Product orientation of environmental work
– barriers & incentives

Mats Zackrisson
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Licentiate thesis
Academic thesis, which with the approval of Kungliga Tekniska Högskolan, will be presented for public review in fulfilment of the requirements for a Licentiate of Engineering in Machine Design. The public review is held at Kungliga Tekniska Högskolan, Brinellvägen 83, Styrelserummet at 10.00 on 20 May 2009.
The research behind this licentiate is spread out over a decade of intensive development of environmental work in industry. A 1998 survey of Swedish companies with newly installed environmental management systems (EMS) concluded that such systems need more product-orientation. Data collected by companies as part of the process of creating their EMS between 1996-2001 offered further evidence that it is environmentally justified to seek improvements in the materials selection, use and disposal phases of products, i.e., to make the environmental improvement work more product-orientated. In a EU-funded project carried out between 2004-2006 it was demonstrated that developing an environmental product declaration could be a cost-effective product-oriented environmental action even for smaller companies.

This licentiate thesis relates to methods for companies to orientate their environmental work on their products. In particular, it examines experience and provides insights on the possibilities for companies, including small ones, to use life cycle assessment in product development in order to design products with an environmental performance well above legal compliance.

It is difficult to give general recommendations to companies about their environmental work because each company has its own unique business idea, customers, work culture, stakeholders etc. Nevertheless, the main findings of the licentiate thesis can be summed up in the following recommendations for, say, a small company in Europe without much previous experience of environmental work:

- Focus your environmental work on your products because you will accomplish more environmentally and the chance of profiting economically will motivate your personnel;
- Consider doing a life cycle assessment, LCA, on a strategically chosen product in order to learn more about your products and how to improve their environmental performance;
- Do not expect to find a general market demand for green products; start a dialogue with your best customers in order to create the demand;
- Engage an LCA specialist to do the LCA and work together with your personnel to interpret the results and generate improvement ideas;
- If your customers demand that you install an environmental management system, ask them if they would not prefer to receive an environmental product declaration on the particular product they are interested in, and a chance to discuss how its environmental performance can be improved.

Keywords
Life cycle assessment, LCA, environmental management systems, EMS environmental product declaration, EPD, ecodesign

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English
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List of appended papers

Paper 1

Paper 2
*Environmental aspects when manufacturing products mainly out of metals and/or polymers*, by Mats Zackrisson. Published in Journal of Cleaner Production. Volume 13, Issue 1, January 2005, Pages 43-49.

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Acronyms

ARPI  Analyze, Report, Prioritize, Improve
EMS   Environmental Management System
EMAS  Eco-Management and Audit Scheme
EPD   Environmental Product Declaration
EuP   Energy using products, as in directive 2005/32/EC
LCA   Life Cycle Assessment
LCIA  Life Cycle Impact Assessment
MEURO Million Euro
MSEK  Million Swedish Crowns
SEK   Swedish Crowns
SME   Small and Medium-sized Enterprises
ISO   International Organization of Standardization
RoSH  Restriction of hazardous substances, as in directive 2002/95/EC
WEEE  Waste electrical and electronic equipment, as in directive 2002/96/EC
1 Introduction

The research behind this thesis started in 1996. Environmental work in industry has developed tremendously since then. Today, in 2009, the issue is no longer whether or not companies should improve their products’ environmental performance as part of their environmental work, but how they should achieve this. This is the issue examined in this licentiate thesis.

1.1 Background

In the middle of the 1990’s, industry’s voluntary environmental work increased in the form of environmental management systems, environmental labelling, environmental product declarations etc. Recent focus on global warming has put further pressure on companies and individuals to act. In order to retain and amplify the trend of industry and individuals voluntarily acting to the benefit of the commons, it is important that the voluntary work is done as efficiently as possible, environmentally and economically.

The evolution of industry’s environmental work has been described by several researchers (Ritzén 1996, Enroth 2006, Schylander 2004). The first strategy was to try and dilute emissions and discharges through high chimneys and sewer systems. This only worked to an extent so the next step was to capture emissions and discharges with so-called end-of-pipe pollution controls. Filters at the end of the pipe made it apparent just how much resources were lost through the pipes, because what was captured still needed to be disposed of, which led to the concept of source reduction or cleaner production. Around that time, in the 1990’s, standards for environmental management systems began to emerge (EMAS, 1993 and ISO 14001, 1996). Also life cycle thinking and life cycle assessments developed during the 1990’s in order to focus environmental improvement work in the areas with dominating impacts. The concept of sustainable development developed by the Brundlandt Committee (Our common future, 1988) urges us not to endanger the needs of future generations while satisfying our own needs. This probably helps companies to justify taking moral responsibility for the entire product life cycle even though no legal requirements apply. To an extent all approaches, from dilution to life cycle accountability, are still applied today.

1.2 Research

The research behind this licentiate is spread out over a decade of intensive development of environmental work in industry. In a 1998 survey of Swedish companies with newly installed environmental management systems, it was concluded that environmental management systems (EMS) need more product-orientation. Data collected by companies when creating their EMS between 1996-2001 offered further evidence that it is environmentally justified to seek

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1 With “voluntary work” is here meant work that is not driven by legal requirements
improvements in the materials selection, use and disposal phases of products, i.e., to make the environmental improvement work more product-orientated. A EU-funded project carried out between 2004 and 2006 demonstrated that doing an environmental product declaration could be a cost-effective product-oriented action even in the case of smaller companies’ environmental work.

This licentiate thesis examines how companies can orientate their environmental work on their products. In particular it shares experience and provide insights on the possibilities for companies, including small ones, to use life cycle assessment for redirecting their environmental work. Legal requirements as a driver for product-orientation are not dealt with in this thesis as these are considered a minimum requirement. The scope of the thesis is design of products whose environmental performance goes well beyond legal compliance.

Life cycle assessment, LCA, is to an extent already considered the ultimate environmental assessment tool. Numerous policy papers and political initiatives advocate and even prescribe the use of life cycle assessment. This is the case for the Integrated Product Policy (2003), the Directive for energy-using products (2005) and the proposed Action plans on sustainable consumption and production and sustainable industrial policy (2007). The problem is that the amount of work and competence needed to do a LCA prevents its widespread use in companies (Frankl et al 2007, Solér 2001). This licentiate thesis sets out to explore whether the benefits of using LCA in companies, in terms of achieving a more product orientated and thereby more efficient environmental work, outweighs the costs in terms of work and competence.

There are certain documented examples of industrial companies using LCA in the context of product development. Frankl et al (2005) describe the introduction and uptake of LCA in mainly larger companies. Ritzén (1995) did some pioneering work investigating the use of LCA in three Swedish medium to large sized companies. However, there is very little discussion in academic literature relating to smaller companies’ use of LCA. Berkel et al (1999) sees a lack of information and LCA-tools to support product-orientated environmental management systems. Le Pochat et al (2005) concludes that the ecodesign tools available are tools for experts. Apart from some published environmental product declarations (EPD) by small companies (www.environdec.com, 2008), the research behind this licentiate thesis has not found any documented examples of LCA use in SMEs. This licentiate thesis, with its supporting papers, aims to spread some more light on the possibilities for companies, including small ones, to use LCA for product-orientation of their environmental work.

1.3 Research questions

A fundamental assumption throughout this licentiate thesis is that it is possible to achieve a better result, environmentally and economically, through adopting a life cycle perspective on the company’s products and activities. Research questions in respective study and their linkage to the main issues of the thesis are described below, followed by a definition of the specific research questions of this thesis.
Every company attempting to build an environmental management system according to ISO 14001 (2004) is faced with the challenge of identifying its environmental aspects and evaluating which of these are significant. Very little guidance on how to do this is given in ISO 14001 and many companies, especially small ones lacking their own environmental expertise, have found this requirement difficult to comply with. This is why the question of how to find a company’s significant environmental aspects is fundamental to the two first papers on environmental management systems, EMS.

The main question in paper 1 was whether EMS is worthwhile environmentally and economically. The central research questions were: What actual environmental improvements have the environmental management systems achieved? What are the costs of the work involved with environmental management systems? Does the introduction of an EMS lead to reduction of cost and/or increased revenue and does it pay for the investment and the operation of the EMS? The questions about environmental and economical gains from EMS are further explored in this licentiate thesis, because of their connection to the questions of how to carry out EMS-work as efficiently as possible.

Doing the research behind paper 1 generated the question in which life cycle phase most products gave most environmental impact, i.e., was product-orientation of environmental management work environmentally justifiable in general? At the time it was not possible to find any meta-studies of life cycle assessments that could possibly address this question. Paper 2, written in 2001, provided some data on which life cycle phase most products give most environmental impact. Since then, several studies show that consumption, i.e. the use phase of products, is generally very significant. The EIPRO study (2006), for example, concluded that the three areas having the greatest environmental impact are: food, private transport and housing. Together these areas are responsible for 70 – 80% of the environmental impact of consumption, and account for some 60% of consumption expenditure. Since the EIPRO study indirectly includes the environmental impacts from business to business consumption, the three product areas should account for about the same percentage of the total environmental impact in society.

One research question which has emerged from the practical work is what is the differences or similarities of the data used in LCA and in EMS. It is obvious that both the EMS and the LCA are built of the same fundamental data on how much energy, raw materials, transports etc are used to produce goods or provide services. How data should be documented and processed so that it can be used both in product LCA and reporting/follow-up of an EMS in a practical and cost-effective way is an interesting question. This, however, will only briefly be discussed in this licentiate thesis.

The third paper is about environmental product declarations, EPDs. The link from paper 1 and 2 to paper 3 is the product-orientation, as EPDs concern the products. Assuming EPDs are good for business and for the environment so far as companies using them will improve their products which in turn will replace less environmentally friendly ones, paper 3 explores the following research questions:
Can EPDs, or rather the underlying life cycle assessment, be used as a basis to identify ways to improve products environmentally?

Can EPDs be used to communicate products’ environmental profiles and ecodesign opportunities with potential customers and thereby create a demand for such products?

Will the customers’ demands and the identified improvement options bring about actual improvements in a product’s eco-efficiency?

How can SMEs make and utilize EPDs based on life cycle assessment?

The thesis will focus on the link or common denominator of the three papers, i.e., the product-orientation of environmental work. The research questions of special importance for the thesis are therefore:

Which is the most cost-effective way to achieve product-orientation of environmental work?

What are the barriers and incentives to a product-orientation of environmental work?

The basic assumption is that there is, in general, too little product-orientation of environmental work and that more of it would give better results from an environmental improvement point of view as well as from an economic one. Special consideration is given to smaller companies and their limited financial and personnel resources.
2 Frame of reference

2.1 Definition of product-orientation

In this thesis, product-orientation of environmental work should be understood as a process to accomplish more and better ecodesign, while sharing the ecodesign goal of minimizing the environmental impact of products.

With “products” are not only meant physical products but also services such as for example baby-sitting, cleaning or research. This is a usual definition of product in standards (ISO 9000, ISO 14001).

Concepts of product-oriented environmental policies and EMSs have been used in the Netherlands by Berkel et al (1999) and Rocha et al (1999), but without defining them. However, there seems to be a general understanding that product-orientation of environmental work implies focusing the environmental assessment on the life cycle impacts of the company’s products and focusing environmental improvement work in the dominant life cycle stages. Furthermore, product-orientation of environmental work implies assuming a moral accountability for environmental impacts occurring outside the production facility itself even when no legal accountability exists. Since the dominant impacts often occur in either the material production phase or the use phase (paper 2, EIPRO), product-orientation of environmental work implies that supply chain communication and cooperation become very important. Furthermore, much more attention has to be paid to how products are used and discarded.

Ecodesign is often defined as an aim in product development to reduce or minimize the environmental impact of a product, see for example Ölundh (2006). The directive on energy-using products (2005) defines ecodesign as “the integration of environmental aspects into product design with the aim of improving the environmental performance of the EuP (energy-using product) throughout its whole life cycle.” This is very similar to the descriptions of concepts of product-orientated policies and EMSs as expressed above.

Product-orientation of environmental work as used in this licentiate thesis strives to describe not only the aim of improving product environmental performance but also how to focus environmental work more on the products, i.e. how to do (more and better) ecodesign. This means that product-orientation of environmental work is a process to accomplish more and better ecodesign, while sharing the ecodesign goal of minimizing the environmental impact of products.

2.2 Subject areas

Product-orientation of environmental work spans over the following subjects: life cycle assessment, environmental management systems, ecodesign and
environmental communication. These will all be discussed below. Life cycle assessment, LCA, is the central part of this thesis.

The standards in the ISO 14000 series that are of particular relevance for this licentiate thesis are described under respective subject area below. Having been elaborated in an international negotiation process involving thousands of stakeholders from industry, government agencies, NGOs and academia, the standards represent a very solid foundation for environmental management.

2.2.1 Life cycle assessment

ISO 14044 Environmental management - Life cycle assessment - Requirements and guidelines (2006), is the cornerstone standard for how to do LCA. It contains the rules and guidance on how to do a life cycle assessment which has to be adhered to by the Stepwise EPD approach in paper 3. Below follows first a general description of LCA methodology, then some important methodological choices.

LCA methodology

LCA according to ISO 14044 (2006) consist of four stages: Scooping, inventory, environmental impact assessment and interpretation. All stages except the one for environmental impact assessment are considered obligatory. The stages are often repeated in an iterative way that gradually refines the assessment. None of the stages are unique to the LCA methodology. What makes LCA unique according to Finnveden (2000) is that all life cycle phases of the analyzed object are considered from raw material extraction to the product’s end-of-life.

Figure 1 Life cycle assessment considers all life cycle phases

The scooping stage consists of the definition of goal and scope. Defining the goal of the LCA requires describing the intended application, the reasons or driving forces behind carrying out the study, the intended audience and whether or not the results are intended to be used in comparative assertions for public use. Defining the scope involves describing the product system to be studied including the system boundaries, its function and the associated functional unit. Furthermore, allocation procedures, environmental impact categories including value choices,
data requirements, critical assumptions and limitations, data quality requirements, critical review and report format are considered during the scooping. Usually at least some of the issues addressed during the definition of goal and scope have to be revisited later on.

The use of a functional unit underlines the relative character of LCA; it is a tool that aims to handle comparisons between different products performing similar, but rarely exactly the same, functions. For some products, it is relatively easy to find a representative functional unit, e.g. litre refrigerated volume for refrigerators. For other products it can be much more difficult. As an example, a personal computer performs many different functions and it is not possible to define a technical performance measure that could represent these functions in a good way. The result is that life cycle assessments of computers use one computer as a functional unit, which makes comparisons of anything but very similar computers difficult (Jönbrink and Zackrisson 2007).

The requirements imposed by the standard on studies intended for comparative assertions intended for the public are quite exhaustive. They also illustrate that LCA is a tool that strives to handle comparisons between different products. ISO 14044 (2006) defines a comparative assertion as an “environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function”. The requirements on studies intended for public comparative assertions include, among others, use of a sufficiently comprehensive set of environmental impact category indicators that are scientifically and technically valid and internationally accepted. Weighting, i.e., adding up different impact environmental impacts by use of weighting factors is explicitly forbidden. Comparisons across impact categories are not considered scientifically correct. The comparison should be done category indicator by category indicator. This makes it more difficult distinguish one product as environmentally superior to another product since the winning product has to show least environmental impact in all used impact categories. Furthermore, in most cases it is questionable whether there is a sufficiently comprehensive set of environmental impact category indicators that are scientifically and technically valid and internationally accepted. For example, there is no international consensus on indicator(s) for toxicity. The consequence is that LCA based comparative assertions rarely reach the general public.

During the life cycle inventory analysis, data relating to physical flows across the system boundaries is collected, validated and normalized to the reference flow of the functional unit. Process flow diagrams including the unit processes belonging to the studied product system are often used to organize the data collection and get an overview of the life cycle, see Figure 2. All inputs and outputs of the product system are compiled in what is often called an ecoprofile that could consist of hundreds of different emissions and resources. Due to the obvious difficulty of interpreting such an ecoprofile, the life cycle environmental impact assessment stage is, though not obligatory, almost always done.
Figure 2  Life cycle inventory analysis involves accounting for physical flows across the product’s system boundary

Life cycle environmental impact assessment facilitates the interpretation by aggregating the long list of inputs and outputs. It consists of choosing environmental impact categories, assigning the hundreds of different emissions and resources of the ecoprofile to the selected impact categories and then calculating the category indicator results. The two last steps, called classification and characterization, are almost always done with dedicated computer software such as SimaPro (www.pre.nl, 2008) or Gabi (2009). Such LCA software also aid in drawing process flow diagrams, documenting all aspects of the data and making error estimations and sensitivity analysis.

The life cycle interpretation involves evaluating the appropriateness of the system boundaries, the functional unit and the data requirements in light of the calculated results and the preliminary conclusions drawn. The output of the interpretation phase is conclusions, limitations and recommendations of the study. Testing of the robustness of the results is an important element of the life cycle interpretation and according to Baumann (2004) this can be done by a variety of tools such as, for example, completeness check, consistency check, uncertainty analysis, sensitivity analysis, variation analysis and data quality assessment.

Methodological choices

Being a consensus document, ISO 14044 (2006), steers around some of the more difficult methodological choices in LCA (Baumann 2004). One such issue is whether one should use retrospective2 LCA or consequential LCA. According to Ekvall et al (2005) retrospective or accounting LCA methodology aims at describing environmentally relevant physical flows to and from a life cycle and its subsystems. Ideally, it should include average data on each unit process within the life cycle. The accounting model does not include unit processes other than those of the life cycle investigated. In contrast, consequential LCI methodology aims at describing how the environmentally relevant physical flows to and from the technosphere will change in response to possible changes made within the life

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2 Retrospective LCA is also called accounting LCA or attributional LCA

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cycle. A consequential model includes unit processes that are significantly affected irrespective of whether they are within or outside the life cycle.

Ekvall et al (2005) describes the major pros and cons with respective method. Rebitzer et al (2005) points out that there are very few data sets available that supports consequential LCA, so the most practical choice today is accounting LCA. Tillman (2000) prescribes accounting LCA for identifying improvement potential and then consequential LCA for evaluating the finds. The rationale is mainly that accounting LCA fits better when little is known about the product and improvement possibilities whereas the strength of consequential LCA is to compare different and well-defined product concepts. With respect to EPDs, the international EPD® system prescribes accounting LCA (General Programme instructions 2008) whereas the proposed Danish EPD-system (www.mvd.dk) prescribes consequential LCA.

Rebitzer et al discusses the need for streamlined or simplified LCA, especially in the context of SMEs, in order to keep costs low. Streamlined LCA is used in the Stepwise EPD method described in paper 3. In a streamlined LCA, typically only data from the own manufacturing is site specific. The remaining data is generic, i.e. it is drawn from existing LCA databases and represent average process technology for a country or region. Todd et al (1999) concludes that there is no sharp division between regular LCA and streamlined LCA. The objective of the particular LCA decides the needed data coverage and system boundaries.

Another, less discussed critical methodology choice in LCA, pertains to the system boundary. Zhang et al (2007) argues that the full energy-use per worker-hour should be accounted for in LCA. Energy-use per worker-hour is 30 MJ in USA and 15-20 MJ in Europe and include the energy of infrastructure such as housing, transportation, health care etc in addition to food. Baumann (2004) notes, without further comment, that personnel-related environmental impact is usually not included in LCA. The EPD® system prescribes (General Programme instructions 2008) that personnel activities need not be included. However, a comparison between a machine-made product and a handmade product would not be very fair if the energy to drive the machine is included but not the energy needed by the worker. It should be noted that no provision exists in ISO 14044 to exclude accounting for personnel-related activities. All significant impacts should be included. Accounting for personnel-related impacts like energy-use per worker-hour links environmental analysis closer to economic analysis because the cost of labour is very important in economic analysis. There is also a close link to working environment issues in which the number of working hours is an important parameter (Zackrisson 1995). According to Zhang et al (2007), it is relatively easy to estimate the energy-use per worker-hour from national statistics, however it includes industrial transportation so there is a risk of double counting.

2.2.2 Environmental management systems according to ISO 14001

ISO 14001 was accepted as an international standard in 1996. Swedish companies and organizations have adopted this standard for environmental management at an impressive scale, see Figure 3.
ISO 14001 is a modern management standard built on the so-called PDCA-cycle where PDCA stands for Plan-Do-Check-Act. It emphasizes continuous improvement of environmental performance.

During the planning phase, the company’s environmental aspects are identified, evaluated and prioritised. Environmental goals are then established based on this information. Note that it is up to the company to decide how to carry out this assessment and thus to decide in which way to improve its environmental performance. A minimum requirement is to comply with environmental laws and regulations and to aim for some improvement of performance. The planning phase, which is the focus of paper 2, is central in an environmental management system according to ISO 14000.

The significant environmental aspects, the legal obligations and the environmental goals defined in the planning phase are then used in the subsequent Do-phase. For example when: allocating resources and authority to those with environment-related roles and responsibilities; educating the staff broadly and in-depth; modifying operational control procedures; and creating procedures for waste, chemicals, purchasing, product development, transports and emergency situations. What is actually done varies from company to company. A popular thing to do in Sweden has been to demand that suppliers implement ISO 14001. In fact, the success of ISO 14001 in Sweden has been largely attributed to a handful of larger corporations who implemented ISO 14001 at an early stage and demanded ISO 14001 from their suppliers. The suppliers in turn demanded the same from their suppliers thus creating a snowball effect. Several studies, Zackrisson et al (2000), Ammenberg (2003) and Axelsson et al (2003) find that client demand is the main reason for companies to implement ISO 14001. However, there is no requirement in ISO 14001 to demand an EMS from suppliers. Instead ISO 14001 (2004) requires “procedures related to the identified significant environmental aspects of goods and services used by the organization and communicating applicable

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procedures and requirements to suppliers”, i.e. the focus is more on the supplier’s products and services than on the supplier’s environmental management system.

The Check-phase consists of both regular monitoring and measurement related to the established goals and key operational characteristics, and periodic auditing that everybody performs according to established procedures and that the system fulfils the requirements of the standard and applicable legal and other requirements. In addition, there should be procedures for corrective and preventive actions in cases of non-conformities, to prevent them happening again.

