PRODUCT-ORIENTED ENVIRONMENTAL MANAGEMENT STRATEGIES

An input to strategic discussions in companies

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Summary:

This report is a revised and updated version of a paper that was written as part of the Leca International Environmental Project. The main aims of this report are to give an overview of the elements in a product oriented environmental strategy, and to give input to discussions about how to develop an environmental management system further.

The aim of the tools and methods presented, is to identify the most important elements in the product systems, to identify the best solution (or set of solutions) and to communicate these data in a good format for new users.

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List of abbreviations

EMAS	Eco-Management and Audit Scheme
EMS	Environmental Management Systems
EPD	Environmental Product Declaration
EPI	Environmental Performance Indicators
ISO	International Standardisation Organisation
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
POES	Product Oriented Environmental Strategies
QFD	Quality Function Deployment
SETAC	Society for Environmental Toxicology and Chemistry

1. INTRODUCTION TO THE REPORT

This report is a revised and updated version of a paper that was written as part of the Leca International Environmental Project. The main aims of this report are to give an overview of the elements in a product oriented environmental strategy, and to give input to discussions about how to develop an environmental management system further.

2. HISTORY OF DEVELOPMENT OF ENVIRONMENTAL MANAGEMENT STRATEGIES

Environmental problems and resource depletion have been important challenges in the business sector all over the world during the last 5-10 years. Historically, most of the industrialised countries, in their efforts to reduce pollution and waste generation, have tried to obtain success with the following four strategies:

1. **The diluting strategy** based on high chimneys into the air and pipelines into lakes, rivers and the ocean. This strategy was used in the 1950's and the 1960's. The common opinion at that time was: if the pollution was spread over a large area, it would do no harm.
2. **The filter strategy** based on end-of-pipe installations. In the 70's and the 80's it was a common opinion that this strategy was the best solution to most environmental problems. However, it was realised that these solutions often transfer or transform one environmental problem to another (from water pollution to hazardous waste).
3. **The recovery/reuse strategy** started in the 1980's. A lot of environmentally friendly activities were carried out and produced results we appreciate today: reuse of paper, glass etc. However this strategy does not deal with the process or problem itself, but often focuses only on used products and recovery of raw materials in waste products.
4. **The cleaner production strategy** emerged in some countries from the late 1980's, and has been the most important pollution prevention strategy in industrialised countries in the 1990's. This strategy is based upon reducing the environmental problems by source reduction and focuses mainly on internal industrial processes.

Just as the 1980s witnessed a shift from end-of-pipe technologies to cleaner production, environmental strategies are now shifting the focus from processes to products. Proactive companies have switched to preventive strategies, based on life cycle consideration of environmental problems related to their products.

5. **Product-oriented environmental strategies.** Life Cycle Assessment (LCA) is one of the important tools in this new strategy. It is the only methodology available that assesses the total environmental load related to the life cycle of a product system.

Product-oriented environmental strategies and life cycle assessments are new approaches to environmental management in companies. This is also reflected in the policy development of environmental authorities. More and more focus is given to market-oriented, preventive policy and regulating measures. Both national authorities (e.g. in Netherlands, Sweden, Norway) and the European Commission have developed policies based on Integrated Product Policies for the Environment.

An interesting observation is that even proactive companies that have changed to preventive strategies have further challenges. The companies which used «green business» as a positioning factor two or three years ago, now find that the same factors are regarded as mandatory today.

Environment as a mandatory system:

- Focus on simpler, more easily achievable solutions
- Environmental concern, one of several factors to be considered in decision making
- More traditional process-orientation to problems
- Focus on ISO 14000 or EMAS (process oriented)
- Case to case application of environmental tools

Environment as a positioning factor :

- Focus on innovative, sustainable solutions
- Environmental concern as a business opportunity
- Product-oriented strategies, life cycle and systems approach in EMS
- Early users of new, innovative tools (LCA, EPI, EPD, Industrial Ecology etc.)
- Systematic implementation of tools and knowledge

3. MAIN OUTLINE OF A PRODUCT ORIENTED ENVIRONMENTAL MANAGEMENT STRATEGY

The main difference between a product-oriented environmental management system and the more traditional management systems, is that the whole life cycle of products and business activities of the companies are considered. This means that both the number of activities involved in a system is increased, as well as the number of actors internally and externally.

