Nitrous oxide (laughing gas) [Inorganic emissions to air]
Nitrous oxide (laughing gas) [Inorganic emissions to air]	Propylene glycol [Group NMVOC to air]

Appendix V- Diagram illustrating the acidification result for comparison of EPS and the impact categories used at SCA

In the diagrams below are the results of the comparison of EPS and the Impact categories used at SCA presented for acidification. The results are presented in relative contribution from total impact (100 %).







Appendix VI - The flows contributing to acidification

Acidification Potential (AP)
Ammonia [Inorganic emissions to air]
Nitrogen dioxide [Inorganic emissions to air]
Nitrogen oxides [Inorganic emissions to air]
Sulphur dioxide [Inorganic emissions to air]
Sulphur trioxid [Inorganic emissions to air]
EPS, Acidification
EPS, Ecosystem production capacity, Fish & Meat, Acidification
Ammonia [Inorganic emissions to air]
Hydrogen chloride [Inorganic emissions to air]
Hydrogen fluoride [Inorganic emissions to air]
Sulphur dioxide [Inorganic emissions to air]
EPS, Ecosystem production capacity, Base cat-ion, Acidification
Ammonia [Inorganic emissions to air]
Hydrogen chloride [Inorganic emissions to air]
Hydrogen fluoride [Inorganic emissions to air]
Nitrogen oxides [Inorganic emissions to air]
Nitrous oxide (laughing gas) [Inorganic emissions to air]
Sulphur dioxide [Inorganic emissions to air]
EPS, Bio-diversity, Extinction of a species, Acidification
Ammonia [Inorganic emissions to air]
Hydrogen chloride [Inorganic emissions to air]
Hydrogen fluoride [Inorganic emissions to air]
Sulphur dioxide [Inorganic emissions to air]
Sulphur trioxide [Inorganic emissions to air]