In ISO 14001, “act” means that management should periodically review the environmental management system and judge its suitability, adequacy and effectiveness. Both the planning and the checking phases provide information used in the management review.

2.2.3 LCA and EMS

Few authors have tackled or even touched upon the connection between LCA and environmental management systems, EMS. This is in a way surprising since the identification of significant aspects, where LCA could fit in very well, has been much discussed in connection with the ISO 14001 and ISO 14004 standards on environmental management systems. One exception is Zobel (2002) who suggests LCA for identifying and assessing environmental aspects in an EMS context and applies it in a large paper mill.

In Zackrisson et al, (1998, 2004) a prescriptive step-by-step method to do a company eco-balance was elaborated in the form of a manual containing a report template. The manual was developed as a result of giving assistance to companies to introduce an EMS according to ISO 14001. Paper 2 describes results from smaller companies using this manual that in essence prescribes a (streamline) life cycle inventory at company level. A “company ecobalance” is a report of all the inputs (raw materials, components, transports, energy etc) and outputs (emissions, waste and products) of a company in the course of, normally, one year. A product life cycle inventory on the other hand reports inputs and outputs in relation to a product specific functional unit, for example, one year of telephone use. Fundamentally it is the same data, but either in relation to a company year or to a product specific functional unit. The functional unit of a company ecobalance is thus one company year. The method used by Zackrisson et al (1998, 2004) was not labelled as LCA by the authors, partly because it was feared that such a label would scare away many industries. Another reason for not using the LCA-label was to steer away from some of the requirements in the ISO 14044 standard (2006).

Braunschweig and Müller-Wenk (1993) describes the concept of a company ecobalance in a book published before the existence of ISO 14001. As described above the method to compile a company ecobalance, is very similar to a streamline life cycle assessment at company level, but the authors did not emphasize the connection.
While the life cycle inventory is well defined in the LCA-standard ISO 14044 (2006), the company ecobalance or equivalent is not mentioned at all in the requirements for an EMS stated in ISO 14001. It is only brought up in the non-binding Annex A of ISO 14001 (2004) that considerations when identifying environmental aspects could include emissions and use of energy and raw materials. Since all environmental impact somehow stem from the use of energy and resources, it is surprising that ISO 14001 suggests it as optional to include energy and resources when identifying environmental aspects. Furthermore, Annex A explicitly states, “The identification of environmental aspects does not require a detailed life-cycle assessment”. This lack of guidance will be discussed in more detail further on.

Finkbeiner et al, (1998) assume that both tools (EMS and LCA) are based on an input/output analysis of physical flows of materials and energy and proceed to analyse the differences between an EMS and an LCA, such as system boundaries, aggregation of data, reference unit, reference system etc. They suggest a combination of both tools as the best solution for many companies.

Other researchers that connects LCA and EMS are Berkel et al (1999). His team identifies a lack of LCA-data and LCA-tools to support Product-orientated Environmental Management Systems (POEMS). They attempt to establish sector-specific databases/tools.

2.2.4 LCA and environmental communication

As described earlier, LCA strives to handle comparisons between competing products. Thus environmental information about products, i.e. marketing claims based on LCA is an area that has received considerable attention. A number of standards aiming at providing a level playing field for LCA-based marketing claims are now in place, for example, the ISO 14020 series of standards described below.

Frankl et al, (2005) found that marketing aspirations was a main driver for companies to start LCA activities. However, it was also found that that companies experienced that LCA, in its present form was not suitable for marketing claims. Instead the results of LCA can be of better use as a knowledge platform for communication with stakeholders on how to value and improve a product’s environmental merits (Frankl et al, 2005).

In the context of environmental marketing claims, the ISO 14020-series of standards is relevant. There is a distinction between type 1 consumer labelling, type 2 self-declarations and type 3 declarations according to programs. ISO 14020 (2000) gives the general principles for all types of environmental labelling and declaration of products. Common to all of them is that they “shall take into consideration all relevant aspects of the life cycle of the product” (ISO 14020, 2000).

The EU Flower is an example of type 1 labelling directed towards consumers. Products that comply with the criteria of the EU Flower may, at a price, put the well-known EU Flower on the product. Product criteria are established by the EU
Flower organization in cooperation with interest groups and are revised and tightened periodically in order to improve environmental performance. ISO 14024 (1999) describes principles and procedures for type 1 environmental labelling. Since a certain volume of products is needed to pay the fees that pay for developing the criteria, it is not possible to label all product groups.

Type 2 self-declarations can take on many different forms. Often they are quite similar to type 3 declarations since these have a more standardized form. As the name conveys, type 2 declarations are developed and issued by individual companies and they are not supported by any programs or official bodies like type 1 and 3 declarations. ISO 14021 (1999) gives guidance on how to develop type 2 declarations, for example by explaining how to use specific terms in a correct way when communicating products’ environmental performance.

Type 3 environmental declarations as described in ISO 14025 (2006) present quantified environmental life cycle product information to enable comparisons between products fulfilling the same function. Such declarations are based on independently verified LCA data and are subject to the administration of a program operator. Type 3 environmental declarations as described in ISO 14025 are primarily intended for use in business-to-business communication, but their use in business to consumer communication is not precluded.

In the future, sector-specific schemes for type 3 declarations are expected. Such schemes are being promoted by the European Commission as expressed by the IPP Working Group on Product Information (2006). ISO 21930 (2007) is the first sector-specific standard for type 3 declarations. It describes the principles and framework for the environmental declaration of building products, including consideration of the building products’ expected service life, seen over a building’s entire life cycle. The standard is expected to form the basis for programs leading to the environmental declaration of building products as described in ISO 14025.

A type 3 environmental product declaration, EPD, is an instrument to communicate LCA-based information about products in a form that makes comparisons possible. The research available on EPDs largely confirm the findings of Frankl et al (2005) that LCA is a poor marketing instrument, at least in its present form. Leire (2004) reviews product related environmental communication and confirms that there is no demand for EPDs. Soler et al (2001) suggest a number of improvements of EPDs from a user perspective. Jönsson (2000) is sceptical to the future of EPD based on the experiences of five companies that were among the first to make EPDs.

The difficulty for anybody but experts to understand the LCA information in an EPD is pointed out in paper 3. Christiansen et al (2006) argue for EPDs based on consequential LCA and for comparing the environmental profile of the product with that of an average product of the same kind. Nissinen et al (2007) propose benchmarks for consumer-oriented life cycle assessment-based environmental information on products based on normalization with national figures and even weighting across impact categories. But as pointed out in section 2.2.1, comparison or weighting across impact categories is not allowed by ISO 14044.

Paper 3 discusses the possibility of the preparatory work needed for a type 1 label, being done in the form of a preliminary type 3 declaration. Possible synergisms between type 1 labelling and type 3 declarations have also been pointed at by Frankl et al (2005 and 2000).

Scientific articles related to environmental communication in general, often concerns how to green consumers, i.e. how to make consumers consider environmental aspects in their purchasing decisions, see for example Leire (2004) and Rex (2007). Rex (2007) suggests that green marketing should learn from conventional marketing and actively engage in market creation.

2.2.5 LCA and ecodesign

Ecodesign is often defined as an aim in product development to reduce or minimize environmental impact of a product, see for example Ölundh (2006). A life cycle perspective is taken for granted or expressed in the definitions, implying that life cycle assessment is needed to focus ecodesign measures to the dominant life cycle stages. Surprisingly, there are very few available articles that describe the use of LCA when carrying out ecodesign. On the other hand, there are an abundance of checklists describing environmental improvement opportunities applicable for the whole product life cycle, but without advocating analysis of where (in the life cycle) the main impact occurs.

Simon et al (2000) do connect ecodesign with LCA with their proposed four-stage ARPI framework for ecodesign: 1) Analyse with LCA; 2) Report LCA and collect feedback; 3) Prioritize; 4) Improve design with relevant tools. The framework applies to both operational and strategic levels. Nielsen et al (2002) and Schmidt et al (2001) have also found strong links between LCA and ecodesign and Lindahl (2005) even explores LCA from a designer’s perspective.

The above ARPI framework for ecodesign (Simon et al 2000) resembles the Stepwise EPD approach as described in paper 3. The Stepwise EPD is based on LCA, publishing the declaration probably takes reporting of the LCA further than envisaged by Simon et al and prioritisation is done in the idea workshops, optional in the Stepwise EPD concept. The improvement, which is done within the normal design process of the company still has to be done. Thus, one way to accomplish ecodesign the ARPI way is to carry out an EPD (which includes LCA and reporting) as well as an idea generation workshop and then feed the results into the normal design process.

Several researchers, such as Ritzén (1996) have perceived that the lack of information about a new design is a major barrier to the use of LCA in ecodesign. As LCA is based on quantitative data, it is difficult to do a meaningful LCA at early stages of design when there is still very few data. Nielsen et al (2002) mean
that this barrier can be overcome by subjecting the product to more and more
detailed LCAs all through its product development cycle.

Ecodesign on its own, without LCA, is a more common topic in scientific papers. Van Hemel (2002) concluded that the success factor of ecodesign is market acceptance, whether real or perceived, of environmentally improved products.

In recent years some important European level ecodesign initiatives have begun. Both the EPIC-ICT (2006) project (Environmental Performance IndiCators for Information and Communication Technology Products) and the directive for energy-using products (2005), target product groups with considerable market size. LCAs are commissioned by the authorities, which use the knowledge to implement obligatory ecodesign measures to a whole product group. In the directive for energy-using products, economic analysis is also used to ensure that the life cycle cost to the consumer is unaffected.
3 Research methods

In this section the research methods and the project designs employed in the studies behind the three papers will be described and to an extent discussed. Surveys and semi-structured interviews are used in connection with paper 1 and 3. In addition, paper 3 uses what could be described as action research in case study form. Paper 2 is based on data collection by way of a manual/questionnaire, i.e. a sort of survey.

3.1 Validity

External validity describes to what degree the findings of the study are valid in general (Trochim, 2006). Since this licentiate thesis is concerned with environmental work in companies, external validity will be discussed in terms of company size, sector/activity, geographical location and maturity of environmental work. Construct validity is related to the degree of generalization in the sense that everyone must uniformly understand the concepts or terms that are the subjects of generalization (Trochim, 2006). EMS, EPD and LCA are relatively well defined concepts, while product-orientation of environmental work is a very broad term with different interpretations in different contexts.

Internal validity is the approximate truth about inferences regarding cause-effect or causal relationships (Trochim, 2006). Thus, internal validity is only relevant in studies that try to establish a causal relationship. It is not relevant in most observational or descriptive studies, for instance. The key question in internal validity is whether observed changes can be attributed to the examined intervention (i.e. the cause) and not to other possible causes (Trochim, 2006). Since this licentiate thesis is concerned with how to focus environmental work more on the products, i.e. how to do (more and better) ecodesign, whether or not it was the tested inferences that actually caused the examined effects is a very important issue.

3.2 Paper 1 method and project design

The research behind paper 1 involved two form of surveys applied to the same survey group. The survey group consisted of all the Swedish companies that had certified environmental management systems according to ISO 14001 or EMAS in November 1998; all in all 360 companies. A questionnaire was sent to all of them. In addition, semi-structured interviews (Kvale, 1997) were carried out with 19 companies randomly selected from the same survey group.

The survey project was a collaborative effort between five Swedish research institutes involving their specialists in environmental management systems. The questionnaire survey and the face-to-face interviews were carried out in parallel, i.e. during the same time period and largely covered the same issues. All project partners participated in the design of the questionnaire and the structuring of the
interviews. Questionnaires and semi-structured interviews (as opposed to more open in-depth interviews) reflect the researchers ideas about what are the most important issues to ask about. An alternative approach starting with in-depth interviews based on, for example, grounded theory (Gustavsson 1998) and then followed by a questionnaire survey could have given more unexpected results. The experience and the broad representation of the researches, all of which had assisted industry in implementing environmental management systems, guaranteed to a certain extent, the relevance of the study.

For the random sample of interview objects a representative distribution was sought between the main groups industry and service/trade, and in those groups between small sized (<100 employees) and large (>100 employees) companies. The actual distribution between the four groups resulted in that the service/trade group could not be subdivided in small and large corporations, so results were presented for only three groups: industry large, industry small and service/trade. It should be pointed out that one of the originally 20 randomly selected companies declined to be interviewed.

The face-to-face interviews were carried out with the aid of pre-prepared questions. The interviewee targeted was typically the environmental manager or environmental coordinator, i.e., the company representative with most knowledge about the environmental management system. He or she was also the person most likely to answer the questionnaire. The results of each interview were documented in consultation with the interviewee to ensure that the interviewer correctly interpreted their answers. Due to the level of detail of the interviews it was not considered useful to interview other staff in the companies.

To analyze the results of the interviews, some results were converted to parameters. Correlations between two continuous parameters were tested by regression analysis. Comparisons between groups (industry large, industry small or service/trade) of continuous parameters were done using dual t-test for different variances. The statistical methods used presupposed that the data was normally distributed for the whole group to which the survey applied to, i.e. the 360 certified companies. This was not certain, but it seems more likely that data should be normally distributed than not.

Triangulation, or the combination of methodologies in the study of the same phenomenon (Jick 1979), can be used to test to what extent results are valid in general. The whole idea in doing a survey of certified companies was to be able to draw conclusions about the whole group, i.e. all certified companies. By using both questionnaires and semi-structured interviews, the external validity of the obtained results could be tested against each other. To an extent, the interviews also gave qualitative case descriptions of some questionnaire issues, for example, market improvements.

The questionnaire response rate was 49%. No dropout analysis was made. Instead the results of the questionnaire were compared with the results of the interviews as described above. This was achieved through a process of co-authorship of the
3.3 Paper 2 method

Paper 2 compares data from environmental reviews in 11 companies. The companies were manufacturing products in steel, polymers and textile ranging from car air filters to production equipment. Inorganic surface treatment was also represented. The companies had between 36 and 110 employees. The data sets were chosen because of their acceptable quality. It would have been interesting to have more acceptable data sets, for example, representing both smaller and larger companies.

The 11 companies collected the data with the help of a manual containing a report template. The manual, first published in 1998, has since then been revised and updated twice (Zackrisson et al 1998, 2000, 2003) as well as translated into English and adapted for European use (Zackrisson et al 2002, 2004). The Swedish version has been sold to more than 1000 businesses.

The description of method with respect to paper 2 is divided in a description of the methods proposed in the manual, “Manual methods”, and in a description of the methods employed by the author for producing Paper 2, “Author methods”.

3.3.1 Manual methods

In section 2.2.3, the method proposed in the manual (Zackrisson et al 1998, 2000, 2003) was described as a prescriptive step-by-step method to do a company eco-balance that in essence is a streamlined life cycle inventory at company level. Each data set represents input and outputs in a company during a specified period, normally one year. It is recommended to use the previous year because of availability of data. The manual proposes grouping of aspects based largely on activities but also on mode of collection. The guiding principle advocated in the manual is that every aspect should have an obvious owner within the company.

It should be noted that the facility gate is not used as a system boundary for the company studies. Instead a procedure much more similar to streamlined LCA is carried out; the input/output data is used as a basis to calculate upstream emissions and environmental loads with the use of generic “cradle-to-gate” data for materials and energy carriers given in the manual. The results are weighted into a one-dimensional figure. Such weighting is scientifically questionable and therefore explicitly forbidden for some LCA applications as mentioned above.

3.3.2 Author methods

To an extent the Manual described above could be viewed upon as a questionnaire. The input/output data collected by the companies, by use of the questionnaire/manual, was checked for accuracy by comparing, for example, inputs with outputs and normalized data to the same normalized data from other
companies. Questionable data was investigated by contacts with the company. The checking procedure ensured some degree of uniformity of data.

Via use of generic “cradle-to-gate” data for materials and energy carriers given in the Manual, the input/output data was converted to Environmental Load Units by use of the EPS weighting method (Steen 1996). In order to validate the application of weighting methods, a more recent version of the EPS-system (Steen 1999) and another weighting method Eco-indicator 99 (Goedkoop, 2000) were used. It was shown that the ranking of aspects was the same regardless of method, giving some justification to using the scientifically questionable weighting for evaluating the significance of environmental aspects in the context of an EMS. In retrospect, more weighting methods could have been included in order to increase the strength of the validation.

The observations were largely made by studying the ranking order of the environmental aspects. The main observation that the largest impacts normally occur in the use and/or disposal phase of products is confirmed by numerous product LCAs.

3.4 Paper 3 method and project design

The research methods employed in relation to paper 3 could best be described as action research (Westlander 1999, Kasanen 1993) in case study form (Yin 2003). For each case at least one Stepwise EPD was developed entailing scoping, data collection, LCA calculations, interpretation of LCA, drafting of EPD and verifying the EPD. The EPD development itself involved numerous meetings and reviews of data and drafts. These actions were carried out by experts in LCA, working in the involved research organizations, in cooperation with the SMEs’ experts in production, sales, design etc. The verification of the Stepwise EPD at the end of the EPD development process can be seen as a form of validation.

The main motivation for the SMEs to participate in the Stepwise EPD project was an anticipation of a demand for EPDs from their customers and clients and a willingness to test new approaches and methods in environmental work. Willingness to spend time and effort to develop and make use of the EPDs was the main criterion for selection of the case study companies.

After finalizing the EPDs, a series of workshops and meetings were carried out aiming at using the Stepwise EPDs in marketing and as a basis for ecodesign. Surveys among potential users were also carried out. Draft records of all workshops and meetings were sent around to the participants for internal validation. National conferences were also carried out to discuss and disseminate the results.

In parallel to the development and utilization of the Stepwise EPDs, the Stepwise EPD concept or method was defined. The research method employed was to discuss among experts the experiences from practical work with the EPDs and draft guidelines (Stepwise EPD guideline, 2006) within the framework of relevant standards and norms such as ISO 14025 (2006) and ISO 14044 (2006).
Throughout the project, experiences were discussed between SMEs, research organizations and other partners at several meetings at both company, national and project level. Draft minutes of all meetings were sent around to the participants for confirmation. The concept discussions also extended to experts and forum outside the project.

At the end of this two-year project, each SME was interviewed by their research partner in order to evaluate the results, i.e. the impacts of the Stepwise EPD-work on design, market communication and sales. The same semi-structured evaluation questions were used in Sweden, Portugal and Latvia. In Denmark a more open and less structured approach was used. The impact of doing the Stepwise EPDs was documented in Impact reports (IVF 2006, INETI 2006, IVL 2006 and 2.0 2006). These impact reports, together with the Stepwise EPDs and all the discussions from the held meetings are the basis for paper 3.
4 Summaries of papers

This section summarizes the three papers included in the licentiate thesis. Paper 1 concludes that environmental management systems need more product-orientation and improving the identification and evaluation of environmental aspects is a key to achieving this product-orientation. Paper 2 offers further evidence that it is environmentally justified to seek improvements in the materials selection, use and disposal phases of products, i.e., to make the environmental improvement work more product-orientated and less manufacturing-orientated. Paper 3 demonstrates that doing an environmental product declaration can be a cost-effective product-oriented action in a company’s environmental work. Furthermore, it explores barriers and incentives to EPD-based product-orientation of environmental work in companies.

4.1 Paper 1: Environmental management systems – Paper tiger or powerful tool

Authors: Maria Enroth and Mats Zackrisson. Published in Conference Proceedings of the 2000 Eco-Management and Auditing Conference. June 2000. University of Manchester. UK. ERP Environment. UK. Pp. 81-92. The paper presents some of the results of a project in which Mats Zackrisson was the project leader. Mats Zackrisson carried out the research in the project together with Maria Enroth and Angelica Widing. Maria Enroth wrote and presented the paper. Mats Zackrisson assisted her in writing the paper.

4.1.1 Purpose

The purpose of the study was to compile and disseminate experience from environmental management systems, EMS, in order to improve the environmental work both from an environmental and economic point of view.

4.1.2 Method

The study was based on the 360 Swedish companies that had certified environmental management systems in accordance with ISO 14001 or EMAS in November 1998. The work included a questionnaire sent to all the certified companies and face-to-face interviews with 19 of them. For more details, see section 3.2.

4.1.3 Summary results

The response rate to the questionnaire was 49%. Among other, answers to the questionnaire revealed some frustration towards the fact that the EMS had not led to more environmental improvements, but that the companies’ market positions had been strengthened. Thirty percent of the companies even claimed increased
revenues as a result of the EMS. When interpreting these results today, one should remember that these were the first companies to use the ISO 14001 standard. Since the standard was released in spring 1996, the maximum experience at the time of the survey was 2.5 years.

Both the questionnaire and the interviews focused on the identification and evaluation of environmental aspects. Answers to the questionnaire revealed that most companies did not work at all with aspects related to the use and/or disposal of their products, thus disregarding aspects that most likely were environmentally significant. Half of the companies interviewed admitted to have missed identifying some very important aspects within the scope of their EMS (both environmentally and economically important).

4.1.4 Contribution to thesis

One of the main conclusions of the study was that EMS could be made more efficient by focusing the improvement work more on the use and disposal phase of manufactured products. The product rather than the production should be put in focus. Many companies which had found identification and evaluation of environmental aspects difficult supported this conclusion, and also expressed their wish for further guidance on this issue. Improving the identification and evaluation of environmental aspects was proposed as a key to achieving more product focus of environmental work.

The study also gave some information on the cost of implementing and maintaining an environmental management system, which is discussed in this licentiate thesis in relation to the cost of doing an EPD. Finally, the study made an attempt to measure the effectiveness of environmental work.

4.2 Paper 2: Environmental aspects when manufacturing products mainly out of metals and/or polymers

Author: Mats Zackrisson. Published in Journal of Cleaner Production. Volume 13, Issue 1, January 2005, Pages 43-49. Mats Zackrisson carried out the research in collaboration with Gunnar Bengtsson and Camilla Norberg at IVF. Mats Zackrisson wrote the paper with the aid of comments and suggestions from Richard Berglund at IVF.