In a product-oriented environmental strategy, focus might be given to areas both upstream and downstream of a company's own processes. For a product producer, strategies related to upstream areas might be:

- Selection of more eco-efficient raw materials
- Selection of more eco-effective energy sources
- Selection of better suppliers

- Selection of more eco-effective transport solutions

Downstream, a company can

- Increase the effectiveness of the application of their products
- Change their product portfolio towards more “green range” products
- Recycle materials from products after use, and substitute for other, virgin materials

Within their own production plants, producers can also

- Reduce emissions to air and water
- Reduce waste generation from production processes
- Reduce energy consumption in the production process

In addition, there might be a lot to do in providing better information to the users, especially about using the right product in the right way.

The aim of the tools and methods presented in the next chapter, is to identify the most important elements in the product systems, to identify the best solution (or set of solutions) and to communicate these data in a good format for new users.

4. BASIC TOOLS AND METHODS WITHIN A PRODUCT ORIENTED ENVIRONMENTAL MANAGEMENT SYSTEM

4.1 Life Cycle Assessment

Life Cycle Assessment (LCA) is a systems approach, taking into consideration all environmental aspects of a given product system. It considers the full technical system related to a product from ‘cradle to grave’, i.e. from raw material acquisition to final waste treatment of waste products. Figure 1 illustrates the main structure of an LCA:

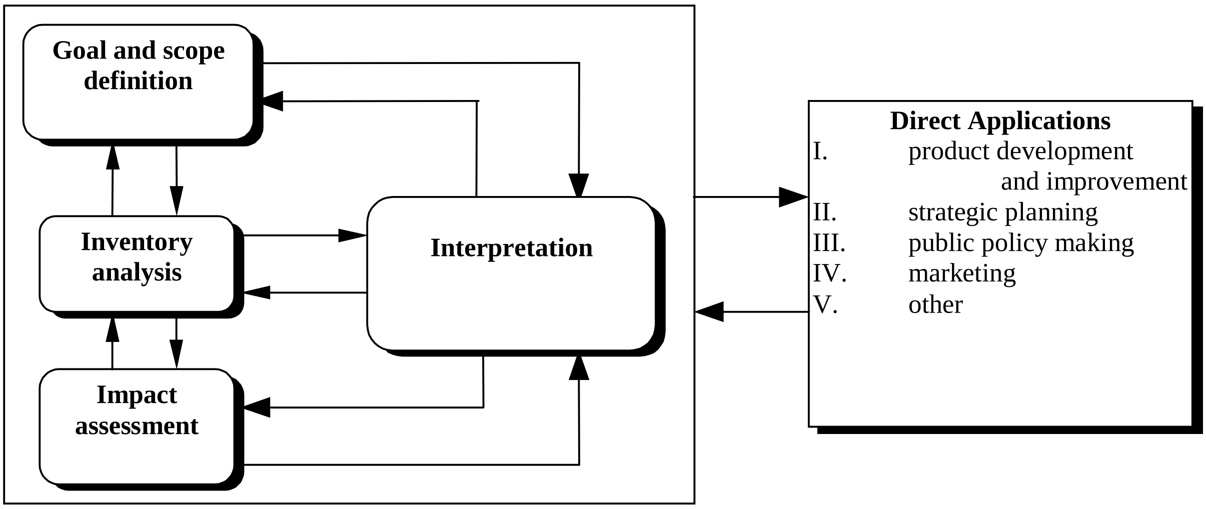

Figure 1 Main Structure of an LCA project (ISO 14040).

Carrying out an LCA is an iterative process where quantifying material and energy flows in the product system is followed by an assessment of their impacts. This should then feed into an Improvement evaluation step, so that the inventory and assessment results can be used to identify areas of improvement. In this way LCA can be used as a tool to identify and evaluate areas where environmental improvements can be made and then as a benchmark for future development.

The modern history of LCA started in 1990, when Society for Environmental Toxicology and Chemistry (SETAC) initiated its broad study on method development and harmonisation of LCA methodology. There have been several workshops, with comprehensive reports documenting the main findings and conclusions. Status for the ISO TC207 process after the last meeting in Rome June 1998 is as follows:

ISO 14040: General framework; International Standard approved.
ISO 14041: Inventory: International Standard approved.
ISO 14042: Impact Assessment: International Standard approved.
ISO 14043: Interpretation: International Standard approved.