Appendix VII - The flows contributing to eutrophication

Eutrophication Potential (EP)	
Ammonia [Inorganic emissions to air]	Nitrogen [Inorganic emissions to agricultural soil]
Ammonia [Inorganic emissions to industrial soil]	Nitrogen (as total N) [Inorganic emissions to sea water]
Ammonia [Inorganic emissions to sea water]	Nitrogen (as total N) [Inorganic emissions to fresh water]
Ammonia [Inorganic emissions to fresh water]	Nitrogen (N-compounds) [Inorganic emissions to air]
Ammonia [Inorganic emissions to agricultural soil]	Nitrogen dioxide [Inorganic emissions to fresh water]
Ammonium [Inorganic emissions to air]	Nitrogen dioxide [Inorganic emissions to sea water]
Ammonium / ammonia [Inorganic emissions to sea water]	Nitrogen dioxide [Inorganic emissions to air]
Ammonium / ammonia [Inorganic emissions to fresh water]	Nitrogen monoxide [Inorganic emissions to air]
Ammonium / ammonia [Fresh water]	Nitrogen oxides [Inorganic emissions to sea water]
Ammonium carbonate [Inorganic emissions to air]	Nitrogen oxides [Inorganic emissions to fresh water]
Ammonium nitrate [Inorganic emissions to air]	Nitrogen oxides [Inorganic emissions to air]
Chemical oxygen demand (COD) [Analytical measures to fresh water]	Nitrous oxide (laughing gas) [Inorganic emissions to air]
Chemical oxygen demand (COD) [Analytical measures to sea water]	Phosphate [Inorganic emissions to sea water]
Nitrate [Inorganic emissions to sea water]	Phosphate [Inorganic emissions to air]
Nitrate [Fresh water]	Phosphate [Inorganic emissions to fresh water]
Nitrate [Inorganic emissions to air]	Phosphate [Fresh water]
Nitrate [Inorganic emissions to fresh water]	Phosphoric acid [Inorganic emissions to fresh water]
Nitrate (as total N) [Inorganic emissions to fresh water]	Phosphoric acid [Inorganic emissions to industrial soil]
Nitrate (as total N) [Inorganic emissions to sea water]	Phosphoric acid [Inorganic emissions to sea water]
Nitric acid [Inorganic emissions to industrial soil]	Phosphoric acid [Inorganic emissions to air]
Nitric acid [Inorganic emissions to air]	Phosphoric acid [Inorganic emissions to agricultural soil]
Nitric acid [Inorganic emissions to fresh water]	Phosphoruos-pent-oxide [Inorganic emissions to air]
Nitric acid [Inorganic emissions to agricultural soil]	Phosphoruos-pent-oxide [Inorganic emissions to fresh water]
Nitric acid [Inorganic emissions to sea water]	Phosphoruos-pent-oxide [Inorganic emissions to sea water]
Nitrite [Fresh water]	Phosphorus [Inorganic emissions to agricultural soil]
Nitrite [Inorganic emissions to air]	Phosphorus [Inorganic emissions to industrial soil]
Nitrite [Inorganic emissions to fresh water]	Phosphorus [Inorganic emissions to air]
Nitrite [Inorganic emissions to sea water]	Phosphorus [Inorganic emissions to sea water]
Nitrogen [Inorganic emissions to sea water]	Phosphorus [Inorganic emissions to fresh water]
Nitrogen [Inorganic emissions to industrial soil]	Sulphur trioxid [Inorganic emissions to air]
Nitrogen [Inorganic emissions to fresh water]	
EPS, Eutrophication	
EPS, Ecosystem production capacity, Fish & Meat, Eutrophication	Chemical oxygen demand (COD) [Analytical measures to fresh water]
Nitrogen (as total N) [Inorganic emissions to sea water]	Nitrogen (as total N) [Inorganic emissions to fresh water]
Nitrogen (as total N) [Inorganic emissions to fresh water]	Nitrogen (as total N) [Inorganic emissions to sea water]
EPS, Bio-diversity, Extinction of a species, Eutrophication	Nitrogen oxides [Inorganic emissions to air]
Ammonia [Inorganic emissions to air]	Phosphorus [Inorganic emissions to fresh water]
Biological oxygen demand (BOD) [Analytical measures to sea water]	Phosphorus [Inorganic emissions to sea water]
Biological oxygen demand (BOD) [Analytical measures to fresh water]	
Chemical oxygen demand (COD) [Analytical measures to sea water]	

Reference

Baumann H., Tillman A-M. (2004) A Hitch Hikers guide to LCA- An orientation in life cycle assessment methodology and application. Edition 1:3. Lund: Studentlitteratur AB.

Bengtsson M, (2000) Environmental Valuation and Life Cycle Assessment. Chalmers University of Technology. ISSN 1403-2694

Bergendahl, C-G. (2002) Ekodesign- Praktisk vägledning *IVF-Swerea publication* 00819
Accessible at: http://extra.ivf.se/lcae/LCA.htm [Retrieved: 31st March 2011]

Carlson R., Pålsson A-C. (2008) Livscykelanalys Ringar på vattnet. Stockholm: SIS Förlag AB.

Centre for Environmental Assessment of Products and Material Systems (CPM) - Success stories. Accessible at: http://www.cpm.chalmers.se/success_story.htm#SCA [Retrieved: 31st March 2011]

Electronic Recyclers International (2008-2011) - Hexachlorobenzene. Accessible at: http://1800recycling.com/green-glossary/hexachlorobenzene/ [Retrieved: 12th May 2011]

EPA- United States Environmental Protection Agency – Methoxychlor hazard waste (2011), Phosphine factsheet (1999), Sodium Fluoracetate factsheet (1995) Accessible at: http://www.epa.gov [Retrieved: 12th May 2011]

Eartthshift Inc. (2011) - Impact assessment methods Accessible at: http://www.earthshift.com/software/simapro/impact-assessment-methods#epd [Retrieved: 8th June 2011]

GaBi Software- A software Solution by PE International. Accessible at: http://database-documentation.gabi-software.com/index.php?id=6725 [Retrieved: 27 th Jan. 2011]

Goedkopp, M., Spriensma, R. (2002) The Eco-indicator 99, A damage oriented method for Life Cycle Impact Assessment. Methodology Report. Amersfoort The Netherlands: PRé Consultants (2nd edition).