Purpose

The purpose of the paper was to offer further evidence that a product use phase focus in EMS is justified, at least environmentally, and to demonstrate a method for identifying and evaluating environmental aspects that is able to capture and highlight aspects associated with the product use phase.
4.2.1 Method

The paper compares data from environmental reviews in 11 companies. The data was collected in a uniform way by use of a manual with a report template. Each data set represents input and outputs in a company during one year. Three weighting methods were used to weight and compare the data. For more details, see section 3.3.

4.2.2 Summary results

It was shown that the most significant environmental aspect for all eleven companies was found either in the use phase of the manufactured product (5 companies) or in the material production phase (6 companies). Environmental aspects associated with in-house energy, personnel travels and goods transports were found to be in the same order of magnitude. Environmental impacts from site emissions, i.e. the only direct environmental aspects were found to be the least significant in all companies. Typically, if the use phase aspects were 1000 units, material aspects were around 100, energy, travel or transport aspects around 10 respectively and site emission aspects 1.

4.2.3 Contribution to thesis

The article offers further evidence that it is environmentally justified to seek improvements in the use, disposal and materials selection phases of products, i.e., to seek improvements outside the manufacturing phase. Furthermore it indicates that non-process specific impacts (by convention often neglected in LCA) can be much larger than process specific inputs in the manufacturing sub sector.

4.3 Paper 3: Stepwise environmental product declarations – ten SME case studies

Authors: Mats Zackrisson, Cristina Rocha, Kim Christiansen and Anna Jarnehammer. Published in Journal of Cleaner Production Volume 16, Number 17, 2008, pages 1872-1886. The research behind the paper was mainly carried out within the framework of the EU-project Stepwise EPD. Mats Zackrisson coordinated this project, which consisted of 18 partners. Mats Zackrisson managed three of the case studies. Mats Zackrisson drafted all the text for the paper, receiving comments and suggestions from the co-authors.

4.3.1 Purpose

The main objective of the Stepwise EPD project was to develop and test a method for stepwise environmental product declarations suitable for SMEs. To be suitable for SMEs, it was postulated that it should be possible to use the method in marketing and as a basis for ecodesign already at early steps and at low costs. The
basic assumption in the project was that EPDs are good both for business and for the environment. The objective of the paper was to explore that assumption.

4.3.2 Method

The method for Stepwise EPD was tested by ten SMEs in Denmark, Latvia, Portugal and Sweden. Research institutes in respective country gave assistance to the SMEs with the life cycle assessment and elaboration of the declaration. Workshops and meetings were carried out aiming at using the Stepwise EPDs in marketing and as a basis for ecodesign. For more details, see section 3.4.

4.3.3 Summary results

Following on from the main assumption of the Stepwise EPD project that EPDs are good both for business and for the environment, three underlying assumptions were put to test in the case studies.

The assumption that producing the Stepwise EPD, or rather performing the underlying life cycle assessment, can be used as a basis to identify ecodesign options, was verified in eight out of the ten case studies. A great deal of improvement options were generated and some, one and a half option per product were also implemented within the 27-month time frame of the project.

The assumption that the Stepwise EPD can be used to communicate a product’s environmental profile to potential customers thereby creating a demand for such improved eco-efficiency products could not be verified. All case study companies were disappointed by the lack of appreciation for Stepwise EPDs in normal marketing activities. More in-depth discussions with selected clients focusing on the LCA rather than the EPD had more success, but only a few of the cases study companies had tried this.

Finally, the third assumption that the customer demand and the identified improvement options would bring about actual improvement in products’ eco-efficiency could not be verified since no customer demand was created. Yet, 15 environmental improvement ideas or options were implemented. It seems therefore that an explicit customer demand is not always necessary for implementing environmental improvements.

4.3.4 Contribution to thesis

The paper demonstrates that EPDs can be a cost-effective product-oriented action in a company’s environmental work. Furthermore, it explores barriers and incentives to EPD-based product-orientation of environmental work in companies.
5 General findings and discussion

In this section, the findings of the three papers related to the focus of the thesis – cost-effectiveness of product-orientation and barriers and incentives to product-orientation – will further be described and discussed. The aim is to explore how to achieve product-orientation of environmental work. The results will be examined in light of the research methods used and the internal validity of the results will be discussed.

5.1 Cost-effectiveness of environmental work

Cost-effectiveness of environmental work is discussed here as a function of economic cost, environmental improvements and economic gains from environmental work. The discussion is focused on EMS and EPDs since these are the principal subjects of paper 1, 2 and 3. It is concluded that a Stepwise EPD could be a suitable first step to environmental work in companies, since the investment cost is much lower than for an EMS. In general there is a lack of data concerning the cost-effectiveness of environmental work in companies.

5.1.1 Economic cost

The research that resulted in paper 1 generated some data on the costs of introducing an EMS and maintaining it. Some of the cost categories are related to the size of the company. Average EMS related costs for a Swedish company with 50 employees are shown in Table 1. The data was derived from the 19 companies. Variations between individual companies were large. This was mainly due to the fact that some made use of large amounts of consultancy, others none. In the right column is given data from an Austrian questionnaire survey including 71 Austrian large and small sites applying ISO 14001 (Schylander 2004).
Table 1  Average costs for an environmental management system in a company

<table>
<thead>
<tr>
<th>Type of expense</th>
<th>Average EMS costs for a Swedish company with 50 employees</th>
<th>Average EMS costs for Austrian companies³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Collected data</td>
<td>Converted to Euro²</td>
</tr>
<tr>
<td>Internal implementation work</td>
<td>1 350 hours</td>
<td>45000</td>
</tr>
<tr>
<td>Consultancy expenses during</td>
<td>SEK 115 000</td>
<td>12778</td>
</tr>
<tr>
<td>implementation phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Certification expenses</td>
<td>SEK 70 000</td>
<td>7778</td>
</tr>
<tr>
<td>Internal work for system</td>
<td>700¹ hours</td>
<td>23333</td>
</tr>
<tr>
<td>operations, per year</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow-up audits, per year</td>
<td>SEK 38 000</td>
<td>4222</td>
</tr>
</tbody>
</table>

¹ Most companies also have minor annual expenses for training and consultancy in connection with running the system. Larger investments in connection with environmental improvement work are not included.
² All figures are here converted to EURO using 300 SEK/hour and 9 SEK/Euro.
³ Questionnaire survey including 71 Austrian large and small sites with ISO 14001 (Schylander 2004).
⁴ The Austrian study gave only a summed up figure for running the system.

For the cost in Table 1, a company gets an EMS that covers all relevant site operations and hopefully also some product/service environmental aspects. As can be seen in the last rows there is a considerable annual cost associated with just keeping the system up and running. It should be noted that larger costs or investments for environmental improvement work are not included.

The cost data for introducing EMS in a Swedish company as shown in Table 1 was collected from 19 randomly selected Swedish companies in face-to-face interviews. The interview report was sent back to each company with a request to check and correct the answers. Thus, it is quite certain that the costs figures given actually relates to implementing and running the EMS and nothing else. The random sample of 19 makes it very likely that the figures are representative for the examined group consisting of all Swedish companies holding an ISO 14001 certificate in 1998. The close correlation of cost estimates with the Austrian study which was carried out several years later, in 2003, indicates that the cost figures are also representative for the average European company.

The cost of making a Stepwise EPD and generate improvement options in an idea-generation workshop, is less than 100 working hours for the company and around SEK 60 000 in consultancy expenses, see paper 3. At that price, the company gets a good platform for improving their product(s). To actually accomplish any improvements, the company has to utilize the platform, i.e. implement some of the ideas, which also has a cost. The ten case study companies in paper 3 implemented, on average, one and a half improvement idea in the short term, but the cost of the implementation was not measured. However, since the ideas were implemented in new designs and mostly consisted of material savings, the implementation cost was probably balanced by material cost savings.

The cost figures for making a Stepwise EPD were confirmed after the project was completed during consultancy with individual companies. The Stepwise EPD cost figure is an average and would be lower for a very simple product and slightly higher for a very complicated project. In the Stepwise EPD project a significantly lower cost level in Portugal was noted due to lower professional salary levels.
the other hand, in Latvia, lack of national LCA expertise made the cost for a Stepwise EPD as high as in Sweden and Denmark.

5.1.2 Environmental improvements

In paper 3, improvement ideas with more than 5% potential reduction of the product life cycle environmental load were defined as significant. It was shown that doing a Stepwise EPD would on average produce 2.3 significant improvement ideas and lead to the implementation of 1.5 of the improvement ideas within one year. With the assumption that the 1.5 ideas that were implemented represented 5% reduction, the Stepwise EPD effort resulted in 7.5% reduction of environmental loads on targeted product lines.

A comparable “improvement figure” for an EMS effort can be based on plant energy savings, which is a common goal in many EMS. Paper 2 suggests that energy use during manufacturing is in the order of 5% of product life cycle impacts. Experience shows that 10% reduction of manufacturing energy in one year is hard but possible to achieve. Ten percent reduction of 5% of product life cycle impacts equals 0.5% of product life cycle impacts. This should be compared to the figure 7.5% of product life cycle impacts in one product line calculated above for Stepwise EPD. In order to compare these figures, assumptions on the number of product lines and/or to the extent to which the 7.5% improvement potential is valid for other product lines have to be made. Since there is nothing to base such assumptions on, it can be concluded that the EPD effort seems to have larger environmental improvement potential than the EMS effort. This is to be expected since the plant gates do not restrain the EPD effort.

Validity of measures of environmental improvements

Is it certain that the 2.3 ideas implemented per Stepwise EPD originated from the Stepwise EPD effort and would they not have been implemented anyway? It was recognized that several ideas were not new, but the idea generation workshops gave them a possibility to be brought up and discussed again. So most ideas did not originate from Stepwise EPD effort, but they gained new momentum by being discussed again and the LCA helped confirm their environmental merits. There is no way to be certain whether the ideas would have been implemented anyway. However, it was observed that the LCA effort actually triggered the implementation.

A cause-and-effect chain can describe the relationship between actions and their potential to effect the environment, see Figure 4. This chain starts with the action or activity (e.g. transport), which causes an interaction with the environment (e.g. CO₂ emission), which in turn gives an impact (e.g. reflecting the sun rays back onto the earth), which in turn can give environmental effects like temperature increase followed by changes in weather patterns, desertification etc. The interaction with the environment is also called environmental aspect (ISO 14001, 2004).
In paper 2 and 3, life cycle impact assessment, LCIA, are used to quantify the environmental improvement potential from the improvement actions: in paper 2 by weighting to a single impact score; in paper 3 by calculating five impact categories. The concern in both cases is the right side of the cause-and-effect chain, as represented in Figure 4. As discussed earlier, LCIA is far from perfect but there is no other quantitative measure for potential environmental impact. Even though weighting, i.e., comparing impacts across impact categories as done in paper 2 is less scientifically correct than comparing category indicator by category indicator as in paper 3, it was favoured because it is easier to carry out for a layman. It can therefore be said that from emission or aspect to environmental impact, see Figure 4, the best quantitative methods available are used with all their inherent limitations. It is still to be seen how well the connection between action (or activity) and emission (or aspect) is modelled, i.e., the left side of the cause-and-effect chain in Figure 4.

The left side of the cause-and-effect chain in Figure 4 concerns the LCA modelling, i.e. the data used to represent the products in the LCA modelling (paper 3) or the data used to represent the whole company in paper 2. This data is of two kinds: site-specific data collected from companies and generic “cradle-to-gate” data relating to processes/activities drawn from various databases.

For paper 2, the site-specific data was collected by the companies using a template (Zackrisson et al 2004). The author then checked the data. For the EPDs, data collection was more a collaborative effort between the companies and the author, due to the iterative character of LCA. Much of the data was collected from invoices, which means it was checked both by the supplier and the receiver. Yet, the need to correlate company input/output data to a certain period of time introduced a source of error even in the case of data from invoices. Other data was collected by surveys and sampling, which introduced errors of varying magnitudes. Data regarding design specifications is an additional important source of information, especially for EPDs. Design specifications are not supposed to contain any errors, but material losses during production have to be added to obtain valid product material figures.

The principal strategy to make the collected data as fair a representation of reality as possible is to use multiple sources for the same data and use mass balancing to check that the data makes sense. Typically, multiplying the design specification
with the annual production of units would give a much lower product material figure than the annual material inflow. The difference would be the production losses. Looking at the waste outflow can often confirm this.

While the company eco-balance, as calculated in paper 2 and described in section 2.2.3, models the environmental impact for the whole company during a specified time, the EPDs model the environmental impact for only one product or function of a product. Since companies often produce more than one single product, EPDs involve allocating, to the studied product the, right amount of activities and resources that are shared between several products. This adds an extra source of error for EPDs.

One should note that site-specific emissions are rarely, if ever, measured. Instead these are calculated by multiplying the site-specific data with generic “cradle-to-gate” data. The emissions from a boiler, for example, are typically calculated by multiplying the fuel consumption (collected from invoices) with generic data on quantities of different emissions and wastes per unit of fuel. The difference between the generic data and the real world data is another source of error.

In conclusion, trying to measure environmental improvements attributable to environmental work involves large amounts of data with potential errors. Using multiple data sources is a functional strategy to minimize these errors. For some data there are no reliable sources at all, thus assumptions and estimations have to be made involving potentially very large deviations from reality. Other researchers have also attempted to, but found it difficult to measure environmental improvements attributable to environmental work. Schylander (2004) concluded in a meta-study of six EMS studies that “finding relevant indicators for environmental performance is no trivial task”.

5.1.3 Economic gains

From an individual company perspective, economic gains can be divided into cost-savings in their own production and increasing revenues by increasing sales volume and/or margin.

Paper 1 explores both cost-savings of EMS and increased revenues of EMS, but not in absolute figures. Interview results indicate that 50% of all environmental targets have a payback time of less than one year, of which 25% are due to cost-savings and 25% to increased revenues. Schylander (2004) reports average annual cost savings due to EMS to SEK 490 000 in Austria and average annual revenue increases to SEK 120 000. Both Schylander (2004) and paper 1 identify waste and energy as major areas for cost savings.

Paper 2 does not attempt to measure economic gains. In the Stepwise EPD project, paper 3, the amount of order value attributed to having a Stepwise EPD was measured. Only in one case was an order confirmed as resulting from possessing a Stepwise EPD. However, the value of the order could not be established. On the whole, market and sales expectations were disappointing. Nevertheless, EPDs are expected to result in increased revenues at some point in
the future, but how much is impossible to predict in general. Paper 3 showed that increased revenues are not to be expected in the first year.

Cost-savings associated with doing a stepwise EPD was not investigated as such. However, many improvement ideas concerning material savings were examined and these could equate to cost-savings. For example, Latvian SME Konto did invest in a new boiler resulting in considerable cost-savings. As described above the cost savings (from material savings) were probably balanced by the costs involved in implementing the ideas. In conclusion, there is need for further research into the possible economic gains of environmental work, whether product-orientated or not.

5.1.4 Cost-effectiveness

Cost-effectiveness can be examined by calculating a cost-effectiveness ratio with the monetary costs in the denominator and some relevant measure of the desired effects in the numerator. Table 2 below summarizes the data discussed earlier in the section Cost-effectiveness of environmental work. As can be seen in Table 2 there are some data gaps. The Stepwise EPD effort is advantageous due to the low investment cost it offers compared to the EMS.

Table 2 Cost-effectiveness data for EMS and Stepwise EPD

<table>
<thead>
<tr>
<th>Type</th>
<th>Stepwise EPD</th>
<th>EMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment (SEK)</td>
<td>90 000⁴</td>
<td>600 000</td>
</tr>
<tr>
<td>Annual cost-saving (SEK)</td>
<td>0⁵</td>
<td>490 000</td>
</tr>
<tr>
<td>Annual costs (SEK)</td>
<td>0</td>
<td>220 000 - 250 000</td>
</tr>
<tr>
<td>Annual revenue increase (SEK)</td>
<td>No data</td>
<td>120 000</td>
</tr>
<tr>
<td>Environmental improvement (%)</td>
<td>0.75⁶ %</td>
<td>0.5⁷ %</td>
</tr>
<tr>
<td>Investment cost effectiveness ratio (% improvement/MSEK)</td>
<td>8.3⁸</td>
<td>0.8⁹</td>
</tr>
</tbody>
</table>

⁴ 60 000 SEK + 100 hours at 300 SEK/hour
⁵ The cost of implementing the improvement ideas is balanced by the cost savings (from material savings) and thus assumed to be zero
⁶ 1.5 idea * 5% of life cycle environmental product load for one product line. For the sake of comparability with the EMS figure for the whole plant, let us assume that the company has 10 product lines so for the whole company the 7.5% in one product line means 0.75% for the whole plant.
⁷ 10% reduction of plant energy use which is 5% of product life cycle impact gives the figure 0.5% reduction for all product lines.
⁸ 0.75/0.09
⁹ 0.5/0.6
Is comparing the costs of an EMS with the costs for a Stepwise EPD meaningful? Implementing an EMS is often the first major environmental effort in a company. But for many companies this represents a too big step. Making an EPD could be an alternative first step at a much lower investment cost, SEK 90 000 compared to SEK 600 000 for an EMS. The figures above indicate that the investment cost-effectiveness ratio is 10 times better for the investment in a Stepwise EPD. This is not surprising since the company is putting less money in an area where there is a larger environmental impact and thus larger improvement potential. On the other hand, the figures suggest that the pay-back time for an EMS is less than two years. Due to the limited data and the data gaps, the figures in Table 2 should be interpreted with caution.

5.2 Incentives to product-orientation

This licentiate thesis rests on the assumption that companies can achieve better results, environmentally and economically, from their environmental work by making it more product-orientated. The main reasons for this are that the work focus on dominating impacts and that the possibilities to improve the company’s products and increase revenues engage the management and personnel in the work.

5.2.1 Environmental improvement

The environmental argument for product-orientation of environmental work is that most environmental improvement can be achieved by concentrating on the life cycle phases with dominating impacts. Paper 2 and numerous other researches, e.g. the EIPRO study (2006), have shown that a company’s own production rarely includes dominating environmental impacts, unless the company manufactures commodities such as steel, paper etc. Therefore, greater improvements will be achieved if environmental work becomes more product-orientated.

5.2.2 Expectations of increased revenues

In a Nordic study on what makes companies carry out ecodesign, Jönbrink and Melin (2008) conclude that the main incentive for ecodesign is the same as for developing new products in general, i.e. increased sales, better profit margin and maintained or increased market share. The economic argument for product-orientation of environmental work to increase product value, customer satisfaction, sales and/or profit margins is therefore very important. However, sales and market expectations have so far rarely been met. In the Nordic study that comprised environmental front-runners, most companies said that they could do more for the environment but saw little incentive to do so. Frankl et al (2000) concludes that the market departments initiate most LCA but that their expectations of being able to show their product’s superior environmental performance and somehow cash in on the LCA are very rarely fulfilled. Furthermore, more than ten Stepwise EPDs on different products did not yield any new orders within one year as described in paper 3. It is probably fair to conclude
that in 2009, lack of market demand is more of a barrier to product-orientation than expectations of increased revenues is an incentive to it. Some of the case study companies attributed strengthening of company image and improved cooperation with selected clients to the Stepwise EPD. This is an indication that there exists already today, in 2009, openings in most organizations for a dialogue on environmental improvement of purchased products. The trick is to find the right opening so that development efforts can be balanced with realistic expectations of increased revenues.

5.2.3 Staff involvement

Schmidt et al (2001) concludes that it is easier to motivate the personnel to undertake product oriented environmental work, because it is the product that the company lives off. The market departments’ interest for LCA as described by Frankl et al (2000) is an excellent example of this.

The readiness to implement improvements shown by some of the case study companies in the Stepwise EPD project (paper 3) indicates the presence of company internal driving forces to implement product improvements. This is supported by van Hemel and Cramer (2002) who found: “contrary to prevailing literature in environmental management in SMEs, it is concluded that internal stimuli are a stronger driving force for ecodesign than external stimuli”.

It would be expected that most of the internal stimuli is at least indirectly connected to the expectations of increased revenues. This is partly supported by Hemel and Cramer (2002) who found the most influential internal stimuli for ecodesign to be opportunities for innovation, expected increase of product quality and potential market opportunities.

5.2.4 Legal requirements

To the extent that applicable legal requirements exist, these are strong drivers for product-orientation of environmental work. The RoSH (2002) and WEEE (2002) directives for electronic products, emission requirements for vehicles and upcoming requirements related the directive on energy using products (EuP 2005) could be mentioned here. However, complying with the law is a minimum requirement to launch a product on the market, but does not give the product any added value. As pointed out in section 1.2, the scope of this thesis is design of products with environmental performance that go beyond current legal requirements. As LCA is used increasingly to prepare for new requirements, for example as used in the EuP-directive (2005), carrying out an LCA could help a company to prepare for future legal requirements.

5.3 Barriers to product-orientation

Apart from weak demand for products with improved environmental performance, the main barriers to product-orientation can be traced back to tradition and habit
and to the fact that environmental issues are very complex and there is a general lack of both knowledge and methods to deal with this complexity.

5.3.1 Weak market demand for green products

The economic argument for product-orientation of environmental work - to increase product value and customer satisfaction and thereby increase sales and/or profit margins – is only valid if there is a market demand for green products. As discussed in the previous section, today’s lack of market demand is probably more of a barrier to product-orientation than expectations of increased revenues is an incentive to it.

5.3.2 Tradition and habit

Environmental management begun in industry sectors with large environmental impact from their own operations, such as in paper and steel mills. It made sense for these types of industries to put all their efforts on what was going on inside the factory gates. Often neighbours to these industries and even factory workers suffered from the pollution generated and put pressure to install filters and effluent treatment systems. ISO 14001 were formulated based on the experience of environmental management from those early users of EMS around 1990. It was mainly environmental managers from industries with experience of environmental work, i.e. those mentioned above, who took part in the standard drafting process and they had little experience of working with product aspects. This is one reason why ISO 14001 lacks a product focus. In addition, environmental aspects connected to “Permits to operate”, local wastewater regulations etc have a very strong position in any EMS. By nature such “regulatory aspects” are site and production orientated, and often the very reason for having an EMS.