For further description of LCA-methodology see Appendix 1.

New tools have also been developed based on LCA methodology, for communication of environmental data internally and externally. Environmental Performance Indicators (EPI) is one method to develop eco-efficiency indicators for the total organisation. They can be used both internally in decision making and management systems, and as the basis for external communication and reporting. Another tool is Environmental Product Declarations (EPD), which is third party certified information about the eco-efficiency of products. ISO standards for both methods are now published, ISO standards 14031 and 14025 respectively.

4.2 Environmental performance indicators

Environmental Performance Indicators can be used for:

- **Formulation of objectives:** Putting focus on essential areas, based on important environmental affects and the stake-holders' needs. Identification of where it is necessary to set environmental objectives for activities, in relation to both the company and the product.
- **Description of results:** The indicators will provide a measurable value for the company's achievements and show developments over time.
- **Reporting, internal and external:** Environmental Performance Indicators can be used to obtain environmental data for annual reports, or other types of report.

Environmental Performance Indicators (EPIs) provide the basis for setting environmental objectives and can be used as part of environmental reporting amongst other things. EPIs can be put into a management loop as shown in figure 2.

Figure 2 is a sketch of how EPIs can form the basis for the setting of environmental objectives in connection with Environmental Management Systems.

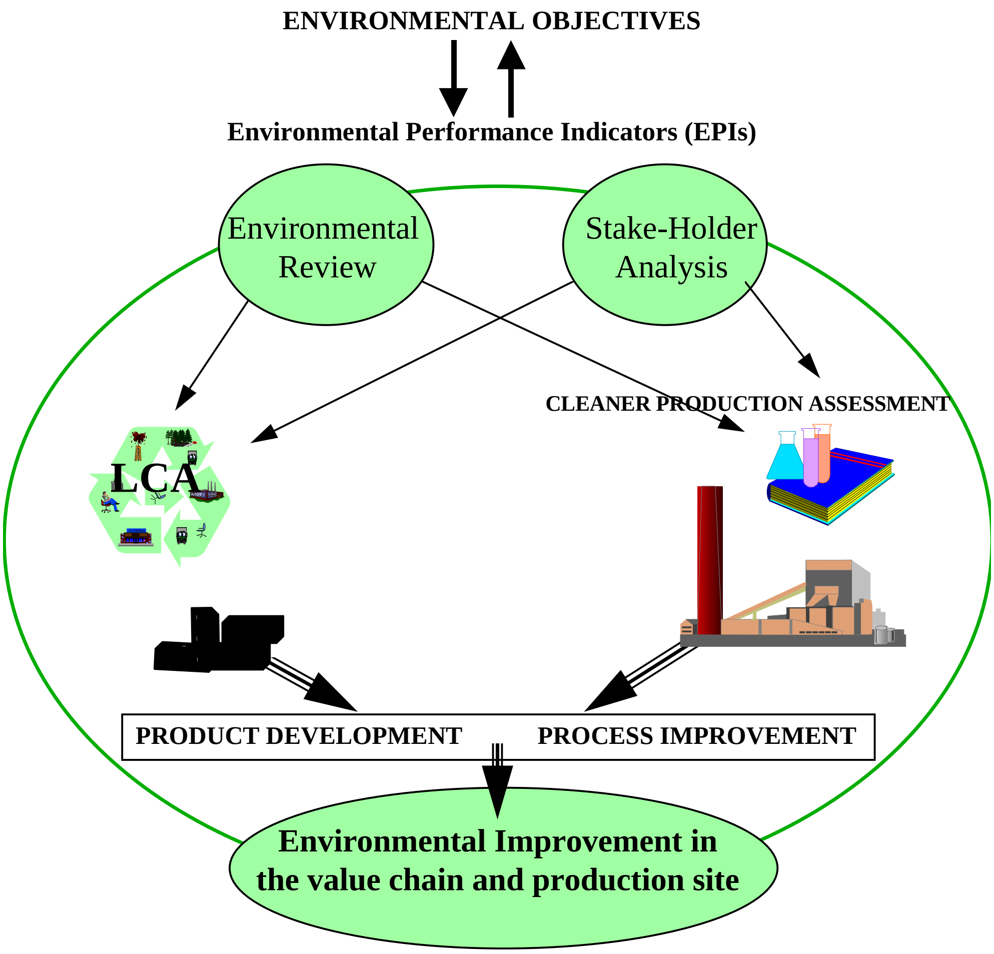

Figure 2 Environmental Management Systems and Environmental Performance Indicators