ILCD handbook (2010). Analysis of existing environmental Impact Assessment methodologies for use in Life Cycle Assessment. European Commission Joint Research Centre (Institute for environment and sustainability)

IPPC (Intergovernmental Panel on Climate Change) Fourth Assessment Report: climate Change 2007 (AR4) page. 212

NPIC (National Pesticide Information Center). Fenamiphos (1996), Resmethrin (1996), Zinc phosphide (1996) Accessible at: http://extoxnet.orst.edu/pips/ [Retrieved: 12th May 2011]

PAN Pesticide Database, Pesticide Action Network, North America. Thallium(I) sulfate (2000-2010), Warfarin (2000-2010) Accessible at: http://www.pesticideinfo.org [Retrieved: 12th May. 2011]

Product Ecology Consultants (PRé). LCA methodology. Accessible at: http://www.pre.nl/life_cycle_assessment/impact_assessment.htm#3steps [Retrieved: 9th Feb. 2011]

Rex E., Baumann H. (2004) Expanding the green practice of LCA. The first decade of life cycle assessment activity in the Swedish forest production industry Gothenburg: CPM and Chalmers University of Technology. (CPM Report 2004:1) ISSN 1403-2694

Rydh CJ., Lindahl M., Tingström J. (2002) Livscykelanalys- en metod för miljöbedömning av produkter och tjänster. Lund: Studentlitteratur AB.

SCA, Svenska Cellulosa Aktiebolaget. Sustanability Policy (2009-04-21), Sustanability Targets (2011-03-23). Accessible at: http://www.sca.com [Retrieved: Jan- May 2011]

SS-EN ISO 14044 (2006) Miljöledning Livscykelanalys- Krav och vägledning. Stockholm: SIS Förlag AB.

Steen B. (1999) A systematic Approach to environmental priority strategies in product development (EPS). Version 2000- General system characteristics. Gothenburg: CPM and Chalmers University of Technology. (CPM Report 1999:4).

Steen B. (1999a) A systematic Approach to environmental Priority Strategies in Product Development (EPS). Version 2000- Models and Data of the Default Method Gothenburg: CPM and Chalmers University of Technology. (CPM Report 1999:5)

Swedish Environmental Management Council (Svenska Miljöstyrningsrådet) Om EPD. Accessible at: http://www.msr.se/sv/epd/Kort-om-EPD/ [Retrieved: 25th Feb. 2011]

The International EPD system What is an EPD? Accessible at: http://www.environdec.com/en/What-is-an-EPD/ [Retrieved: 25th Feb. 2011]

Thormark C. (2006) Resursanvändning I ett 12-vånings lågenergihus utan värmesystem. Lund: Avdelningen för byggnadsekonomi Lunds Tekniska Högskola. ISBN: 91–85257–94–X

Wahlström Å., Olsson-Jonsson A. (2002) Miljöpåverkan från byggnaders uppvärmningssystem Etapp 2. Borås: SP Sveriges Provnings- och Forskningsinstitut och Chalmers Tekniska Högskola. (Rapport effektiv 2002:02) ISSN: 1650-1489

Personal communication

Pålsson, Ann-Christin. Environmental specialist at SCA, contact: ann-christin.palsson@sca.com, personnel contact spring 2011.

Riise, Ellen. Senior scientist at SCA, contact: ellen.riise@sca.com, personnel communication November 2010 to September 2012.

Sjölin, Matilda. Environmental specialist at SCA, contact: matilda.sjolin@sca.com, personnel contact spring 2011.

Steen, Bengt. Professor at Chalmers, contact: bengt.steen@chalmers.se, meeting March 23rd, May 19th, and email communication spring 2011.