5.3.3 Lack of easy-to-use and flexible assessment tools

To carry out an LCA is not easy. Berkel (1999) found a lack of information and LCA-tools to support product environmental management systems. Popular software like SimaPro and Gabi are very powerful and have a lot of generic cradle-to-gate data included. However, they require specialist users who can work with the software and data regularly, and this kind of personnel is normally not available in most companies.

Other ways of carrying out LCA are with easy-to-use software tools such as Eco-it based on SimaPro (SimaPro 2008) or do-it-yourself handbooks like Measuring your Company’s Environmental Impact by Zackrisson et al (2004) or Ökobilanzen für Unternehmungen by Braunschweig et al (1993). Such products allow and promote a life cycle perspective on the assessment. However, there is always a trade-off between do-it-yourself functionality and flexibility. Furthermore, to buy an LCA do-it-yourself tool, like for example ECO-it from SimaPro, and using it without any previous LCA experience is probably not a very good idea economically nor environmentally. However, such software adapted to the needs of the company by an LCA expert together with company
personnel may be a possibility for smaller companies to do some in-house LCA modelling on their own in a cost-effective way.

Using an external expert to do a screening LCA or an equivalent assessment of environmental aspects is probably very cost-efficient for most companies. The Stepwise EPD approach, as described in paper 3, includes the use of an external LCA specialist. To work together with an LCA expert has proven to be a good way for the small companies to cope with the complexity of environmental issues. The end result need not be a Stepwise EPD. The most important phase is the joint interpretation of the LCA results. This interaction between the LCA expert and the company expert(s) will create new knowledge and ideas.

The increased use of streamlined LCA by LCA practitioners has resulted in LCA being much more affordable today. You do not allow yourself to get buried in data collection any longer. In turn this means that there is more time and energy left to interpret the results in cooperation with product experts and even the possibility of generating improvement options together with a cross-functional team of experts in design, production, sales and marketing. It must be noted that streamlined LCA requires just as much expert knowledge as normal LCA, since it involves using generic data instead of specific data and in order to do that well good knowledge of available generic data is needed. In the context of affordability it should be mentioned that LCA databases and LCA software have improved a great deal the last ten years. Today a license to use the Ecoinvent databases with 4000 process data sets (Ecoinvent 2008) costs as much as did buying two commercial data sets in 1995.

To an extent, top-down approaches like the directive on energy using products (2005) or the EPIC-ICT (2006) can replace the need for every individual company to make a LCA. Instead they can use the results of the LCA done in such approaches, see for example Zackrisson and Jönbrink (2007), which would typically pin point the life cycle phases to focus on and even improvement areas and detailed ecodesign measures. The existence of such LCAs will however be limited to product groups with large markets. Furthermore, the advantages of LCA as a vehicle for supply chain cooperation and learning about a company’s own product through collecting product specific data cannot be exploited by just studying the results of an LCA carried out by someone else. Several researches emphasize the learning effects of LCA, for example Ritzén (1996), Finnveden (2000) and Bauman (2004). Just requesting data from suppliers sends signals that their environmental performance is being monitored and may lead to improvements as such (Heiskanen 1999). For example, Vattenfall with a long history of making EPDs, regularly collect environmental information from their suppliers for updating the EPDs. They have noticed that the suppliers’ environmental data tend to improve from year to year even without Vattenfall explicitly asking for any environmental improvements (Vattenfall 2006).

5.3.4 EPD cost scare

When EPDs are viewed as market instruments only, doing and maintaining EPDs for all the products of a company is often seen as a barrier because of the time and
cost involved. However, there are several ways to overcome this barrier. One way is doing EPDs only on strategically chosen products and concentrating more on the general lessons learned from the LCA than on the numbers in the EPD. This solution applies equally well to LCA on its own. Instead of doing LCA on all products and maybe several times during product development as suggested by for example Gurkbahash et al (2003) it may be wiser to limit LCA to strategically chosen products and put more focus on generalizing the results into concrete ecodesign measures as suggested by for example Milleta et al (2007). Then the use of LCA specialists and powerful LCA software is less of a problem.

The new rules of the EPD®system (2008) allow a company to verify its own EPDs, in order to increase the cost-effectiveness. The cost for the external verification of individual EPDs is thereby eliminated, but replaced by the cost of internal verification of EPDs and the external verification of the internal verification procedures. For those companies that aim to cover all products at all times with EPDs, this is an opportunity to increase cost-effectiveness. The external verification of the internal EPD verification procedure could probably be done as an add-on to the verification of the EMS most probably already in place in such ambitious companies. A complementary strategy for companies aiming to cover all products with EPDs is to group the products. Vattenfall covers 99.9% of all their electricity production by grouping them into five EPDs (Vattenfall 2006).

5.3.5 The lack of product focus in ISO 14001

The lack of a product focus in ISO 14001 has been pointed out by several researches, for example Ammenberg (2005), as a barrier to product-orientation of environmental work. However, the standard text does not forbid product-orientation of environmental work. On the contrary, there are several paragraphs that could be interpreted as promoting product-orientation of environmental work. Clause 4.3.1, for example, requires “…procedure(s) to identify the environmental aspects of its activities, products and services within the defined scope of the environmental managements system that it can control and those that it can influence…..”. Another example of ISO 14001 promoting product-orientation of environmental work is the requirement in clause 4.4.6 which states that “…procedures related to the identified significant environmental aspects of goods and services used by the organization and communicating applicable procedures and requirements to suppliers”. Clause 4.4.6 could be interpreted as a requirement to demand product-orientation of suppliers’ environmental work.

It is rather the Annex of ISO 14001 that discourages to an extent product-orientation of environmental work with advice such as: “…considerations when identifying environmental aspects could include emissions and use of energy and raw materials” and “The identification of environmental aspects does not require a detailed life-cycle assessment”.

In conclusion, ISO 14001 does not stop product-orientation of environmental work. Interpreted with a product focus in mind and avoiding its non-binding Annex that could be misleading, ISO 14001 serves as a foundation for product-orientation of environmental work.
It appears that future revisions of the ISO 14001 standard will require rewriting its Annex. Since all environmental impact somehow stem from the use of energy and resources, it should not be conveyed as optional to include them when identifying environmental aspects. Instead it should be recommended to base the identification and evaluation of aspects on a streamlined LCA or company ecobalance, in other words, an input/output analysis of the physicals flows of materials and energy through the company should be carried out as described in paper 2 and by Finkbeiner (1998), Braunschweig (1993) and Zobel (2002, 2004).

Such an analysis would not only promote a product-orientation of the EMS, but would also constitute a base upon which more detailed LCAs and/or EPDs could be made if desired. In this context Finkbeiner (1998) sees a difference between the company ecobalance, in which as much data as is readily available about company operations is included, and LCA, comprising only the specific processes concerning the product in question. Since the company ecobalance should include general activities such as personnel transports, marketing and design, room heating etc, which are often excluded in LCA data, environmental impact per functional unit, based on an ecobalance, can be much higher than the environmental impact per the same functional unit based on a traditional LCA. Finkbeiner (1998) favours including only the specific processes that concern the subject product because including general activities would mask differences between specific processes. This can be seen as saying one should not include the dominating impacts because they divert our attention from the small ones. As mentioned before no provision exists in ISO 14044 (2006) to exclude accounting for general activities. All significant impacts should be included according to ISO 14044.

5.3.6 Client demand for EMS

For the individual company, client demand is often the decisive factor for implementing an EMS (Zackrisson et al 2000, Ammenberg 2003). It is rarely a strict client requirement that the supplier should have an EMS but often extra points are given in evaluation of contracts, a slightly higher price may be accepted and/or lengthy questionnaires can be avoided. The client is always right, so when the client asks for an EMS, many companies without further analysis launch costly EMS implementation projects, see section 5.1.1 on costs for EMS. However, many demands for ISO 14001 are not that rigid; often the client asks for an EMS according to ISO 14001 or equivalent in the purchasing process of a specific product. This leaves, in many cases, room for the supplier to actually satisfy such a request with, for example, an EPD and an improvement program for the specific product or service in question. Providing the client with the environmental data related to the product that the client is interested in ought to satisfy the clients information needs much better than the general information conveyed by an ISO 14001 certificate. From an ISO 14001 perspective, replying with an EPD when asked for an ISO 14001 certificate is a correct reply to an odd reading of the standard. As pointed out in section 2.2.2, the standard does not require companies to demand that suppliers install EMS, even though this interpretation of the standard is common. Instead the standard requires the purchasing organization to communicate to suppliers applicable procedures and
requirements related to the identified significant environmental aspects of the goods and services that they buy.

### 5.3.7 Limited accountability

The lack of a product focus in ISO 14001 can be partly blamed on the legal system in the USA, where any admittance of accountability can be turned against the company in a lawsuit. This was the main argument used by the representatives of the USA during the development of the ISO 14001 standard to avoid a product focus. It also explains why the European EMAS (2001) is more product-orientated than ISO 14001 (2004).

The life cycle approach implies a form of social planner’s view on environmental issues, rather than minimizations of a company’s direct environmental liabilities, according to Heiskinen (2002). Thus, a company that is not prepared to assume any responsibility for the manner in which their suppliers perform, should not commission an LCA. Yet many companies do so for different reasons and this action may change their attitude towards supply chain responsibilities, and “contribute to a transformation of the way we view (and do) economic activities” (Heiskinen, 2002).

### 5.3.8 Ownership of product

Subcontractors performing work on products owned by their clients, for example paint shops and metal surface treatment shops, fall into a special category. For these companies, opportunities for product-orientation are restricted by the wishes of their client(s). However, as was demonstrated in paper 3, entering into an environmental dialogue based on LCA can strengthen the client-supplier relationship.
6 Conclusions

This section gives the main conclusions and recommendations to companies on how to orientate their environmental work on their products. Life cycle assessment and environmental product declaration are suggested as important tools in designing products with improved environmental performance as well as in the creation of markets for such products. Finally, the generalizability of the conclusions is discussed and suggestions made for future research furthering product-orientation of environmental work.

6.1 Main conclusions and recommendations

In the 1990s, when paper 1 and 2 were written it was not evident that a product-orientation was the correct thing to do from an environmental perspective. Today there is overwhelming evidence that most companies’ own production rarely include dominating environmental impacts. Instead, it is often when products are used that the dominating impacts occur, or sometimes (but less often) the production of raw materials has most environmental impact. From an environmental point of view, product-orientation of environmental work needs no more justification.

The main incentive for developing environmentally improved products is the same as for developing new products in general, i.e. expectations of increased sales, better profit margin and maintained or increased market share. This means that it is easy to motivate the personnel to engage in product-orientation of the environmental work, because it is the product that provides them with their salary. It also means that there must be an interested buyer for the environmentally improved product, otherwise, market expectations will not be met and human and natural resources will be wasted. Experience shows that a market demand for environmentally superior products cannot be taken for granted. Therefore companies are recommended to enter into a dialogue with prospective customers to actively create a market for the improved products. Such a dialogue could be centred around an environmental product declaration based on a life cycle assessment.

The results of a life cycle assessment visualize where in the life cycle the dominating environmental impacts occur. It thus helps to break the habitual focus on the own production. It is also an excellent platform for internal and external consideration on how to improve the product environmentally. Improvement efforts can then be focused on individual processes and life cycle stages with major environmental impacts. Engaging the customers in this process can help in creating the needed market for the environmentally improved product.

Using a consultant to do a streamlined life cycle assessment on a strategically chosen product has been shown affordable and cost-efficient even for small
companies. The end result need not be an environmental product declaration. The most important phase is the joint interpretation of the LCA results, in which the interaction between the LCA expert and the company expert(s) will create new knowledge and ideas. Engaging a cross-functional team of experts in design, production, marketing and sales in a brainstorming exercise can generate further ideas, see 5.3.3.

The increased use of streamlined life cycle assessment by LCA experts and the existence of low cost databases have made life cycle assessments much more affordable today than they were ten years ago. Life cycle assessment software has also improved and often allows programming of more user-friendly interfaces. For companies aspiring to do LCA modelling on their own, such software interfaces adapted to the needs of the company by a life cycle assessment expert together with company personnel, may be a cost-effective possibility, see 5.3.3.

Doing and maintaining life cycle assessments and/or environmental product declarations for all the products of a company, is often seen as a barrier because of the time and cost involved. But since there is little market demand for life cycle assessments and/or environmental product declarations, most companies can instead choose some representative product and concentrate on generalizing the results into concrete ecodesign measures. Then the use of life cycle assessment specialists and powerful software is less of a problem. For those (few) companies that aim to cover all products at all times with environmental product declarations, EPDs, the new rules of the EPD® system that allows a company to verify its own EPDs could increase cost-effectiveness. A complementary strategy for companies aiming to cover all products with EPDs is to gather them in groups of similar products and only carry out one EPD for each group, see 5.3.4.

There is nothing in ISO 14001 that stops product-orientation of environmental work but the standard could be more encouraging in this respect. For future revisions of the standard, it is recommended to rewrite the non-binding Annex. Since all environmental impact somehow stem from the use of energy and resources, it must not be conveyed as optional to include them when identifying environmental aspects. Instead it should be recommended to base the identification and evaluation of aspects on a streamlined life cycle assessment or equivalent. Such an analysis would not only promote a product-orientation of the environmental management system, EMS, but also constitute a base upon which more detailed life cycle assessments and/or EPDs could be made, see 5.3.5.

The first environmental action of a company is often to install an environmental management system because a client company demands it. However, many demands for ISO 14001 are not that rigid; often the client asks for an EMS according to ISO 14001 or equivalent in the purchasing process of a specific product. This leaves, in many cases, room for the supplier to actually answer such a request with, for example, an EPD and an improvement program for the specific product or service in question, see 5.3.6. Such an action is a more suitable first step for environmental work in companies compared to installing an environmental management system, since the investment cost is much lower, see 5.1.4. Replying with an EPD, when asked for an ISO 14001 certificate, may even...
help to open the right door for a dialogue about how to improve the product environmentally and thus help create the demand for the improved product.

The conclusions above could be summed up in the following recommendations for, say, a small company in Europe without much previous experience of environmental work:

- Focus your environmental work on your products because you will accomplish more environmentally and the chance of profiting economically will motivate your personnel;

- Consider doing a life cycle assessment, LCA, on a strategically chosen product in order to learn more about your products and how to improve their environmental performance;

- Do not expect to find a general market demand for green products; start a dialogue with your best customers in order to create the demand;

- Engage an LCA specialist to do the LCA and work together with your personnel to interpret the results and generate improvement ideas;

- If your customers demand that you install an environmental management system, ask them if they would not prefer to receive an environmental product declaration on the particular product they are interested in, and a chance to discuss how its environmental performance can be improved.

6.2 Generalizability

To what extent the results discussed in section 5 are true for any type of company anywhere in the world will be discussed in this section. The “results” that will be discussed here are the benefits of product-orientation and if doing a Stepwise EPD or similar exercise could be a suitable first step for environmental work in companies.

6.2.1 The benefits of product-orientation

The general assumption is that most companies would profit from more product-orientation of their environmental work, both environmentally and economically.

Companies that have the dominating environmental impacts within their own operations and thus already focus on their product’s environmental hot-spot, are not really exceptions. Whether or not it is environmentally and economically profitable for this category of companies to do more product-orientation is outside the scope of this licentiate thesis.

Subcontractors performing work on products owned by their clients, for example paint shops and metal surface treatment shops, may have limited possibilities to reap the benefits of product-orientation because they are restricted by what their client(s) want. However, the improvement opportunities as such are not affected
by the ownership of product, only the potential to implement them. Since the service this type of companies performs, for example surface treatment, often dominates their environmental impact, a service-orientation would be equivalent to a product-orientation.

A company with no previous environmental experience may need to focus on environmental issues in their own production. This is often necessary in order to comply with legal requirements. But even companies with no environmental experience can profit from a product orientated environmental work. This was demonstrated in the Stepwise EPD project where there was no relationship between maturity of environmental work and ability to profit from product-orientation of it.

Service companies normally have very few environmental regulations to comply with. This means that product-orientation can immediately become the main effort. In countries without proper environmental regulations and/or enforcement, companies would probably first have to improve their production site environmental performance before focusing on product aspects.

In conclusion, most companies in countries with a good environmental legal framework are likely to be able to profit from more product-orientation of environmental work. This is true even for service companies that have not yet carried out environmental work. An exception to this generalization is probably manufacturing companies with no previous environmental work.

6.2.2 To start environmental work with a Stepwise EPD

Is a Stepwise EPD, or an equivalent exercise\(^{10}\), a suitable first step for environmental work in all or most companies? As noted in section 6.2.1, manufacturing companies with no previous environmental work, would hardly benefit from product-orientation directly and thus not from a Stepwise EPD. However, in countries that have and enforce environmental legislation that compels companies to have a minimum of environmental work, a Stepwise EPD could be a suitable first proactive environmental step.

The Stepwise EPD concept was developed for small companies. However, experience has shown that larger companies are just as interested in the cost-efficiency of the Stepwise EPD concept.

Possible synergisms between type 1 labelling programs and type 3 EPD programs were described in section 2.2.4. There is also a degree of competition between type 1 labelling and type 3 declarations. So for product groups with type 1 labelling possibilities there should be less need and resources for EPDs from a communication perspective. However, from an analytical point of view (as a basis for ecodesign), there is no competition between type 1 and type 3. Type 1 does not give any input for innovative ecodesign (Jönbrink and Melin 2008). It is

\(^{10}\) The ARPI framework described in section 2.2.5 is a good example of what is meant by “an equivalent exercise”.

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difficult to imagine sectors that could not benefit from making an EPD or Stepwise EPD. As mentioned above, companies that do not own their product can still make an EPD of the service they perform, for example surface treatment.

Geographical limitations may exist due to lack of LCA infrastructure in the form of experts and relevant databases in some parts of the world. Using foreign consultants is an expensive solution. Furthermore, as highlighted in the Stepwise EPD project, a national EPD-program or at least institutions that can be supportive to companies wishing to enter international EPD programs is part of the needed infrastructure.

In conclusion, a Stepwise EPD, or an equivalent exercise, seems to be a suitable first step for all sizes of companies, in all sectors of the economy, and in all countries that have and enforce environmental legislation that compels companies to have a minimum of environmental work, given that the necessary LCA infrastructure is available in the country.

6.3 Future research

The weak market demand for environmentally superior products is the toughest barrier to overcome. All research and development in this area is very much needed. Further research into supply chain cooperation in connection with life cycle assessment and eco-design seems very interesting in this context.

In order to cut costs of carrying out LCAs, which are still too high for many companies, the link between LCA data and company eco-balance data should be further investigated and highlighted.

The question of what makes companies ecoinnovate without any demand from clients and customers is of importance. A company’s internal driving forces for eco-innovation should be further explored.

As mentioned in section 5.1, a lot of research is needed to develop ways to measure environmental improvements attributable to environmental work. Ideally, these measures should be linked to economic costs and gains, so the cost-effectiveness of environmental work could be measured and improved.
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Appended papers
Paper 1

*Environmental Management Systems – Paper tiger or powerful tool*

Maria Enroth and Mats Zackrisson

Environmental Management Systems – Paper Tiger or Powerful Tool

Abstract

In this study, we have evaluated what the environmental and economical efficiency of environmental management systems has been like up until now according to ISO 14001 and EMAS. The long-term objective of the study is to develop environmental management systems (EMS) and make them more efficient. Almost 200 Swedish companies have contributed with their experiences. The study was carried out in 1999.

The study comprised a questionnaire sent to all ISO-certified and EMAS-registered companies in Sweden as well as interviews with 19 randomly selected companies from the group.

Some of the most important observations concerning the environmental efficiency of EMS were:

- The environmental performance of EMAS-registered companies seemed to be better than that of companies with only ISO 14001.
- Companies using environmental indicators to follow up environmental objectives and targets seemed to attain better environmental performance than others.
- Half the environmental objectives and targets would also have been achieved without EMS.

Some of the most interesting observations concerning the economical efficiency of EMS were:

- Half of all the environmental objectives and targets gave payback within one year.
- The largest cost savings were made through reduced expenses for energy, waste treatment and raw materials.
• Most of the companies thought that their position on the market had been strengthened thanks to EMS. 1/3 of the companies also showed increasing revenue.

The following should be given priority in the initial stage to make EMS more efficient:
• Clarify the identification process and assessment of environmental aspects.
• Streamline and co-ordinate different management systems.
• Improve the follow-up of the environmental work.
• Link EMS to product design and put more focus on the use and disposal phase of manufactured products.

Introduction

Our study was based on the assumption that it is possible to create the right conditions for developing and streamlining environmental management work by applying experience gained so far from practical environmental management work. Compiling and disseminating experience provides companies with the right conditions for optimising their efforts, whether they have already made relatively good progress with their environmental work or whether they have yet to begin.

If the environmental efficiency of environmental management systems is to make headway, it is essential to identify and give priority to the correct significant environmental aspects. This will enable the companies to focus their resources on the areas, which give the maximum environmental benefit in relation to the economical input.

ISO 14001 and EMAS can be seen as two systems with a common basis. Even so, there are certain differences. The greatest difference is that according to EMAS, companies have to produce an official, assessed environmental statement. EMAS also has more explicit demands as regards the preliminary environmental review.

Some previous Swedish studies have shed light on environmentally related, financial and strategic consequences of environmental management systems. These have considered environmental management systems to be worthwhile from an environmental point of view, but it has been difficult to determine whether the systems also give any financial payback. This is due in part to the companies’ unsatisfactory environmental accounting methods (Elfors 1998, Nordström 1998). Nevertheless, in the opinion of supervisory authorities, progress has been made in the quality of companies’ reports since EMAS was introduced (Nordström 1997). Apart from specific studies of environmentally certified companies in Sweden, more extensive studies have also been conducted

**Methods**

Our aim has been to provide answers principally to the following questions:

1. Do companies give priority in their work to environmental aspects that have a major impact on the environment?
2. What actual environmental improvements have the environmental management systems achieved?
3. What are the costs involved with environmental management system work? Has it been possible to make any financial savings?