The EPIs should be developed considering an actual environmental review and a survey of the most important stake-holders' needs. With this approach it is also important to prepare for EPIs on both a company and product level. It is therefore recommended that a review of the products (LCA) and of the actual production site (cleaner production assessment, safety, health and environment documentation) is performed. Also a survey of the different stake-holders' needs for environmental information should be performed. This should again be on a product and company level. With the help of this information EPIs can be developed. The information described is used to set environmental objectives and is input to product and process improvement initiatives. It is the basis for documentation of achievements (the baseline for reviewing purposes) and so is suitable for setting new goals after improvement initiatives are implemented.

Environmental Review

None of the standards, or directives for Environmental Management Systems (EMS) provide methodology for how an environmental review ought to be performed. Often the focus is just on environmental data connected to the production site. In order for an environmental review to be usable as the basis for setting environmental objectives over and above activities occurring inside the factory gate, it is also important to undertake a survey of the environmental data for the products. The environmental survey/review should also focus on both the company and their products, see figure 3.

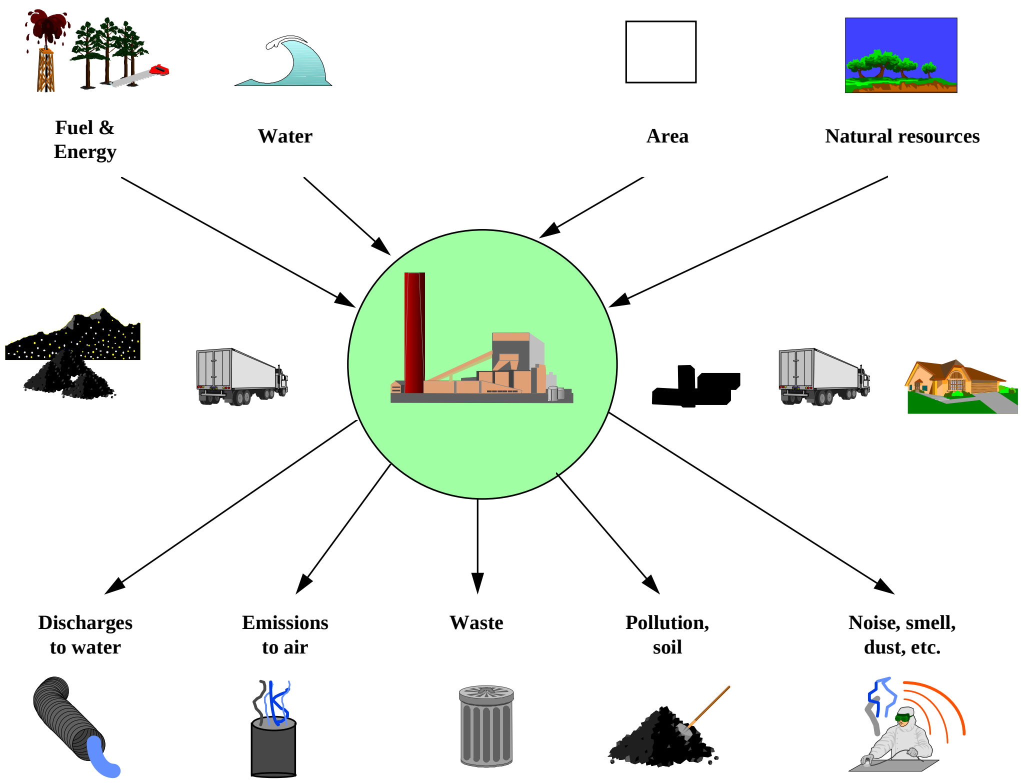

Figure 3 The Main Components of an Environmental Review

Companies ought to assess environmental effects from their products through the whole of the products' life time. This should be done using a life cycle assessment of the products. In addition to this the choice of environmental performance indicators should be based upon an understanding of the most important affects on the environment from site specific processes and activities. Such affects can be identified with the use of mass balances to record product, or energy loss, measurement of emissions and wastes to the surroundings, together with knowledge of the effects on the local recipients. The part of safety, health and environment systems which concerns the environment is a good starting point for this review.