The study is based on the experience of the 360 Swedish companies that had certified environmental management systems in accordance with ISO 14001 or EMAS in November 1998. The work included a questionnaire sent to all the certified companies, interviews with 19 randomly-selected companies, as well as some background literature. Most of the certified companies have between 20 and 500 employees. This differs from the size distribution of all Swedish companies where companies with less than 20 employees dominate. Predominant enterprises among the environmentally-certified Swedish companies are manufacturing industries, agency and wholesale trading, as well as pulp and paper industries.

Before evaluating the results of the questionnaire and selecting companies for interviews, the 360 companies were divided into two main groups: industry and service/trade. The companies we interviewed were selected at random. A representative distribution was sought between the two main groups and between small-sized (<100 employees) and large (>100 employees) companies within each group.

We interviewed the environmental officers or environmental co-ordinators of the companies and interviews lasted from 2 to 5 hours. The interviews were documented in consultation with each company. In order to analyse the information from these interviews, we translated it into some 40 parameters. It was not easy to translate all of the information into parameters in a satisfactory way so some questions were analysed in a more qualitative way. Table 1 gives examples of the defined parameters.

Various statistical methods have also been used. A regression analysis has been applied to study the correlation between two continuous parameters. An F-value below 0.05 here gives about a 95% confidence level that the model is correct. This is described though as there being a statistically validated correlation.
When a continuous parameter has been compared between two groups, e.g. EMAS-registered and non EMAS-registered companies, a two-sided t-test for different variances has been carried out. A p-value below 0.05 here gives a 95% confidence level about the difference between the average values for the two groups. This is described though as there being a statistically validated difference between the average values.

The statistical methods used assume that data has a normal distribution for the entire group to which the study applies, i.e. all (or the defined groups of) environmentally-certified Swedish companies. This is not certain, but it seems more likely than not that data would have a normal distribution.

The objective with the questionnaire and the interviews was to collect statistically representative material so that valid inferences for all environmentally-certified companies in Sweden could be made. The following are some of the restricting factors in the study:

- As we now compile this report, there is almost three times the number of environmentally-certified companies in Sweden as when our survey began. Strictly speaking therefore, the inferences apply only for the 360 companies or so that were environmentally certified in autumn 1998.
- Strictly speaking, the questionnaire represents the half of the companies that responded. However, here we have made the assumption that these answers are representative for the entire group.
- The greatest limiting factor with the interviews is the relatively small number of companies interviewed.

Table 1 A selection of data parameters that were used to analyse the results of the interviews.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Errors in identification</td>
<td>I-Errors/No</td>
<td>Describes whether serious mistakes have been made in the identification of environmental aspects. In this study, the criterion for ‘serious’ is that the environmental aspect has both a major environmental impact and a considerable effect on the financial outcome, as well as that the company agrees that a mistake has been made.</td>
</tr>
<tr>
<td>2. Errors in environmental assessment</td>
<td>EA-errors/No</td>
<td>Describes whether serious mistakes have been made in the assessment of environmental aspects. In this study, the criterion for ‘serious’ is that the environmental aspect has both a major environmental impact and a considerable effect on the financial outcome, as well as that the company agrees that a mistake has been made.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Unit</td>
<td>Comments</td>
</tr>
<tr>
<td>----------------------------</td>
<td>-------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>3. Target area production</td>
<td>% related to the plant and upstream</td>
<td>Describes the percentage of the stated targets that affect the company’s own production and the subcontractors’ production.</td>
</tr>
<tr>
<td>4. Target area transport</td>
<td>% related to goods transport, business trips, travel to/from work</td>
<td>Describes the percentage of the stated targets that affect different types of transport.</td>
</tr>
<tr>
<td>5. Target area product</td>
<td>% related to the product use or disposal phase</td>
<td>Describes the percentage of the stated targets that affect the environmental impact of the company’s own product or service during the use or disposal phase.</td>
</tr>
<tr>
<td>6. Target attack method</td>
<td>% source reduction</td>
<td>Describes the percentage of the stated targets that try to reduce the source of the problem’s origin, e.g. by reducing consumption, recycling, etc. The opposite is end-of-pipe solutions, e.g. chimneys and waste recycling.</td>
</tr>
<tr>
<td>7. Target payback</td>
<td>% of targets with maximum one year’s payback</td>
<td>Describes the percentage of the revenues and/or savings for the stated targets that exceed or is expected to exceed expenses after just one year. If revenues in relation to expenses are expected to be large, it is assumed that payback time is less than one year.</td>
</tr>
<tr>
<td>8. Target payback cause</td>
<td>% of one year’s payback that is only due to revenue increase</td>
<td>Explains why payback, according to the above, is achieved after just one year. The percentage indicates targets with one year’s payback, according to the above, due to increased revenue alone.</td>
</tr>
<tr>
<td>9. Target follow-up</td>
<td>% relative measures</td>
<td>Tries to give a quality rating for the follow-up of environmental targets by giving a mean average for all stated targets according to the following: 100% = measure related to something relevant, e.g. production size. Relation to years has only been accepted when this is considered relevant. 50% = non-related measure, e.g. the number of chemical products. 0 % = only verification of that measures/activities have been carried out. No value has been calculated for companies having less than 3 targets.</td>
</tr>
<tr>
<td>10. Target results physical</td>
<td>To what extent has emission or resource reduction been achieved: 0%=no physical set targets, 50%= physical set targets,</td>
<td>Gives one quality rating for the results of the environmental target work by explaining to what extent emission or resource reduction has been achieved. Targets such as &quot;introduce a waste sorting system&quot;, that have been reached but where there is no quantitative target, are considered to be 50%. An ambitious target that has been partly reached is considered to be 90%. No value has been calculated for companies having less than 3 targets. Note that</td>
</tr>
<tr>
<td>Parameter</td>
<td>Unit</td>
<td>Comments</td>
</tr>
<tr>
<td>-----------</td>
<td>------</td>
<td>----------</td>
</tr>
<tr>
<td>100%</td>
<td>physical reached targets. Mean average for all targets.</td>
<td>work with indirect environmental effects through for example staff training, is not rewarded by this parameter.</td>
</tr>
</tbody>
</table>

## Results

We received a 49% response to our questionnaire. The number of responses from companies of varying sizes broadly reflects the number of certified companies within each group. As a general observation, of those companies that responded, the majority was certified in 1997-1998 (approx. 80%). 55% of the companies that responded must hold an environmental permit to operate and 13% must notify the authorities about their operations on environmental grounds.

When asked to indicate on a scale of 1 to 6 the extent to which the environmental management system has reduced the environmental impact from the company, most of the answers tended to be somewhat closer to “not at all” than “to a very great extent”, see Diagram 1.

![Diagram 1](https://via.placeholder.com/150)

### Diagram 1
Companies’ assessment of the extent to which the environmental impact from the company has reduced as a result of its environmental management system. On a scale of 1-6, where 1 is “not at all” and 6 is ”to a very great extent”

Approximately 30% of the companies claimed that they were able to demonstrate increased revenues as a result of their environmental management
work. On a scale of 1 to 6, most of the companies reported that their market position had improved. Most of the answers clearly tended towards "to a very great extent" rather than "not at all", see Diagram 2.

![Diagram 2](image)

Diagram 2 The companies’ assessment of an improved market position as a result of their environmental management systems, on a scale of 1 to 6, where 1 is "not at all" and 6 is "to a very great extent".

The identified significant environmental aspects corresponded well in general with the areas within which companies had established environmental targets, see Table 2.

Table 2 Common significant environmental aspects and environmental targets according to the questionnaire. The number of companies that specified each area is given as a percentage.

<table>
<thead>
<tr>
<th>Common significant environmental aspects</th>
<th>Common environmental target areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy consumption (71%)</td>
<td>Waste (78%)</td>
</tr>
<tr>
<td>Waste (69%)</td>
<td>Energy consumption (73%)</td>
</tr>
<tr>
<td>Goods transport (67%)</td>
<td>Emissions from the plant (62%)</td>
</tr>
<tr>
<td>Emissions from the plant (62%)</td>
<td>Goods transport (49%)</td>
</tr>
<tr>
<td>Chemical management (55%)</td>
<td>Chemical management (48%)</td>
</tr>
<tr>
<td>Input goods/raw materials (55%)</td>
<td>Input goods/raw materials (48%)</td>
</tr>
</tbody>
</table>

The interview results for the parameters that are explained in Table 1 are shown in Table 3 below. The table specifies any significant correlation or differences between parameters.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Errors in identification</td>
<td>A small amount, 26%, of companies has failed to identify some environmental aspect that would have been of significance to the company.</td>
</tr>
<tr>
<td>2. Errors in environmental assessment</td>
<td>A small amount, 32%, of companies has failed to assess some significant environmental aspect as being important.</td>
</tr>
<tr>
<td>3. Target area production</td>
<td>Most of the companies’ targets (average 72%, median 80%) focus on problems in their own or their subcontractors’ businesses. The equivalent percentages for just the industrial companies are average 83%, median 80%. There are no significant differences between large and small-sized industrial companies. Service and trade companies have, as expected, considerably fewer production targets, average 41%, median 38%. The difference between the industrial companies and the service and trade companies is significant according to the t-test.</td>
</tr>
<tr>
<td>4. Target area transport</td>
<td>Only a few of the companies’ targets (average 10%, median 0%) focus on transport. There are no significant differences between large and small-sized industrial companies or between industry and service and trade.</td>
</tr>
<tr>
<td>5. Target area product</td>
<td>Few of the companies’ targets (average 18%, median 0%) focus on problems related to the use and disposal phase of their own products. The equivalent percentages for just the industrial companies are average 8%, median 0%. There are no significant differences between large and small-sized industrial companies.</td>
</tr>
<tr>
<td>6. Target attack method</td>
<td>Many of the companies’ targets, average 77%, deal with source reduction. There are no decisive differences between industry and service and trade.</td>
</tr>
<tr>
<td>7. Target payback</td>
<td>Over half (average 59%, median 60%) of all environmental targets give or are expected to give a financial profit after just one year. There are no significant differences between large and small-sized industrial companies or between industry and service and trade. However, the variation between individual companies is large, 0 to 100%.</td>
</tr>
<tr>
<td>8. Target payback cause</td>
<td>Just over half (average 52%, median 66%) of the economically profitable targets according to the above are such, simply because they give, or are expected to give, increased revenues. On the other hand, the other half achieves rapid profits thanks to savings in expenses. There are no significant differences between large and small-sized industrial companies or between industry and service and trade. The variation between individual companies is large, however, 0 to 100%.</td>
</tr>
<tr>
<td>9. Target follow-up</td>
<td>The quality rating for the target follow-up gives a mean average of approx. 60% for all the companies’ targets. There are no significant differences between large and small-sized industrial companies or between industry and service and trade. However, variation between individual companies (and targets) is considerable, 0 to 100%.</td>
</tr>
</tbody>
</table>
100%. According to a regression analysis, there is correlation between the Target follow-up parameter and the Target results physical parameter, see Diagram 3.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. Target results physical</td>
<td>The quality rating for the results of the environmental target work gives a mean average of 66% for all the companies’ targets. The variation between individual companies (and targets) is considerable, 10 to 100%. For just the industrial companies, the average is 70%, median 69%. There are no significant differences between large and small-sized industrial companies. The t-test indicates that on average, EMAS companies have better environmental results (according to the parameter Target results physical) than the non-EMAS companies, average 80% and 57%, see Diagram 4, where the standard deviation is shown as error columns.</td>
</tr>
</tbody>
</table>

Diagram 3 Correlation between how well the environmental targets are followed up with relative measures (Target follow-up parameter) and the environmental results, rated using the Target results physical parameter.
Diagram 4  Correlation between EMAS and the environmental results, rated using the Target results physical parameter.

More resources are required when introducing an environmental management system at a large-sized company than at a small-sized company, see Table 4. However, as regards, for example, internal work in connection with the introduction of an environmental management system, there is no linear correlation to the number of employees at the company. Nor can this be expected since a certain amount of initial groundwork has to be done regardless of the number of employees.

Table 4  Cost of introducing environmental management systems in large-sized (>100 employees) and small-sized (<100 employees) Swedish companies 1996-1999.

<table>
<thead>
<tr>
<th>Company group</th>
<th>Internal work (hours)</th>
<th>Consultancy expenses (SEK 000)</th>
<th>Certification expenses (SEK 000)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>AVERAGE</td>
<td>Max</td>
</tr>
<tr>
<td>Large-sized companies</td>
<td>240</td>
<td>4140</td>
<td>2200</td>
</tr>
<tr>
<td>Small-sized companies</td>
<td>160</td>
<td>1350</td>
<td>4800</td>
</tr>
</tbody>
</table>

The interviews point to a linear correlation between the number of employees at the companies and the annual internal work of running the environmental management systems. An equivalent correlation has also been ascertained for the number of employees and the cost of annual external audits. Table 5 gives a
cost estimation, based on the study results, for implementing and running an environmental management system in a company with 50 employees.

Table 5  Estimation of costs for an environmental management system in a company with 50 employees.

<table>
<thead>
<tr>
<th>Type of expense</th>
<th>Internal work and expense</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal implementation work</td>
<td>1350 hours</td>
</tr>
<tr>
<td>Consultancy expenses during</td>
<td>SEK 115 000</td>
</tr>
<tr>
<td>implementation/introduction phase</td>
<td></td>
</tr>
<tr>
<td>Certification expenses</td>
<td>SEK 70 000</td>
</tr>
<tr>
<td>Internal work for system operations</td>
<td>700 hours/year</td>
</tr>
<tr>
<td>Follow-up audits</td>
<td>SEK 38 000/year</td>
</tr>
<tr>
<td>Most companies also have minor annual</td>
<td></td>
</tr>
<tr>
<td>expenses for training and consultancy in connection with running the system. There are also expenses for the environmental target work.</td>
<td></td>
</tr>
</tbody>
</table>

Discussion

1 WHAT PRIORITIES DO COMPANIES GIVE IN THEIR WORK TO ENVIRONMENTAL ASPECTS THAT HAVE A CONSIDERABLE IMPACT ON THE ENVIRONMENT?

In order to be able to discuss this, we have to start with an assumption about which environmental aspects have a major environmental impact. This is based on the fact that only about 20% of the certified companies are involved in the production of raw materials. The remaining companies manufacture or sell products or provide services. Life cycle analyses and other studies have (for this latter type of company) shown that these rarely have particularly large emissions from their own plant. The greatest environmental impact is often linked to consumption or disposal of the manufactured product or service. A considerable environmental impact is also often associated with the production of raw materials/input goods, which means that the input goods should also constitute a significant environmental aspect for most companies. Energy consumption and different types of transport are also often so important that their environmental impact is highly significant, yet often to a much lower degree. Of course, this is a rough picture which may not apply at all for some companies.

However, for the group of certified companies as a whole we should be able to expect that most of the significant environmental aspects and environmental targets are to do with the product or service, raw materials/input goods as well as energy and transport. Since these environmental aspects also constitute a more than marginal economical degree of importance for the companies, it naturally becomes all the more serious if they are disregarded.
The questionnaire showed that most of the companies were working with waste, energy consumption and emissions from the plant, see Table 2. Around half of the companies were also working with goods transport and input goods/raw materials. According to the questionnaire, few companies, not quite 20%, were working with the use or disposal of the products. The questionnaire thus indicated that most of the companies were failing to work with some of the environmental aspects that are most important of all, from both an environmental and a financial point of view.

The interviews confirmed what emerged from the questionnaire, that companies all too seldom have targets that concern the environmental impact during the use or disposal phase of the products. It also emerged from the interviews that half the companies have made some essential mistake in their identification or their environmental assessment of environmental aspects. Note that the criterion for "mistake" was that the environmental aspect means both major environmental impact and significant economic effects, plus that the company agreed with the interviewer that a mistake had indeed been made.

In conclusion, we can say that there is room for a great amount of improvement as regards which environmental aspects the companies choose to work with. Still, this conclusion does not imply that most of the companies’ environmental work today is completely misdirected. On the contrary, the study indicates that most of them have environmental targets within the majority of those areas that can be regarded as important.

2 WHAT ACTUAL IMPROVEMENTS TO THE ENVIRONMENT HAVE THE ENVIRONMENTAL MANAGEMENT SYSTEMS ACHIEVED?

FOCUSING MAINLY ON WASTE

The results of both the questionnaire and the interviews have indicated that the majority of companies feel the greatest environmental improvements have been achieved in the area of waste. Better waste treatment and less waste are the most frequent answers in the questionnaire about which have been the companies’ most effective environmental measures. As far as what certification has meant to the company, almost everyone interviewed mentioned "better order and greater systemisation" and gave the example of improved waste sorting system.

As mentioned previously, waste has also been the most common environmental target area. But it is not just about sorting waste. Our questionnaire showed that a smaller amount of waste, i.e. resource economy, appears to be almost as common as improved waste sorting. According to the interviews, 77% of the companies’ targets can be classed as source reduction (i.e. they attack the cause of the problem, not the symptom) and waste sorting has nothing to do with it.
EMAS COMPANIES ACHIEVE BETTER ENVIRONMENTAL RESULTS

The results of the interviews have indicated that the environmental achievements of EMAS-registered companies are better than those of companies that do not have EMAS, just ISO 14001. The difference is moderately large - 80% compared with 58% accomplishment of physical targets in the form of emissions and resource reductions. Even so, the subjective impression at the interviews confirms that there should be a difference to the advantage of the EMAS companies. The most likely explanation for this is that the EMAS regulations requirements for companies to publicize their environmental results exert greater pressure on the companies to actually achieve real results.

THE BETTER THE TARGET FOLLOW-UP, THE BETTER THE ENVIRONMENTAL RESULTS

The interview results have shown that the better a company’s target follow-up, the better its environmental results. Many questionnaire respondents mentioned environmental performance evaluation with key indicators as useful tools, revealing that most of the companies are aware of the importance of target follow-up.

DO COMPANIES NEED CERTIFICATION?

The interviews have shown that half of all environmental targets would have been realised even if the environmental work had not been certified. In response to the question about the extent to which the environmental management system has reduced the environmental impact from the company, some frustration emerged about the environmental management work not having achieved more environmental improvements. We might then question whether certification is justified from an environmental view point, considering all the extra costs and bureaucracy involved. What might have been achieved if these resources had, instead, been channelled towards making environmental improvements?

What does argue in favour of certification is that almost all the companies we interviewed emphasis that it leads to better order and greater systemisation. Although the bureaucracy is frustrating, it is considered necessary. What’s more, it is far from certain that the resources a company saves by not being certified are really used for making environmental improvements.

3 EXPENSES, ECONOMY AND REVENUES IN CONNECTION WITH ENVIRONMENTAL MANAGEMENT SYSTEMS

Using the results of this study, it is possible to estimate the cost of introducing and running environmental management systems in Sweden. The study also provides some idea about possible cost savings and revenue increase.
IS THE COST OF INTRODUCING AND RUNNING ENVIRONMENTAL MANAGEMENT SYSTEMS TOO HIGH?

If we compare the estimated costs in Table 5 with, for example, the turnover of a company with 50 employees, expected to be around MSEK 50, we can see that a company should not be deterred too much by having to spend the equivalent of 0.4% of turnover and 1.5% of the working hours to implement the system, and the equivalent of 0.08% of turnover and 0.8% of the working hours to run it.

Yet a really small-sized company with 10 employees might find that the costs for the implementation phase and the running of an environmental management system constitute a decisive barrier. However, it ought to be possible for these costs to decrease in the future.

COST SAVINGS AND REVENUES

According to the questionnaire, companies have achieved the greatest cost savings through reduced energy costs, waste treatment, raw materials and transport. Interview results have indicated that approximately 25% of all environmental targets give payback within one year due to cost savings (however, the variation between the targets of each company is considerable).

Nevertheless, the really major advantages with an environmental management system could be expected to be increased revenues rather than cost savings. Our survey could not, however, give any quantitative evidence for this. On the other hand, approximately 30% of the questionnaire companies have said that they can demonstrate increased revenues as a result of their environmental management work, and the results of the interviews show that at least 25% of all environmental targets give payback within one year due to increased revenues (however, the variation between the targets of each company is considerable).

AN ENHANCED MARKET POSITION

According to the questionnaire, several companies feel that their market position has been improved as a result of their environmental management systems, see Diagram 2. Considering that the most obvious motive up until now for companies to certify their environmental management systems has been to gain a competitive edge, for most of the companies this has actually been the case.

ARE ENVIRONMENTAL MANAGEMENT SYSTEMS A WORTHWHILE BUSINESS?

Obviously, what is most interesting is the size of costs in relation to the savings and revenues that can be expected. Neither our questionnaire nor the interviews have provided any completely clear-cut answers to this. A reasonable inference is that it depends both on the company’s opportunities (potential for environmental improvements in product design and production, customers’ interest, competitors’ behaviour, etc.) and on how the environmental management system is designed (simple, co-ordinated, target-oriented, etc.), as to whether or not it will be a worthwhile business for a company.
DEVELOPMENT OPPORTUNITIES

The following is a summarisation of some of the areas that ought to be given priority with the aim of making environmental management systems more efficient.

WORKING WITH ENVIRONMENTAL ASPECTS

A professional and thorough assessment of environmental aspects forms the basis for all the environmental work of a company as well as the basis for effectively achieving improvements, which is essential if the environmental management work is to progress and develop. Based on this and the fact that working with significant environmental aspects is what companies feel is the most difficult aspect of environmental management work, there is real reason for companies to receive support in this area in the future.

It is vital that the methods used do not reject important environmental aspects too early on in the process. There is much to be said for the environmental impact assessment being conducted together with regard to legislative requirements, but separately from any technical and economical aspects.

The ISO 14001 and ISO 14004 standards should elucidate questions about environmental aspects, environmental impact and significant environmental aspects. In the long term, the standards should provide concordant and possibly also more distinct guidelines as to how it could be possible to implement the identification of environmental aspects and the assessment of associated environmental impact.

STREAMLINING AND COORDINATING MANAGEMENT SYSTEMS

It would be expedient with fewer bureaucratic routines for environmental management systems. A lot of companies have announced an increased coordination in their quality and health and safety systems as well as a switch to electronic documentation management in order to simplify and streamline their business management. Other ways of cutting the red tape could be to replace regulation management with target management as well as to invest in training and skills rather than complicated routines.

BETTER TARGET FOLLOW-UP

The tools necessary for continuing with improvements are, according to the questionnaire responses, chiefly linked to a better follow-up of the environmental targets with, for example, environmental indicators. This could lead to better environmental results in terms of less red tape and improved external communications. Backup is needed here in the form of real examples of environmental indicators, measuring methods and data for comparison in each line of business.
The study shows that the focus of companies today is mainly on waste, energy and emissions. This is often linked to cost savings and has pedagogic consequences. To maintain continual improvements in future environmental management systems and enhance the economical profitability, the focus should, however, be shifted towards work on the company’s own products and/or services.

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Our thanks go especially to the 200 or so companies that have shared their experience with us. The study was financed by The Swedish Board for Industrial and Technical Development (NUTEK).

**Literature**


EMAS regulations, no.1836/93 concerning voluntary participation by industrial companies in the EU Eco Management and Audit Scheme.


Environmental aspects when manufacturing products mainly out of metals and/or polymers

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Environmental aspects when manufacturing products mainly out of metals and/or polymers

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Abstract

The most fundamental aspect in the ISO 14001 standard Environmental management systems—Specification with guidance for use is to find out ways by which an organisation influences environment to a significant degree. This paper examines environmental data from companies manufacturing products mainly from metals and/or polymers. The data were collected in a uniform way by use of special guidelines. Weighting or valuation methods often used in life cycle assessments were used to quantitatively compare and rank environmental aspects. The study results suggest that, in general, the largest environmental impact in the investigated manufacturing sub-sector can be associated with product use and/or disposal phases. This in turn shows a need for more attention on environmental work on the design for environment than what the ISO 14001 standard requires. It is further suggested that weighting or valuation methods can aid in determining the significance of environmental impacts and aspects in the context of ISO 14001.

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Keywords: Environmental management systems; Life cycle assessment; Design for environment; Weighting; Valuation

1. Introduction

Several studies [1,2] indicate that the benefits of environmental management systems would be greater, environmentally as well as economically, if environmental work in the ISO 14001 context paid more attention to the use and disposal phases of the products manufactured. The purpose of this paper is to offer further evidence that a product use phase focus in environmental management is justified, at least environmentally, and to demonstrate a method for identifying and evaluating environmental aspects that is able to capture and highlight aspects associated with the product use phase.

Possible causes as to why environmental management is not often optimally directed range from unclear wordings in ISO 14001 on the choice of system boundaries when evaluating the significance of aspects [3]; to that, traditionally, the production sites were seen as the main sources of pollution of industry. Furthermore, determining the significance of environmental aspects and correctly ranking them require a comparison of different environmental impact categories. This is difficult for several reasons, one of which is a general lack of scientific knowledge about environmental cause and effect relationships [4].

In Sweden, the standard practice when developing an EMS according to ISO 14001 is to start with an initial environmental review by which a deeper understanding of the organization’s environmental impact is gained. IVF Industrial Research and Development Corporation (hereafter referred to as IVF) have developed a guide for doing this initial environmental review—Template for initial environmental review [5].

The template for initial environmental review has been used by hundreds of Swedish companies. IVF has analysed environmental data from 11 companies manufacturing products mainly from metals and/or polymers, collected in a uniform way by the use of the aforementioned guide. This paper investigates the general conclusions about the significance and ranking of
environmental aspects from the particular manufacturing sub-sector that can be drawn from these data.

2. Methodology

The template for initial environmental review contains the methodology used for collecting data and for the evaluation of environmental aspects. A summary is provided below. The 11 data sets investigated in this paper were those available to the author, i.e., they were not chosen for any particular reason, except for availability.

2.1. Data collection

Data collection is mainly carried out as an input–output analysis. Normally, the company as a whole can be treated as a unit process. However, in some cases, input–output analyses of individual processes within the company are carried out.

As mentioned by ISO 14031 [6], not only physical inputs and outputs but also some management areas are covered. Hence, the following areas are investigated:

1. Legal and regulatory requirements
2. Accidents
3. Raw materials and components
4. Chemicals and chemical products
5. Energy consumption
6. Waste and recycling
7. Local environmental impact: water and effluents, emissions to air or land, noise
8. Transportation
9. Products

The facility gate is not used as a system boundary for data collection. Instead, more of a life cycle perspective is used: transports are tracked up-stream and down-stream as far as practically possible and, if relevant, use and disposal phases of the manufactured products are considered. The general idea is that there is a greater chance of identifying considerable improvement potential with wider system boundaries, since the size of the improvement potential would be strongly linked to the size of the environmental impact.

Invoices are the major source of data on use of energy, electricity, raw materials, etc. Since most of these resources need surface transportation, estimates of transport work can be made at the same time. Staff and duty travel warrants separate investigations. Data sources for local environmental discharges and environmental aspects associated with product use and disposal phases vary, but these aspects can be sometimes estimated from other resource flows. The emphasis is always on major resource flows.

Emissions and raw material consumption for electricity and heat used at the company facility are calculated from “cradle-to-gate” data for electricity and heat generation. Similarly, emissions and resources associated with the different transport modes are computed from the generally available “cradle-to-gate” data, with the aim of including all the major emissions and resources associated with each environmental aspect.

All data are collected and computed on an annual basis to enable comparisons. Data from the previous year are often the best practical choice. The calculation basis used could therefore be described as one year of company activities. In life cycle assessment terminology, this would correspond to the functional unit.

2.2. Environmental weighting

As mentioned in Introduction, it is difficult to compare different types of environmental impact, for example, the consumption of a non-renewable resource such as oil, with NOx emissions, which causes acid rain and over-fertilising. One way of facilitating such comparisons is to convert all impacts to the same unit by weighting or valuation methods used in life cycle assessment.

The template for initial environmental review uses the Swedish EPS (Environmental Priority Strategies in Product Design) system [7,8]. Here, emissions and resources are converted to environmental load units (ELU). The conversion calculation is very simple, involving multiplying an emission figure, for example, the emission of 5000 kg of carbon dioxide over one year by an ordinary vehicle, by the ELU value for carbon dioxide, 0.108 ELU/kg. The environmental impact (in this case, the greenhouse effect) of 5000 kg of carbon dioxide is thus evaluated at 540 ELU.

By the use of such valuation methods, it is possible to achieve an approximate ranking of the company’s environmental impacts, provided that all data are collected and computed on an annual basis (or any equal basis). In the context of an EMS, due to the uncertainty factors inherent in the calculations, it is recommended using the results only for separating large impacts from small ones and obtain an approximate ranking of aspects. In this paper, the Eco-indicator 99 method [9] is used in addition to EPS-2000 and EPS-1996, in order to verify that the ranking is reasonably correct.
3. Results

Inventory data for one of the 11 companies, company A, are shown in some detail in Table 1. Company A was manufacturing a vehicle component. The improvement potential associated with the product use phase is described here as the total annual diesel savings if the product becomes 10% lighter. The figure of 10% was chosen because it was an achievable weight reduction in the short term for the particular products according to the company.

The reason for representing the product use phase with figures for potential savings instead of figures for the full load, i.e. in this case, the total annual diesel consumption, is twofold. Firstly, there is a scale problem, since we want to fit all environmental aspects neatly into the same diagram, see Fig. 1. Secondly, while it may be difficult and hard for a manufacturing company to readily assume responsibility for energy consumption during the use phase of their product, the benefits of being able to help their customers to save fuel are much more readily appreciated.

Fig. 1 shows the environmental impacts corresponding to the environmental aspects listed in Table 1. The environmental impacts have been calculated using three different sets of weighting indices, EPS-2000 [8], EPS-1996 [7] and Eco-indicator 99 [9].

The materials have been grouped together under the heading “material production”. The largest individual contributions in that group come from steel and PUR (polyurethane).

4. Discussion

Figs. 1 and 2 show that both weighting methods give the same ranking results for company A. Among life cycle assessment practitioners, gaining the same result by the three methods is usually considered as a strong indication that the ranking is reasonably correct. Here, only two, albeit one of them in two versions, methods are used. Thus, for the purpose of finding the order of significance of the environmental impacts, the results indicate that any of the two weighting methods could be used.

The results in Table 2 indicate uniformity in the ranking of environmental aspects based on the environmental impacts in the investigated manufacturing subsector. This indicated ranking is:

<table>
<thead>
<tr>
<th>Environmental aspect</th>
<th>Annual quantity</th>
<th>Unit</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xylene emission</td>
<td>70</td>
<td>kg</td>
<td>Site emissions</td>
</tr>
<tr>
<td>Paper</td>
<td>3</td>
<td>ton</td>
<td>Material consumption</td>
</tr>
<tr>
<td>Wood</td>
<td>28</td>
<td>ton</td>
<td>Material consumption</td>
</tr>
<tr>
<td>Plastic Primo</td>
<td>2</td>
<td>ton</td>
<td>Material consumption</td>
</tr>
<tr>
<td>PVC</td>
<td>6.7</td>
<td>ton</td>
<td>Material consumption</td>
</tr>
<tr>
<td>Epoxy powder</td>
<td>3.5</td>
<td>ton</td>
<td>Material consumption</td>
</tr>
<tr>
<td>Plastic Orion</td>
<td>5.9</td>
<td>ton</td>
<td>Material consumption</td>
</tr>
<tr>
<td>Plastic Era-Perstorp</td>
<td>6.2</td>
<td>ton</td>
<td>Material consumption</td>
</tr>
<tr>
<td>Water</td>
<td>3200</td>
<td>ton</td>
<td>Material consumption</td>
</tr>
<tr>
<td>Textiles</td>
<td>36.9</td>
<td>ton</td>
<td>Material consumption</td>
</tr>
<tr>
<td>Duty travel</td>
<td>151,000</td>
<td>Person km</td>
<td>44% by air, 66% by car</td>
</tr>
<tr>
<td>Leather</td>
<td>50</td>
<td>ton</td>
<td>Material consumption</td>
</tr>
<tr>
<td>Screws</td>
<td>8</td>
<td>ton</td>
<td>Material consumption</td>
</tr>
<tr>
<td>Transportation of goods</td>
<td>536,400</td>
<td>ton km</td>
<td>Road transport, mostly long distance, 50% fill</td>
</tr>
<tr>
<td>Staff travel to and from work</td>
<td>259,800</td>
<td>Person km</td>
<td>87% by car</td>
</tr>
<tr>
<td>Electricity consumption</td>
<td>625</td>
<td>MW h electricity</td>
<td>Energy consumption</td>
</tr>
<tr>
<td>Steel</td>
<td>275.4</td>
<td>ton</td>
<td>Material consumption, low grade steel</td>
</tr>
<tr>
<td>District heating</td>
<td>645</td>
<td>MW h district heating</td>
<td>Energy consumption</td>
</tr>
<tr>
<td>PUR Cirrus</td>
<td>73</td>
<td>ton</td>
<td>Material consumption</td>
</tr>
<tr>
<td>Product use phase</td>
<td>173,000</td>
<td>Litres of diesel</td>
<td>Illustrated as total annual diesel savings if product becomes 10% lighter</td>
</tr>
</tbody>
</table>
1. **Product use phase.** If emissions and/or resource use occur during the product use phase, the associated environmental impact would be the largest in the company, often 10 times larger than any other impact (in the example presented in Figs. 1 and 2, all materials are grouped together which would normally not be done). However, note that for six out of the 11 companies in the study, a product use phase aspect was not found dominant. In half of those six cases, a use phase aspect of any significance could not be identified at all. For the other half, the use phase was not dominant.

2. **Materials.** If a “product use phase” aspect is not dominant or relevant, the materials and components then tend to contain the largest environmental impact. It should be noted that the impact figure here, for Eco-indicator, includes both resource use and emissions during material production, i.e. cradle-to-gate data, while for ELU, only resource use is included. Nevertheless, the different valuation meth-
ods produce the same ranking. Typically, environmental impact associated with materials production is valued 10 times larger than the aspects associated with in-house energy consumption and transports, see Fig. 2.

3. **Energy and transports.** Environmental impacts associated with in-house energy and transports are normally in the same order of size. The way the aspects are grouped would decide the exact ranking order. Heating and electricity are, for example, often treated separately. Environmental impacts associated with the different travel modes investigated are in the same range. It comes as a surprise to many that there is often at least as much environmental impact from staff and duty travel as there is from the transport of goods. Note that goods transports are tracked up-stream and down-stream as far as possible, while staff and duty travel concerns only those from the investigated company.

4. **Water consumption.** Environmental impacts associated with fresh water as a resource are usually not very large for the particular industry investigated. The usual practice in this industry is that processes using water are closed looped, i.e. no routine process water discharges are made. Floor drains are normally sealed to prevent accidental spillages entering the sewage system. The local municipality normally treats the sanitary water. It can therefore normally be assumed that environmental impacts from water discharges would not be larger than those associated with fresh water as a resource which the calculation refers to.

5. **Site emissions.** The aspect that traditionally attracts most attention from environmental authorities and regulations, are found by most companies to be the least significant of the investigated environmental impacts. However, it should be pointed out that there were no large paint shops (using organic solvent based paint) among the investigated companies.

<table>
<thead>
<tr>
<th>Environmental aspect</th>
<th>Company</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Product use phase is dominant</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Material production</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>In-house energy consumption</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Staff travel to and from work</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Transportation of goods</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Duty travel</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Water consumption</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Site emissions</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 2
Ranking of environmental aspects based on environmental load in ELU

A survey of 10 randomly picked certified environmental product declarations (EPDs) according to the EPD system administered by the Swedish Environmental Management Council [13] showed similar results as above: in six out of 10 EPDs, the environmental impact during the use phase was clearly dominant. In two out of 10, it could not be decided which phase was dominant and in the remaining two (sawn timber and electricity generation), the production phase was dominant. This “mini” survey indicates that the product use phase often has the largest environmental impact for other types of products also than those mainly out of metals and/or polymers.

Another result of this study with relevance to product life cycle assessments, PLCA, is that the environmental impact from staff and duty travel, while being small, is not negligible. Guidelines, e.g. the EPD guidelines [14], and general practice for PLCA are to exclude “personnel activities”, like staff and duty travel. The results here indicate that for PLCA of products made mainly out of metals and/or polymers personnel activities such as travelling are indeed significant and should therefore be included.

While it might be possible to generalize the study results about the importance of the product use phase into other manufacturing industry sectors and even other countries, this would not be possible concerning the small environmental impacts found from site emissions and water use. One reason for their smallness is surely the successful work by regulating authorities (in many but not all countries) in curbing point-source emissions. Another reason is that the particular manufacturing sector only has relatively few processes generating emissions and that the emissions from those processes are relatively small, at least compared to manufacturing of commodities like paper, steel, etc.
Waste is missing from the above list of environmental aspects as a stand-alone aspect category. Production material waste could however be measured and evaluated as part of the aspect named material consumption, since an effective way of reducing environmental impacts associated with material production is to close the material cycle, i.e. make sure the products are reused, repaired or recycled and to use recycled material in the production. The strong interrelationship between the material production phase and the disposal phase supports the conclusion that the product use and disposal phases are dominant in this sub-sector, because as mentioned above, the results indicate that if a product use phase aspect is not dominant or relevant, materials and components then tend to contain the largest environmental impact.

Hazardous waste, e.g. from the above mentioned closed loop systems, is impossible to evaluate with the baseline weighting indices. This is a limitation indicating that toxicity issues needs to be addressed with methods other than those described in this paper.

The issue of scope for an environmental management system and the connected issue of which system boundaries to use while determining the significance of environmental aspects have been discussed extensively during the revision of the 14001 standard [15]. In the 1996 version, the standard can be interpreted as only requiring consideration of aspects that the organisation can control and influence. Since manufacturing companies normally do not have ownership of their products in the use and disposal phases, associated environmental aspects can easily be dismissed on the grounds that full control is impossible. A Swedish study has shown that many companies indeed fall into this trap of narrowing down the scope of their EMS. In combination with the difficulties involved in comparing and ranking different impact categories, they thereby omit to work with some of the environmental aspects which are the most important from both an environmental and economic viewpoint [2].

The system boundaries recommended in the template [5] comprise the whole life cycle of the products manufactured. However, availability of data and thereby the level of detail decline rapidly as one moves away from the production site in question. This variation in data quality would not be acceptable in a normal life cycle assessment. There are however wordings in ISO 14001 that support that such a variation in data quality would be acceptable and even desirable in an initial environmental review. That a variation in data quality would be acceptable when identifying significant environmental aspects for an environmental management system has also been suggested in the literature [16,17].

The main conclusion of this paper, that for the investigated sub-sector, the largest environmental impacts normally can be associated with the use and/or disposal phase of products rather than the manufacturing phase, should come as no surprise to anyone. Most environmental policy initiatives during the last decade have focussed on the use and/or disposal phase, for example, the Integrated Product Policy and extended producer responsibility for certain products. Has enough then been done and said? A recent English government study says no. It concludes that most of the relevant policy activity at UK and European level still remains focused on the point-source impacts of production and end-of-life waste [18].

Since LCA weighting methods like EPS or Eco-indicator can do quantitative examination and ranking of environmental aspects as has been shown in this paper, they are interesting for evaluating the significance of aspects. However, the user must be aware of their limitations:

- Lack of indices for hazardous waste and many other common emissions and resources;
- It is not always easy to see which environmental impact(s) a specific index cover; and
- The user has to possess a fair degree of knowledge about the weighting methods in order to feel confident of the results.

Because of the limitations mentioned above, the methods give at best a rough estimate of the order of magnitude of the significance. Nevertheless, as demonstrated in this paper, LCA weighting methods can with relatively few and quick calculations transform an inventory list of emissions and resources into a graph that at a glance provides a comprehensible overview of a company’s environmental impact.

5. Conclusions

For the investigated sub-sector, the data analysed in this paper show that the largest environmental impacts normally can be associated with the use and/or disposal phase of products rather than the manufacturing phase. Many other studies, for example product life cycle assessments, confirm this conclusion.

Other studies point to a lack of focus on the product use and disposal phases in environmental management work. Policy initiatives directed towards products during recent years also indicate that environmental impacts during the use and disposal phases of products do not receive enough attention in environmental work today.

Possible causes as to why companies with environmental management systems often neglect to work with design for environment are discussed and it is suggested that it is both a scope, or system boundary, problem and a lack of evaluation tools that can
compare and correctly rank different impact categories. Since weighting methods used in LCA can compare and rank environmental aspects quantitatively, it is suggested that these could be used for evaluating the significance of environmental aspects and thereby aiding companies to focus their efforts on the most important areas.

With respect to product life cycle assessments, the study results indicate that for the particular sub-sector, the environmental impacts from staff and duty travel exceed those from goods transportation. Hence, the common practice in product life cycle assessments to pay much attention to goods transportation while excluding personnel travels should be questioned.

References


Paper 3

Stepwise environmental product declarations – Ten SME case studies

Mats Zackrisson, Anna Jarnehammer, Cristina Rocha and Kim Christiansen

Stepwise environmental product declarations: ten SME case studies

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Abstract

The lack of reliable communication tools is anticipated to become an important barrier to design and sell products with improved environmental performance. In this paper, environmental product declarations, EPDs, and in particular a Stepwise EPD approach is investigated as a means to overcome the communication barrier. The experiences of ten European SMEs who have tried to use Stepwise EPDs for market communication and as a basis for eco-design are described and discussed. The experiences suggest that Stepwise EPDs based on life cycle assessment can be a cost-efficient tool to improve the environmental performance of products. For normal marketing activities the Stepwise EPDs were disappointing. Using the underlying LCA as a platform for in-depth communication with selected parties in the supply chain showed more promise.

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Keywords: Environmental product declaration; EPD; Environmental communication; Eco-design; Environmental management; Life cycle assessment; Integrated product policy; Product information; ISO 14025; Product development

1. Introduction

Environmental policymakers around the world have increasingly been looking at ways to improve the environmental performance of products throughout their life cycle. In February 2001, the European Commission published its thinking on these issues in the Green Paper on Integrated Product Policy [1]. One of the overarching goals of IPP is to stimulate demand for greener products through easily accessible, understandable and credible information. In the following communication on IPP [2], the European Commission emphasized that environmental labelling including environmental product declarations (EPDs) is a very important tool in the IPP toolbox. In 2006, the IPP Working Group on Product Information has further developed how to make Product Information Work for the Environment [3]. It recognizes that the investment of effort by government and business on product information can be highly cost-effective in delivering improvement, compared with ‘traditional’ regulatory mechanisms. One of the recommendations is related to improving the delivery of green public procurement at the same time as creating a strong market ‘pull’ for standardized forms of product information, encouraging the development of sectoral EPDs. As will be shown in this paper, there is presently very little pull for environmental product information.

The Stepwise EPD project was carried out during 2005 and 2006 with funding from the European Union’s Cooperative Research programme. The overall objective of the project was to develop a method for stepwise environmental product declarations suitable for SMEs, small and medium sized enterprises. To be suitable for SMEs, it was postulated that it should be possible to use the method in marketing and as a basis for eco-design already at early steps and at low cost. The amount of work and competence needed to do a full EPD based on LCA has been identified as a major obstacle for SMEs to use EPDs [4–6].

Why then, if it is so difficult, should SMEs attempt to use LCA? One answer is that LCA is considered the most
comprehensive environmental assessment tool for eco-design purposes [7]. LCA may contribute to a transformation of the way we view and do economic activities [8] and LCA is well-supported by standards [9,10]. Another answer is that way we view and do economic activities [8] and LCA is purposes [7], LCA may contribute to a transformation of the comprehensive environmental assessment tool for eco-design held are the main foundation for this paper.