From this analysis priorities for which areas shall be described with Environmental Performance Indicators are decided upon.

Stake-holder Analysis

A stake-holder analysis identifies the most important stake-holders and enables priorities to be established. Such an analysis records their demands and needs for environmental information. How the Environmental Performance Indicators shall be used, both internally and externally, is mainly decided upon by who the most important stake-holders are.

There are at least two areas which ought to be included in an assessment of stake-holders' needs:

– Are there special environmental topics that particularly interest the stake-holders?
– How would the stake-holders like the information presented?

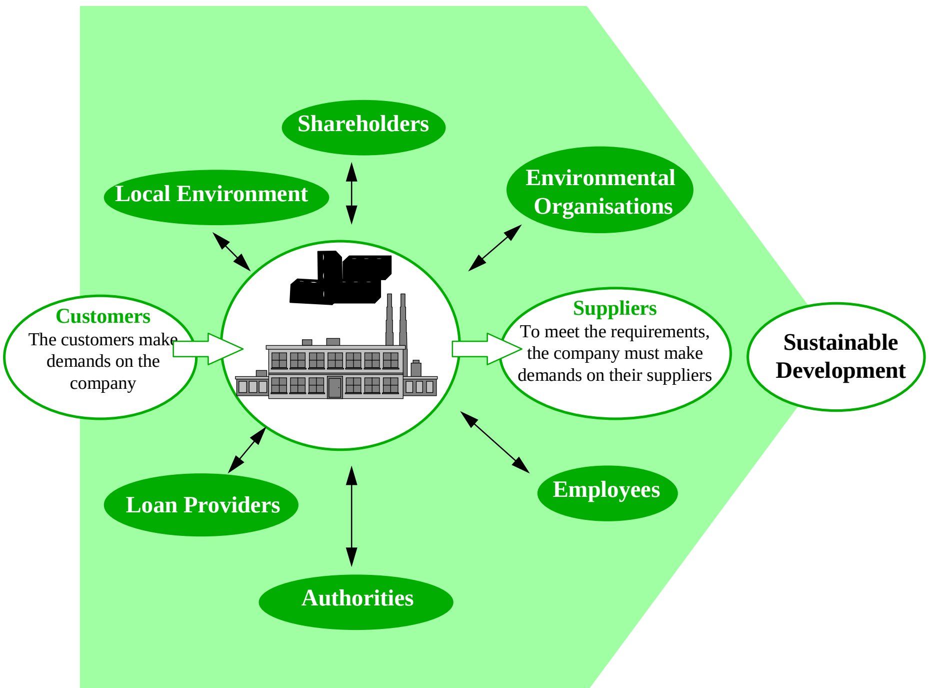

Figure 4 Different Stake-holder Groups

Essentially a lot of knowledge of the stake-holders' needs is present in the organisation. However, it should be assessed to what extent additional information can be brought in with inquiries to some of the stake-holder groups.

4.3 Environmental Product Declarations Type III (EPD)

The overall need for a system for Environmental Product Declarations (EPD) is related to the decisions taken by professional customers in companies and the public sector, to increase the long-term eco-effectiveness of business activities. EPD-systems should help companies with:

- Decision support to select the most eco-efficient product, or service system alternative
- Increasing the awareness of environmental problems related to products and product types in the society. Also increasing awareness of more environmentally sound products
- Increasing the availability of data and information about the environmental profiles of product systems in the business sector.

The most important type of application of the EPD-system is supposed to be in professional commerce. It would be used in development of criteria for environmental purchasing and in comparisons between product alternatives. The activities involved are marketing and purchasing between industrial companies, private companies and the public sector as a customer (main application).