The method for Stepwise EPD has been tested by ten SMEs in Denmark, Latvia, Portugal and Sweden. Research institutes in respective country have aided the SMEs with the life cycle assessment and the Stepwise EPD. The SMEs have used the Stepwise EPDs both for market communication and as a basis for eco-design and the Stepwise concept has been further developed. The basic assumption of the project was that EPDs are good for business and good for the environment. The objective of this paper is to explore that assumption.

1.1. Research method and activities

The research methods employed could best be described as action research in case study form. Each participating SME represents one case study, i.e. ten SMEs equal ten cases. For each case at least one Stepwise EPD has been developed entailing scoping, data collection, LCA calculations, interpretation of LCA, drafting Stepwise EPD and reviewing Stepwise EPD. Workshops and meetings aiming at using the Stepwise EPDs in marketing and as a basis for eco-design have been carried out. These actions, which are described in more detail below, have been carried out by experts in LCA, belonging to the involved research organizations, in cooperation with the SMEs’ experts in production, sales, design, etc.

In parallel to the elaboration of the Stepwise EPDs, the Stepwise EPD concept or method was defined. The research method here was to discuss the experiences from the practical work with the EPDs and draft text to arrive at consensus guidelines [11] within the framework of relevant standards and norms.

At the end of the two-year project, each SME was interviewed by their research partner in order to evaluate the results, i.e. the impacts of the Stepwise EPD-work on design, market communication and sales. The same semi-structured evaluation questions were used in Sweden, Portugal and Latvia. In Denmark a more open and less structured approach was used.

Throughout the project, experiences have been discussed between SMEs, research organizations and other partners at several meetings at both company, national and project level. The impact of doing the Stepwise EPDs has been documented in impact reports [12–16]. These impact reports, together with the Stepwise EPDs and all the discussions from the meetings held are the main foundation for this paper.

2. The Stepwise EPD concept

The Stepwise EPD concept or method was developed in parallel with elaborating the Stepwise EPDs for the case study companies. The starting point was an initiative from a consortium of Swedish research institutes in 2002, resulting in the programme On the road to EPD [17].

An environmental product declaration, EPD, presents independently verified data on environmental aspects and impacts of a product throughout its life cycle. A Stepwise EPD is an initial EPD with simplified data collection and review. In short, making an EPD involves the following activities:

A. Making a simplified or streamlined life cycle assessment, LCA, to identify the most significant environmental aspects and impacts of the product;
B. Formulation of Product Category Rules together with interested parties;
C. Making a detailed life cycle assessment to validate and supplement the results of the initial assessment;
D. Drafting of EPD; and
E. Independent verification of the life cycle assessment and the EPD.

Stepwise EPD only consists of steps A, D and a simplified version of step E. Thus, Stepwise EPD could be seen as a cost-effective way of trying out to work with EPDs. But it does not go the whole way of engaging the interested parties in the process, i.e. step B, and making a detailed life cycle assessment, which often means involving the suppliers, i.e. step C. It should be pointed out that following the Stepwise route to a full EPD (A, D, E, B, C, and D and E again) entails very little extra work compared to going for the full EPD right away (A, B, C, D and E), since the work done in steps D and E can be reused to a large extent.

Stepwise EPD is not an independent EPD programme. Instead it is a first step to participation in any national or international type III environmental declaration programme in accordance with ISO 14025 [18]. It is up to the programme operator, to decide the status of a Stepwise EPD. The EPD® system [19] allows pre-registration of Stepwise EPDs in their system.

Another major difference between a full EPD and a Stepwise EPD is that Stepwise EPDs use a streamlined process for developing the EPD and a standardized layout. The process (encompassing steps A, D and E above), which builds upon cooperation between an LCA expert and the company’s experts, can be further subdivided into the following six steps [11]:

1. Scoping together. This maybe a short day’s exercise including introduction to LCA and Stepwise EPD, analyzing and deciding which product or product group to focus on and introducing the data collection procedures;
2. Inventory by the company of resources and emissions from their own production associated to the target product. How much time is needed is dependent on the complexity of the product and the availability of data. Various templates are available [20].
3. LCA calculations and outline Stepwise EPD by the LCA expert. How much time is needed for the LCA is dependent on how well the inventory has been performed, availability of representative process data for the other stages of the life cycle, and the complexity of the product.

4. Examination of LCA and drafting of EPD together. In this step new knowledge about the product’s environmental performance is created. Normally one short day is enough for this exercise, but you may decide to do step 3 again and refine the LCA. Then you would also do step 4 again.

5. Critical review of the Stepwise EPD by another LCA expert who has previously done a Stepwise EPD. This is also a mechanism to share experiences and develop the Stepwise concept. Typically, the LCA expert needs to correct some things in the LCA and in the Stepwise EPD as a result of the review. After checking such corrections with the company, the final version of the Stepwise EPD can be issued.

6. Making a plan to take the next step into a real EPD programme. This is done, by the LCA expert, in the form of a bid describing all the costs involved to make a full EPD.

In the Stepwise EPD project, we tried to exploit the new knowledge about the product’s environmental performance in various ways, e.g. by performing idea generation workshops to brainstorm environmental improvement opportunities. Typically half a day was used for these workshops that involved a mix of staff functions. Since such activities are not part of the Stepwise concept itself they are not described further here.

2.1. The Stepwise EPD

A Stepwise EPD has a standardized layout and mandatory contents for two reasons: it is assumed cost-effective and it is supposedly easier for the reader to learn to interpret the Stepwise EPD when the layout does not change [5,6,21]. Below follows a description of the mandatory headlines and standardized layout as laid down in the Stepwise EPD guideline [11]. The guideline is mainly based on inputs from ISO 14025 [18], the EPDs® programme [19], the Intend requirements for an International EPD scheme [22] and the upcoming Danish EPD programme [23].

It should be noted that the Stepwise guideline [11] contains a layout option 2. The Danish partners used this layout during the Stepwise EPD project. It is not further discussed in this paper, but more information can be found in a separate report [24].

2.2. The company

Under the first mandatory headline a very short description of the company is made, for example, which products or services they offer, reference to certified management system, etc. Company logo and contact information are given.

2.3. The product

This section describes the product or product category that is being declared. All relevant information is included so that the user can clearly identify which product is being declared. It could be, for example, how and where to apply the product with references to key standards. A picture of the product is included.

2.4. List of materials and chemical substances

All materials contained in the product are listed with their respective weights, including consumables delivered with the product. Packaging, if relevant, is listed separately. Substances that are classified according to EU-legislation are listed separately (Fig. 1).

2.5. Product life cycle information

This section describes the life cycle of the product with a picture of the system boundary and explanatory text. Numerical data for each life cycle stage are given in different environmental impact categories, e.g. global warming potential, and inventory parameters, e.g. renewable resources. Fig. 2 below contains a graph where the different life cycle stages are compared to each other. The figure makes it easier to appreciate that, in this case, the use phase has the largest environmental impact in all reported impact categories.

Often the functional unit is defined as the life cycle of one product, i.e. production of one product, use of it during its economical lifetime and end-of-life treatment of the product. In Fig. 2, however, numerical data are given per cubic meter of treated water, since this is the service provided by that particular product.

2.6. Additional environmental information

This section describes environmental information about the product that does not fit under the previous headings. It could be, for example, information on suitable end-of-life treatment and/or how to use and service the product to minimize environmental impact. As with the rest of the information in the EPD, whatever is stated here must be relevant, verifiable and non-misleading.

It is not very clear to what extent other types of product information may be included in the EPD. In ISO 14025 it is stated that it shall be environmentally relevant, i.e. related to an environmental aspect of the product life cycle, but this leaves room for a lot of interpretation. The Stepwise guideline, which closely follows ISO 14025, contains the same ambiguity. Doing a Stepwise EPD may highlight and demonstrate the need for including such “questionable” information. The ensuing negotiation of Product Category Rules with stakeholders, which would follow before doing a real EPD, may then decide on the issue [6].
This EPD provides a quantitative and verified description of membrane filtration viewed from a life cycle perspective.

The company
Mercatus Engineering AB
Box 84
598 22 Vimmerby
Sweden
Contact person: Peter Hallberg

Mercatus Engineering AB is specialized in recycling and purification of industrial process waste water, offering products and know-how ranging from chip/particle separation, purification and recycling to taking care of industrial waste water. The company has an environmental management system certified to ISO 14001.

The product
This EPD concerns membrane technology consisting of ultrafiltration and reverse osmosis. The technology is typically used to clean industrial process water so that it can be used again. Another benefit of the membrane unit is to save the heat in the process water. The studied membrane unit treats 25 m³/h water of which 18 m³/h is purified and used as process water. Assuming 30 °C temperature gradient, the purified 18 m³/h water contains more than 600 kW heat. In a year (assuming 320 days operation), approximately 4800 MWh heat and 136000 m³ water can be saved for this size unit. Depending on the process, the remaining 7 m³/h has to be treated as hazardous waste or could be used as by-product.

Though the data could be generalized to represent any size membrane unit in this application between 5-50 m³/h capacities, smaller units would save less and larger units would save more energy and water. The temperature gradient and the recovery rate (18 m³/h of 25 m³/h assumes a very polluted inflow) would also affect the savings.

List of materials and chemical substances
The ultrafiltration and reverse osmosis unit consists of the materials and chemical substances in the table below.

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight (kg)</th>
<th>Weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless steel</td>
<td>1473</td>
<td>33</td>
</tr>
<tr>
<td>Glass fibre reinforced polypropylene</td>
<td>777</td>
<td>18</td>
</tr>
<tr>
<td>Steel</td>
<td>396</td>
<td>9,3</td>
</tr>
<tr>
<td>Polypropylene plastic</td>
<td>394</td>
<td>9,3</td>
</tr>
<tr>
<td>PVC plastic</td>
<td>387</td>
<td>9,1</td>
</tr>
<tr>
<td>Aluminium</td>
<td>279</td>
<td>6,5</td>
</tr>
<tr>
<td>Polyamide plastic</td>
<td>130</td>
<td>3,1</td>
</tr>
<tr>
<td>Galvanized steel</td>
<td>89</td>
<td>2,1</td>
</tr>
<tr>
<td>EPDM/synthetic rubber</td>
<td>85</td>
<td>2,0</td>
</tr>
<tr>
<td>Copper</td>
<td>83</td>
<td>1,9</td>
</tr>
<tr>
<td>Polyester plastic</td>
<td>74</td>
<td>1,7</td>
</tr>
<tr>
<td>Polyurethane plastic</td>
<td>30</td>
<td>0,70</td>
</tr>
<tr>
<td>Cellulose acetate</td>
<td>25</td>
<td>0,59</td>
</tr>
<tr>
<td>Nitrile</td>
<td>14</td>
<td>0,33</td>
</tr>
<tr>
<td>Lubricating oil (consumable)</td>
<td>10</td>
<td>0,24</td>
</tr>
<tr>
<td>Polyethylene plastic</td>
<td>8,4</td>
<td>0,20</td>
</tr>
<tr>
<td>PTFE plastic</td>
<td>5,1</td>
<td>0,03</td>
</tr>
<tr>
<td>Brass metal</td>
<td>6,9</td>
<td>0,22</td>
</tr>
<tr>
<td>ABS plastic</td>
<td>0,2</td>
<td>0,005</td>
</tr>
<tr>
<td>Glycerine</td>
<td>0,2</td>
<td>0,005</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Substances classified according to EU-legislation</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
</tr>
</tbody>
</table>

| Total:                            | 4256       | 100 %      |

Fig. 1. The first page of a Stepwise EPD describes the company, the product and what the product consists of [11,25].
Product life cycle information

The life cycle of the membrane unit begins with resource extraction and component manufacturing. A Swedish subsupplier operating under instruction and testing by Mercatus assembles the unit. Service during use is carried out by Mercatus. The end-of-life stage is included only where transportation to a recycling facility and declaration of all materials in the unit as waste to recycling is specified. See diagram.

The control equipment normally used for the unit is not included. The unit is expected to be in use for 15 years including two shifts of membranes. The technical life of the unit is much longer. Only the environmental data for design, testing and servicing of the unit by Mercatus is case specific. See diagram. All other environmental data is generic.

In the typical application the major benefits of using a membrane unit are that it facilitates water and energy savings and reduces the amount of water that needs further treatment before discharge.

Therefore, data is given both per m³ reused (or reduced) wastewater and per MWh saved heat during the 15 years of service life. The inflow process water is assumed to be on average 30 °C above alternative sources, for example tap water.

The energy savings could be seen as an alternative way of heating the process water. Thus it is relevant to compare emission data for alternative heating sources, for example electricity, with the data per MWh below.

Electricity consumption during use (for pumping) dominates all the reported environmental impact categories, see picture. Environmental data representing Nordic average electricity has been used for the use phase. The electric power needed is 3,2 kW for the ultrafiltration unit and 16,6 kW for the reverse osmosis unit.

<table>
<thead>
<tr>
<th>Environmental parameter</th>
<th>Production per m³</th>
<th>Production per MWh</th>
<th>Use per m³</th>
<th>Use per MWh</th>
<th>End-of-life per m³</th>
<th>End-of-life per MWh</th>
<th>Total per m³</th>
<th>Total per MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource, non-renewable (g)</td>
<td>1.4</td>
<td>136</td>
<td>31</td>
<td>678</td>
<td>0.000</td>
<td>0.000</td>
<td>36</td>
<td>1010</td>
</tr>
<tr>
<td>Resource, renewable (g)</td>
<td>0.26</td>
<td>7.3</td>
<td>0.41</td>
<td>1160</td>
<td>0.000</td>
<td>0.000</td>
<td>41</td>
<td>1170</td>
</tr>
<tr>
<td>Resource, recycled (g)</td>
<td>0.58</td>
<td>17</td>
<td>0.010</td>
<td>28</td>
<td>0.000</td>
<td>0.000</td>
<td>0.59</td>
<td>16.8</td>
</tr>
<tr>
<td>Energy resource, non-renewable (kWh)</td>
<td>0.077</td>
<td>2.2</td>
<td>1.3</td>
<td>38</td>
<td>0.001</td>
<td>0.028</td>
<td>1.4</td>
<td>39.7</td>
</tr>
<tr>
<td>Energy resource, renewable (kWh)</td>
<td>0.007</td>
<td>0.21</td>
<td>1.2</td>
<td>34</td>
<td>0.000</td>
<td>0.000</td>
<td>1.2</td>
<td>34.2</td>
</tr>
</tbody>
</table>

*Environmental impact category indicators:

Global warming (g CO₂ equivalents) | 17 | 493 | 142 | 4020 | 0.26 | 7.2 | 159 | 4520 |

Photosynthesis, oxidant formation (mg ethene equivalents) | 2.3 | 64 | 6.5 | 185 | 0.095 | 2.7 | 8.9 | 252 |

Eutrophication (g O₂) | 2.0 | 57 | 2.4 | 67 | 0.016 | 0.65 | 4.4 | 124 |

Acidification (mol H⁺) | 0.005 | 0.15 | 0.020 | 0.57 | 0.000 | 0.003 | 0.026 | 0.73 |

Ozone depletion (mg CFC 11) | 0.011 | 0.32 | 0.012 | 0.35 | 0.000 | 0.000 | 0.024 | 0.67 |

Waste:

Waste, hazardous (g) | 0.021 | 0.59 | 0.077 | 2.2 | 0.000 | 0.000 | 0.098 | 2.8 |

Waste, other (g) | 15** | 36** | 0.26 | 74 | 0.000 | 0.000 | 13 | 376 |

Waste to recycling (g) | 0.17 | 5.0 | 0.79 | 22 | 1.9 | 53 | 2.4 | 81 |

*The generic data used for electricity includes resources for infrastructure, for example gravel, which does not leave the system.

**Generic data for stainless steel includes outflow of mixing waste that is not included in the resource inflows, thereby resulting in more waste outflows than resource inflows.

Additional environmental information

Chemical consumption is 0.15 g cleaning chemicals per m³ treated water. A waste plan detailed for each component is delivered with the unit. Material or energy recycling is possible for all components.

Date of publication

This environmental product declaration was published in May 2006. It is valid until May 2008.

References

Project EPD Mercatus in the LCA database of [Link to database].


This Stepwise EPD, which follows the Stepwise EPD guideline, has been prepared in cooperation between Mercatus Engineering AB and [Cooperation partner]. It is pre-registered in the Swedish EPD system at [EPD system]. Environmental declarations from different programmes may not be comparable.

Fig. 2. The second page of a Stepwise EPD mainly describes the environmental impacts during the life cycle of the product [11,25].
2.7. Date of publication

A Stepwise EPD is valid for two years. This means that the next step into an EPD programme should be taken within two years.

2.8. Critical review

An independent party should review the LCA and the EPD in order to eliminate, as much as possible, mistakes pertaining to the data used and the calculations performed and misinterpretations of the guideline. The review is documented separately. In the Stepwise EPD, the name of the reviewing organization is stated under a separate heading or in the footer of the last page, as a sign that the review has been carried out.

2.9. References

In this section references relevant to the Stepwise EPD are stated. This would typically be the LCA-report, some key data source, the Stepwise guideline and the guideline of the EPD programme that one is aiming to take the next step into.

To aid users to interpret the Stepwise EPD, a four-page brochure has been developed [26]. The idea is to hand this brochure out together with the Stepwise EPD.

3. Ten case studies

The main assumption of the Stepwise EPD project is that EPDs are good for business and good for the environment. This implies that companies using EPDs will improve their products and that the improved products will be sold more successfully than their predecessors. Thus, the main assumption can be broken down in the following assumptions:

1. Producing the EPD, or rather performing the underlying life cycle assessment, can be used as a basis to identify eco-design options;
2. The EPD can be used to communicate a product’s environmental profile to potential customers thereby creating a demand for such products with improved eco-efficiency;
3. Together, the customer demand for environmentally improved products and the identified improvement options can bring about actual improvements in a product’s eco-efficiency.

It should be emphasized that the assumptions focus around environmental improvement of products. The ability of EPDs to market and sell products on environmental merits as such (not involving any improvements) has not been the main focus of the Stepwise EPD project.

To test the above assumptions ten cases have been studied. The case studies involved ten SMEs that all did at least one EPD each and then used it for eco-design and market communication.

3.1. Doing the EPDs and trying to use them

The Stepwise EPD project was carried out during a two-year period. First the EPDs were developed by the SMEs in cooperation with the research institutes, broadly following the six-step process outlined above.

The process of developing the EPD was supplemented by eco-design workshops and different market communication activities. While eco-design workshops were carried out more or less in the same way, market communication activities differed since they needed more tailoring to meet the specific needs of each individual company. However, they all shared the same objective of stimulating the use of the EPDs. These activities were mostly carried out at the end of the first year and in the beginning of the second year. While most workshops and meetings included only one SME and their research partner, a mid-term meeting was held in which most partners were represented.

The second year of the project was originally planned to allow time for the companies to use the EPDs in marketing and to use the results of the eco-design workshops during design of new models. However, discussions at the mid-term meeting led to the development of a second round of improved EPDs. The improvements focused on comparisons as a means to make the EPDs more understandable. The second round of improved EPDs was only completed towards the end of the project so their usability has not been tested as much as the first EPDs.

3.2. The companies, their products and their customers

The Stepwise EPD method has been tested in ten small and medium sized companies, SMEs, in Denmark, Latvia, Portugal, and Sweden. In Table 1 follows summary descriptions of the participating companies. Two of the three Danish companies wished to be anonymous and are referred to as Danish Company B and C.

The main motivation for the SMEs to participate in the Stepwise EPD project was an anticipation of a demand for EPDs from their customers and clients and a willingness to test new approaches and methods in environmental work. Willingness to spend time and effort to develop and make use of the EPDs was the main criterion for selection of the case study companies.

The previous experience of environmental work in the participating SMEs varied quite a lot. Some characteristics of this are mentioned in the column environmental awareness in Table 1. Differences in environmental awareness are discussed below as a possible explanation to why most of the case study companies believe that they will continue to work with EPDs, while two are quite sure they will not.

During development of the project, both Etac and Concretope, grow out of the formal definition of an SME by organic growth (Etac) and change in ownership (Concretope). From an organizational viewpoint, Etac was the largest company participating in the project and Concretope one of the smallest.
3.3. Basis for eco-design

This section will explore the assumption that producing the EPD, or rather performing the underlying life cycle assessment, can be used to identify eco-design options. Project targets associated with this assumption were as follows:

- to identify at least two significant environmental improvement options with each declared product, i.e. at least 20 significant\(^1\) environmental improvement options in total;
- to start at least five product environmental improvement efforts based on above identified options.

Table 2 outlines the results of the life cycle assessments and the eco-design workshops carried out. As mentioned above, the eco-design workshops were based on the results of the LCA, i.e. improvement options were foremost sought in areas/life cycle stages with a high environmental impact.

Project targets for identification and implementation of significant environmental improvements options are exceeded. On average, 2.3 significant ideas were identified per investigated product and on average 1.5 ideas per product were also implemented. The large difference between companies is, at least partly, explained by the following:

- No formal eco-design workshops were carried out in Denmark. (Danish Company B and C discussed eco-design

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1. Significance was originally defined as 30% improvement in any of the EPD impact categories. For products having the dominant impact in the material production stage, this turned out to be very hard to achieve. It would for example imply cutting the weight of such products with much more than 30%, everything else being equal. Instead two classes of significance were used.
options at several occasions with internal technical staff, suppliers and customers and Melitek had improvement options on the agenda of several meetings with the scientific partner.

- In Portugal, the so-called life cycle design checklists [39,40] were used as additional tools for finding improvement ideas. As these provide practical improvement tips based on several eco-design strategies, this could explain the large number of ideas generated by the Portuguese companies.

- Product cycles are normally longer than the one-year time allowed by the project for implementation. Mercatus is an exception. For them, every new order is a unique installation.

### Table 2: Product environmental improvement options

| Company                  | Producta                      | Main result of life cycle assessment                                           | Improvement ideas | Implementation
|--------------------------|-------------------------------|-------------------------------------------------------------------------------|-------------------|------------------|
| Prototyper AB            | Metal covers for battery pack of forklift | At small series the tool material is environmentally dominant, favouring the Quintus press that only needs one tool half | 7 3 3 0 | No new model to implement ideas on
|                          | Forming of prototypes in sheet metal | At longer series (>300) product material is environmentally dominant, favouring the hydraulic press because potential for less scrap Most economical is the same as lowest environmental impact [27,28] |                      |                  |
| Mercatus Engineering AB  | Membrane filtration, flue gas condensate Membrane filtration, general purpose | Electricity consumption during use (for pumping) dominates all environmental impact categories [25,29] | 12 2 2 0 | Eight ideas implemented in different orders
| Etac AB                  | Toilet armrest                | The production phase dominates all environmental impact categories [30]       | 23 7 0 0 | Four ideas implemented in new model
| Konto Ltd                | Wooden panel for furniture    | Four main environmental improvement areas were identified Heat generation, transportation to customer, forestry and logging and electricity generation [31] | 4 0 4 0 | One new boiler installed
| Melitek A/S              | Plastic compound for medical and healthcare products | Focus on benchmarking with material combinations from competitors Improvement options by choice of supplier in Europe not possible due to quality requirements [32] | - - - 0 |                  |
| Danish Company B         | Wheelchair                    | Aluminium and other material components dominate the environmental profile Reuse and recycling of wheel chair partly implemented as improvement option [33] | - - - 0 |                  |
| Danish Company C         | Mini wastewater treatment plant | Electricity consumption during use (for pumping) dominates all environmental impact categories [34] | - - - 0 |                  |
| Cruzinox Lda             | Pressure cooker               | Electricity consumption during use dominates all environmental impact categories (between 92 and 98% of totals) [35] | 64 1 0 0 | 39 Ideas will be incorporated in new model
| Polisport Lda            | Bicycle seat                  | The extraction and production of raw materials (stainless steel and polypropylene) dominate all impact categories (between 96 and 99% of totals) [36] | 49 1d 0 0 | Four material reduction ideas will be implemented in new baby seat Bilby
| Concretope Lda           | Ready-mixed concrete          | The extraction and production of raw materials (clinker) dominate all impact categories (between 96 and 99% of totals) [37,38] | 4 0 0 0 | 2

Totals: 162 14 9 15 Implemented

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\* Here is mentioned only the product(s) that was the subject of the study, the EPD.

\* Definitely better than today (5–30%); A lot better than today (>30%). The percentage refers to improvement in at least four of the five environmental effect categories: global warming, smog, eutrophication, acidification or ozone depletion. Note that this is quite a conservative significance criterion because a lot of improvement options cannot be evaluated with these impact categories, e.g. all options related to toxicology.

\* Already implemented or implementation started so much that it is highly likely that the idea will be fully implemented.

\* Combined the four material reduction ideas achieved 5% improvement. Another five ideas led to further activities.
The maturity of the product. It is for example not surprising that it is more difficult to find significant improvement options in a standard product like a pressure cooker, compared to membrane filtration where every installation is a unique design.

- The amount of control of the dominant impacts. At Huskvarna the huge cutting losses (60%) pile up on the shop floor. Polisport does not see their corresponding losses of stainless steel since they occur at a sub supplier, hence they did not generate any ideas relevant to these losses.

- The limited amount of impact categories. For example, since toxicity is not included among the used impact categories (for lack of a universally accepted method), it was not possible to judge the significance of improvement options related to toxicity.

The companies carrying out idea generation workshops were generally very enthusiastic about the findings. In fact, many of them describe the main benefit of doing a Stepwise EPD as one of learning more about their product’s environmental performance and how it can be improved. The idea generation workshops together with the examination of the LCA and drafting of the EPD (step 4 of the Stepwise process described above) were the main activities for achieving this learning.

Two companies, Danish Company B and C, did not learn anything from doing the LCA and drafting the EPD. Their main explanation for why they did not learn anything is that they already knew a lot about their product’s environmental merits and performance.

3.4. Market communication

This section will explore the assumption that the EPD can be used to communicate a product’s environmental profile to potential customers thereby creating a demand for such products with improved eco-efficiency. Project targets associated with this assumption were as follows:

- to attract, during the two-year project, at least one new customer per SME thanks to the EPD, with total order prospects exceeding 600,000 Euro;
- to identify at least 10 different ways of using the EPD in marketing of product and/or company.

Table 3 outlines the activities of the case study companies and the results achieved in relation to using the EPDs for market communication.

As shown in Table 3, in terms of new orders, customers’ responses on the Stepwise EPDs were disappointing. Only Etac AB experienced that the Stepwise EPD actually qualified them to take part in a bid (concerning building products) that they would otherwise have been excluded from. Some companies (Mercatus, Melitek, Etac, Polisport and Cruzinox) mention general strengthening of the image and likely long-term effects on sales thanks to the Stepwise EPD.

As mentioned above, the main motivation for the SMEs to participate in the project was an anticipation of a demand from some key client or client group. In only one case, Melitek, this anticipated demand was confirmed.

In terms of identifying different ways of using the EPD in marketing of product and/or company, project targets are exceeded in quantitative terms. In more qualitative terms, market communication ways that met with a positive customer response were as follows:

- **Meetings or work sessions with clients focusing on the results of the LCA rather than on the Stepwise EPD.** Examples are Melitek’s work sessions with a major pharmaceutical client, Etac’s meeting with public procurement body Westma and Huskvarna’s eco-design workshop with the truck manufacturer BT.

- **Sending the Stepwise EPD with bids.** Etac, Mercatus and Concretope used this way and got a positive customer response. Etac even claim to have won a contract that they could not have won without the EPD, see above, although no order sum has been confirmed.

- **Presenting the EPD at sales meetings.** Melitek, Mercatus, Cruzinox and Konto got various positive responses from presenting the EPD to customers at sales meetings, ranging from appreciation without further interest to discussions on possibilities to differentiate the product from other similar products.

However, the three ways of communicating a Stepwise EPD with potential or established clients described above are not always successful. As can be seen in Table 3, Danish Company B and C got nothing but negative responses when presenting the EPD to clients and other stakeholders in both sales meetings and more environmentally focused meetings.

A research question was if customers in some sectors are particularly amenable to EPDs. Both Etac and Concretope experienced that some form of environmental declaration is a requirement in the building sector. This sector has a long tradition of using different declarations (material, environmental, energy, etc) and this is now being streamlined in an international standard [21].

Even though some positive aspects of EPD as a marketing tool are highlighted above, all of the companies also experienced EPD as a difficult marketing tool. Too technical, does not tell you if the product is environmentally good or bad, incomprehensible terminology, perceived lack of some well-known environmental problems, nothing to compare with and not enough graphics were some typical customer reactions.

The assumption that the EPD can be used to communicate a product’s environmental profile to potential customers and creating a demand for products with improved eco-efficiency could not be verified by the case studies. As will be discussed below, the underlying LCA shows more potential in this respect.

4. Discussion

The discussion will focus on two perspectives: the usefulness of Stepwise EPDs at society level and the usefulness of Stepwise EPDs at company level.
<table>
<thead>
<tr>
<th>Company</th>
<th>Customera</th>
<th>Used ways of communicating</th>
<th>Customer response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huskvarna Prototyper AB</td>
<td>BT, producer of forklift trucks Automotive industry</td>
<td>Eco-design workshop with client BT E-mail to customers’ personnel in charge of environment issues</td>
<td>Good response from BT designers, but no interest in EPD No noted response No response yet</td>
</tr>
<tr>
<td>Mercatus Engineering AB</td>
<td>Power stations burning waste or biofuels Process industry</td>
<td>Given to clients during sales meetings with the words: “We have done an LCA. We know how our equipment impact on the environment” Sent with bids for public contracts including the UN CEO included in general presentation of company Environmental part of environmental technology verification</td>
<td>Appreciation but no interest in any details of the EPD. Not triggering any further discussions No response yet Strengthening company image No response yet</td>
</tr>
<tr>
<td>Etac AB</td>
<td>Retailers of building products Public procurers</td>
<td>Sent with bids for public contracts Meeting with public procurement body Westma Customer service</td>
<td>Bids in the building sector required an EPD EPD can be used for establishing relevant product requirements in public purchasing No recorded response</td>
</tr>
<tr>
<td>Konto Ltd</td>
<td>Furniture industry</td>
<td>Questionnaire to customers Given to clients in sales meetings Information about Stepwise EPD in printed materials about Konto</td>
<td>One out of seven customers thought that EPD could be positive for business. The rest were more negative No order yet due to the EPD but it contributes to the customers having a more positive picture of Konto Very positive response. Cooperation continues Impressed. Reinforces Melitek’s green image</td>
</tr>
<tr>
<td>Melitek A/S</td>
<td>Pharmaceutical companies</td>
<td>Several discussions and work sessions with one key customer Presentation to 5–10 other customers</td>
<td></td>
</tr>
<tr>
<td>Danish Company B</td>
<td>Public institutions such as nursing homes, hospitals, day care centres and municipalities</td>
<td>Presenting the EPD to environmental and technical managers and discussing the need for environmental documentation of products Presenting the EPD to public procurers and asking for a written evaluation of the EPD as a tool for green public procurement Meetings with therapists responsible for selecting rehab aids focusing on how to select rehab aids based on environmental merits An open questionnaire to visitors to the Scandinavian rehab exhibition</td>
<td>The EPD is too technical, not understandable and not credible. Cost, not environment is important when purchasing rehab aids The EPD is of no use in this context; it is too technical. Environmental issues are not important compared to issues like price Lot of support for the idea of going green, but the information has to be brief and present real advantages for customers and users. Cost, not environment is important The environmental information must be brief, relevant and present real advantages for the customer. Instructions or labels on the product are preferred</td>
</tr>
<tr>
<td>Danish Company C</td>
<td>Mainly private property owners in densely populated rural areas, who buy from local plumbers, who buy from wholesalers</td>
<td>Presenting the EPD to wholesalers and local plumbers and discussing the need for environmental documentation of products Presenting the EPD to municipal environmental authorities responsible for regulating the wastewater treatment locally and discussing the use of the EPD as a means to facilitate the environmentally sound solutions to be approved in a local area Informal meetings with visitors to an environmental exhibition</td>
<td>Too technical, not understandable, not credible Does not answer the questions relevant for the kind of political and technical decisions related to local wastewater treatment policy Not relevant — how does it work, and what is the price?</td>
</tr>
</tbody>
</table>

(continued on next page)
4.1. Usefulness at society level

Within the context of an integrated product policy, it is important how environmental product declarations can interact with a number of other instruments in the IPP toolkit. Below is discussed how EPDs in general and Stepwise EPDs can advance type I labelling, public procurement, product legislation and supply of verified LCA data.

4.1.1. Public procurement criteria setting

Public procurement body Westma, buying mainly for the hospitals in western Sweden, already today make use of EPDs when they develop environmental criteria for different product groups. The project partner Etac had a discussion with Westma about their EPD on a toilet armrest. This public procurement body was very enthusiastic about engaging with proactive companies to aid them in deciding on relevant environmental criteria. It was, however, pointed out that only a handful of Swedish public procurement bodies today have the necessary expertise to appreciate a life cycle assessment and make use of the information for developing environmental criteria.

Also project partner Danish Company B approached a public procurement body, but they got the response that the EPD is too technical and that environmental issues are not important compared to the issue of price. The difference in response between the Swedish and the Danish public procurement body is not so large as it may seem. Also the Swedish body Westma declared clearly that the EPD as such would not give any extra points in a competitive bid; at most the EPD could be used to verify pre-determined criteria. Thus, from a societal perspective EPDs can be useful when deciding on product criteria in public procurement, but it requires more expertise than is generally available. That EPDs can be useful in the context of green public procurement has been pointed out in other studies [6,41].

From a company perspective, direct credits for an EPD in a competitive bid should not be expected. However, an EPD and LCA can influence the environmental criteria for a product group. This could put the company who made the EPD in a more favourable market position.

4.1.2. Step towards type I labelling

One idea that has been discussed in the Stepwise project and in other studies [6,42] is that EPDs could help identify new product groups for the EU eco-label (and/or other eco-labelling schemes). Today, eco-label programme operators have to invest quite a lot before they can “open” a new product group. A market survey is needed. Environmental criteria have to be developed and some sort of cost—benefit analyses of the environmental improvement potential has to be done. All this work has to be done together with the concerned
industry sector. An EPD, even a Stepwise EPD, would give a first indication of the environmental improvement potential and relevant environmental criteria without costing the eco-label programme operator anything. A full EPD would engage the industry sector in this work and take the environmental analyses even further, still at no expense for the eco-label programme operator.

4.1.3. Introducing product legislation

Modern environment related product legislation must be based on a life cycle perspective in order to avoid sub-optimizations. The most prominent example is the European directive on energy-using products [43], which prescribes the use of life cycle assessments combined with life cycle cost calculations to identify those eco-design requirements that could/should be regulated. It is not difficult to imagine proactive companies making EPDs based on life cycle assessments that will show considerable improvement potential and thus introducing new product groups or product areas as target for regulations. The possibility for companies to support public initiatives with LCAs has been noted by, for example Frankl and Rubik [44].

4.1.4. Supply of verified LCA data

Numerous public documents [1–3] describe a need for verified product information on the life cycle environmental impacts. Among other, good product information is seen as a necessary condition for effective market-facing product policies, support of eco-design and innovation in product development and making the market into a powerful force for delivering environmental improvement [3]. An EPD is a verified information about a product’s life cycle environmental impacts, thus, EPDs could support effective product policies, eco-design and innovation in product development and making the market deliver environmental improvement.

4.2. Usefulness at company level

4.2.1. EPD/LCA as a basis for eco-design

For those familiar to LCA, it probably comes as no surprise that the case study companies found so many opportunities to improve their products environmentally. Doing an LCA is fundamentally a learning experience. To do brainstorming in a multi-functional group (sometimes even including clients) would give lots of improvement ideas even without an LCA. However, combining the two gives more weight and credibility to the results and could explain the high implementation achieved.

A common question [6] is: Why do an EPD? Is it not enough with the LCA? One answer is that the Stepwise EPD concept is potentially cost-effective because it is based on streamlined LCA and that it is standardized to a large extent. The aim is to do the whole process in 6–8 days each for the company and the consultant [45]. Normal LCA can vary between six to as many as you can afford days. Another answer is that unless you communicate with your customers about the environmental excellence of your new design, they may not ask for it, so ultimately, you will need a communication tool. It should also be considered that company-internal communication is very important for eco-design implementation as pointed out by Simon et al. [46].

It should be noted that the criteria used to evaluate whether or not an improvement idea was significant was quite hard to achieve, especially for “mature” products. Furthermore, improvement ideas related to environmental issues not covered by LCA, e.g. toxic substances, would by default be characterized as non-significant. Nevertheless, the case study companies found on average 2.3 significant ideas per product and implemented on average 1.5 ideas within the two-year project time frame. If this can be achieved for the prize of 6–8 days each for the company and the consultant (which has not been shown), it must be considered cost-efficient.

The downside of using LCA is that it is so comprehensive that it by necessity becomes too complex to be easily understood. Some of the case study companies experienced LCA as a black box and when the figures did not make sense to them they lost faith. The solution, close cooperation between an LCA practitioner and the company expert resolved such difficulties in most cases but not in all cases.

4.2.2. Public procurement

As mentioned above a company cannot expect to get direct credits for an EPD in a competitive bid. However, an LCA-based EPD can influence the environmental criteria for a product group. This could put the company who made the EPD in a more favourable market position compared to its competitors. At present, however, few public procurement bodies have the capacity to appreciate and use a life cycle assessment for criteria setting.

4.2.3. Communication in the supply chain

All participating SMEs were disappointed by the poor response from customers in general on the Stepwise EPD, although there were some exceptions with individual clients. This indicates that the Stepwise EPD-format is not that suitable in normal marketing of products. Few times the case study companies felt some appreciation of the Stepwise EPD in a marketing/sales situation were when little time and attention was spent on any details of the EPD. The claim to have made an LCA and waving the proof, like Mercatus, worked to an extent whereas taking time to present the EPD in detail resulted generally in critique for incomprehensible terminology, lack of well-known environmental problems, nothing to compare with, not enough graphics, lack of credibility, etc.

Meetings or work sessions with clients focusing on the underlying LCA rather than the Stepwise EPD met with more appreciation. Examples include Melitek’s work sessions with a major pharmaceutical client, Etac’s meeting with public procurement body Westma and Huskvarna’s eco-design workshop with the truck manufacturer BT. Also the company-internal eco-design workshops could be seen as examples of that the LCA behind the EPD is a powerful platform for communication.
LCA as such stimulates cooperation in the supply chain as one needs to ask ones suppliers about environmental data and the end-users about how they use the product [6]. Vattenfall, who took part of in the project as a mentor, has experienced that just by asking suppliers regularly about certain data can induce environmental improvements. A Stepwise EPD, which uses generic data for upstream processes, does not automatically engage with the suppliers and end-users like a normal LCA (or full EPD) does. However, the few attempts that were made in the project to engage clients in a dialogue about how to improve the products environmentally were very promising. More promising than the often-exasperating attempts that were made to use the Stepwise EPD as a sales argument.

The Portuguese companies wanted to print the Stepwise EPD logo on product packaging. Since Stepwise EPDs are not a programme this is not allowed according to the Stepwise guidelines [11]. EPDs supported by a proper programme would generally allow such use of the logo. Hence, real EPDs have a better potential as a marketing instrument than Stepwise EPDs.

A commonly heard barrier or critique against EPD is that it will be too demanding and costly for a company to make EPDs for all their products and keep them updated as the products change. Several of the case study companies expressed this as a barrier. Doing EPDs only on strategically chosen products and concentrating more on the general lessons learned from the LCA than on the numbers in the EPD, is a way of avoiding this barrier.

4.2.4. Comparisons

For the Stepwise EPD case study companies the need to be able to compare or relate the abstract impact figures has been a very important issue in order to facilitate the communication with the EPD — how does my product perform in comparison with others? In the mid-term meeting it was concluded that the value of an EPD would be much higher if it could enable this comparison. Also other projects related to EPD have pointed to improvement potential regarding interpretation of data and comparisons, see for example Refs. [5,48].

ISO 14025 and the EPD programmes are designed to make comparisons between competing products possible. The elaboration of Product Category Rules is the key facilitator of such comparisons. But in most of the cases competing EPDs to compare with simply does not exist yet [6,49]. On the other hand, comparisons with competing products within one and the same EPD are not allowed according to ISO 14025 [18]. With support in ISO 14021 [47], the Stepwise EPD guideline [11] recommends that comparisons or relations be performed regarding:

- The company’s own prior or existing process or product;
- Realistic product usage scenarios/options;
- EU, national or product group average information often referred to as normalization. Layout 2 developed for the Danish SMEs in the Stepwise EPD project includes an option to compare the impacts relative to the impacts of spending the same amount of money on the average product in the same category [32–34].

In the Stepwise EPD of Huskvarna Prototyper AB [27], forming of sheet metal prototypes with a Quintus press is compared to forming them in a hydraulic press, at two different batch sizes. Fig. 3 helps to illustrate the knowledge gained from the LCA that at small series the tool material is environmentally dominant, favouring the Quintus press that only needs one tool half. At longer series (>300) the product material is environmentally dominant, favouring the hydraulic press because of its potential for less scrap.

5. Conclusions

Following on from the main assumption of the Stepwise EPD project that EPDs are good for business and for the environment, three underlying assumptions were put to test in the case studies as discussed above.

The assumption that producing the Stepwise EPD, or rather performing the underlying life cycle assessment, can be used as a basis to identify eco-design options, was verified in eight out of the ten case studies. A lot of improvement ideas were generated and some, 1.5 ideas per product, were also implemented within the 27-month time frame of the project.

The assumption that the Stepwise EPD can be used to communicate a product’s environmental profile to potential customers thereby creating a demand for such products with improved eco-efficiency could not be verified. All case study companies were disappointed by the lack of appreciation for Stepwise EPDs in normal marketing activities. More in-depth discussions with selected clients focusing on the LCA rather than the EPD had more success, but only a few of the case study companies tried this.

The third assumption that the customer demand and the identified improvement options would bring about actual improvement in products’ eco-efficiency, could not be verified since no customer demand was created. Yet, 15 environmental improvement ideas were implemented. So it seems that an
explicit customer demand is not always necessary for implementing environmental improvements. It should be the focus of future research what exactly is driving the implementation of environmental improvements. In a more general sense the case study companies in the project have identified and experienced the following barriers and opportunities with Stepwise EPDs:

- The lack of a market pull for EPDs, as experienced in all ten case studies, is a serious barrier for the use of EPDs in marketing and sales. It is of course also a barrier for spreading of the EPD concept as such, as EPDs fundamentally are seen as marketing instruments.
- The lack of EPDs as such is a barrier to comparing similar products environmentally. There is rarely more than one EPD available in each product group.
- The difficulty in understanding the language of LCA and EPD is a serious barrier for most applications. The Stepwise EPD project has experimented with comparisons of different kinds as a means to overcome this barrier. Much more work is needed in this area.
- There is an opportunity for public procurement bodies to use EPDs during formulation of relevant environmental criteria for different product groups. Lack of environmental expertise in public procurement bodies is a barrier in this context.
- When viewed as a market instrument, doing and maintaining EPDs for all the products of a company, is often a barrier because of time and cost. Doing EPDs only on strategically chosen products and concentrating more on the general lessons learned from the LCA than on the numbers in the EPD, is a way of managing this barrier.
- The project has shown that doing a Stepwise EPD and combining it with a brainstorming exercise will generate many opportunities to improve a product environmentally.
- Using the LCA/EPD as a platform for eco-design and supply chain communication could be an opportunity for smaller companies to engage with larger clients, as experienced by some of the case study companies. Reversed, LCA/EPD may be a suitable platform for larger companies in a supply chain to manage environmental issues in the chain upstream and downstream.
- There is an opportunity for governments to ensure a supply of verified information on the life cycle environmental impacts of products by supporting and promoting projects, programmes and initiatives on EPD.

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Product orientation of environmental work – barriers & incentives

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