Other types of application, which can obtain information from EPD-systems due to increased availability of certified data and information, are:

- Product development and improvement processes giving competitive advantage within companies
- Input to LCA studies - more easy available data throughout the value chain
- Regulatory work by governmental authorities (Product-oriented environmental strategies)
- Education at different levels

The most important types of decisions taken by two principally different users (end users and users of raw materials and components) are presented in Table 1

Table 1 Decisions of two main users

User of raw materials /components (Producer)	End user
• choice between components • choice of material • choice between suppliers • best assembly/production process to get a functionally efficient product	• choice between product solutions • correct use of products • choice between suppliers • what to do with the product after use • best service/maintenance practice

The main difference in user demands is that the end user needs additional information about the products user efficiency and functionality, service and maintenance and recycling, or waste treatment of materials, after product use.

5. APPLICATIONS OF ENVIRONMENTAL MANAGEMENT TOOLS WITHIN A PRODUCT ORIENTED ENVIRONMENTAL STRATEGY

5.1 Strategic decision making

There are several types of strategic decision processes which are important from a Product-Oriented Environmental Strategy view point. First of all, the types of business a company will be part of in the future, and the portfolio of products and applications of products it will give priority. Several companies have made LCA studies of their product types and used this information as a basis for decisions to switch to more "green range" products or applications (see Christiansen et al. 1995, Hanssen et al. 1995). This is for instance the case with one of the worlds larger white goods producers, Electrolux. Electrolux has defined clear goals and developed indicator systems for "green range products" (see Økstad 1997). For other companies, it is maybe important to discuss both "green range applications" and "green range products". This is because it is important to see in which types of applications the company's products are most competitive from an environmental perspective.

Another type of strategic decision which may be integrated with LCA is location of production plants in relation to raw material suppliers, energy suppliers, transport infrastructure and important customers.

5.2 Investment and financial decisions

Investment in new types of production lines and process equipment is another type of decision making process into which POES and LCA may be integrated. Examples of this are investments which make it possible to use new energy sources, new equipment for cleaning of air emissions etc. Based on experience from LCA studies of products and applications, it is possible to evaluate both the cost-effectiveness and the priority of different investment strategies.

In some countries, financial institutions are also requesting information concerning environmental aspects of new investments. Some of these institutions are now focusing on the life cycle dimension of environmental aspects. By using a POES approach, proactive companies might be better prepared for such requests when negotiating for loans, or funding of investments (see Økstad 1997).

5.3 Marketing

In a POES, green marketing is important to inform customers about the environmentally positive aspects of a product, a service, or an application. LCA might be an important basis for such marketing activities, but should be used with great care. External application of LCA results is regulated in the ISO 14040-43 standards, and needs some type of critical review by a third party to be valid.

Environmental Product Declarations of both Type II and Type III are tools to be used in green marketing. Both tools are under development for building products, and will certainly be important supplements to the more traditional Ecolabeling Schemes in Europe (see Møller et al. 1998).

5.4 Reporting

Environmental Reporting is an important part of a POES, and is required as a part of the EMAS scheme. Reporting should be based on some Environmental Performance Indicators (EPIs), based on significant environmental aspects and assessment of stake-holder interests assessment. Environmental Reporting should be based on specific goals for improvements, which under a POES these could include both raw material processing and supplier selection, as well as development of product portfolio and end-of-life aspects of products. The indicators could be selected by use of an LCA approach, not to make detailed comparisons between products, but to identify “hot spot” environmental aspects of a company’s business activities (see Økstad 1997).

5.5 Product development

The best opportunity for cost effective improvements in the product, or process properties of a company, is to integrate environmental aspects into product development processes (see Hanssen et al. 1995). This is perhaps one of the most important and most applied elements in a POES in companies today. Several methods and models are described in the literature from

Scandinavia (Hanssen et al. 1995), Denmark (Wentzel et al. 1997a, b) and the Netherlands (Brezet & van Hemel 1997).

It has been shown, with several types of products, that integrating LCA methods with Life Cycle Cost assessments might be important. This illustrates the added value for the customer, or user of a product, from environmental improvements (Hanssen et al. 1995). When an LCA has been carried out for a specific product type, it will often be possible to develop more general "rules of thumb" for designers, or product developers, to identify problems with existing products and to set criteria for improvements. For further description of this method, see Appendix 2.

5.6 Environmental management systems

An Environmental Management System will mean that a company will consider the environment in daily operation. It will be on a par with other activities like budgeting and marketing. With the aid of an Environmental Management System a company will obtain much better control over its use of raw materials and energy, what type and quantities of waste and emissions it produces, as well as how the company's activities influence, and are influenced by, the value chain of the product. figure 5 shows the activities involved in an Environmental Management System.

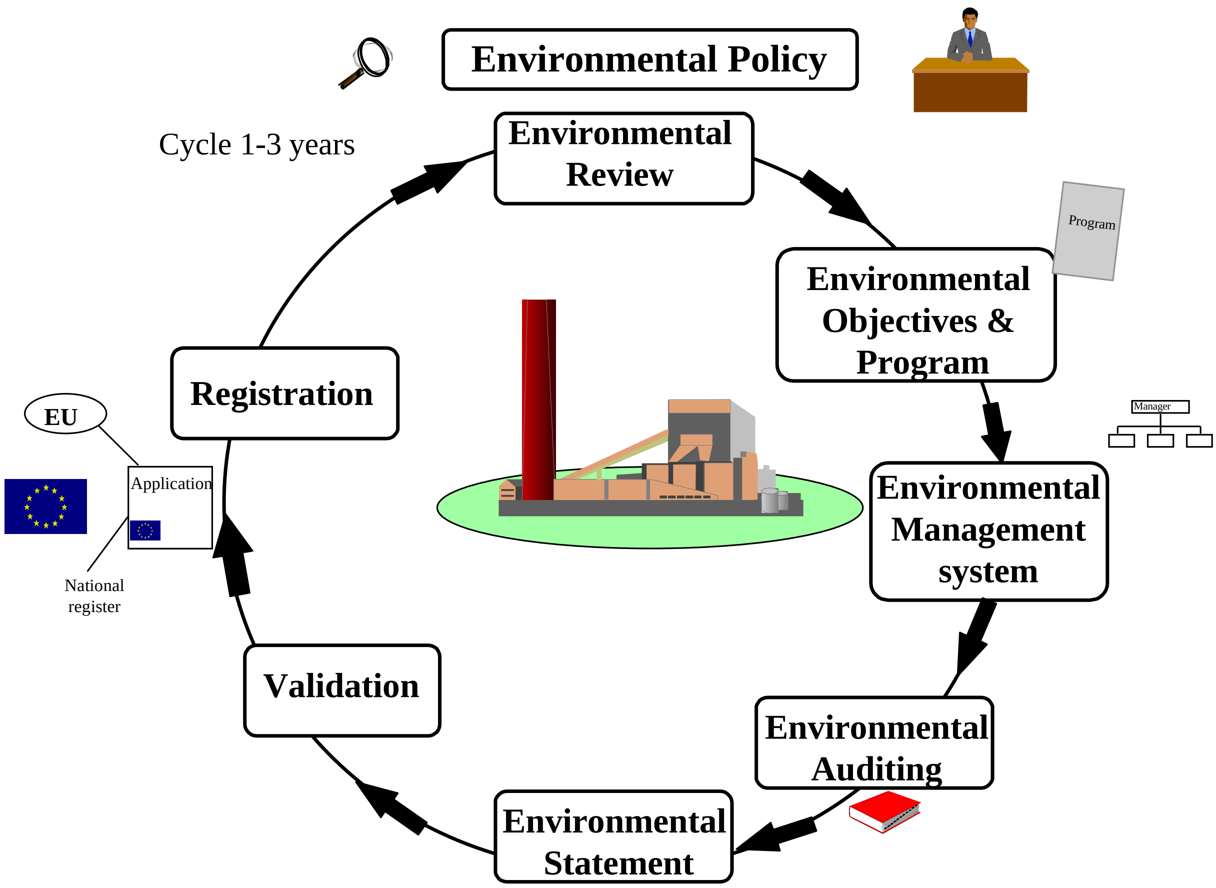

Figure 5 The Components of an Environmental Management System

Traditionally, product oriented environmental strategies have not been focused upon in environmental managing systems, as mentioned in chapter 2.

When integrating a product into EMS:

1. The environmental review is based upon both process site and life cycle assessments, with a better understanding of the company's own products.
2. Based upon the results from the environmental review, EPIs and EPDs are developed for communication of the (often) large amount of information.
3. EPIs/EPDs are used in environmental management systems to:
   - set environmental objectives for process and product improvements (improvements both on the production site and along the value chain)
   - reporting both internally and externally.

A model illustrating how these aspects are linked is shown in figure 6.

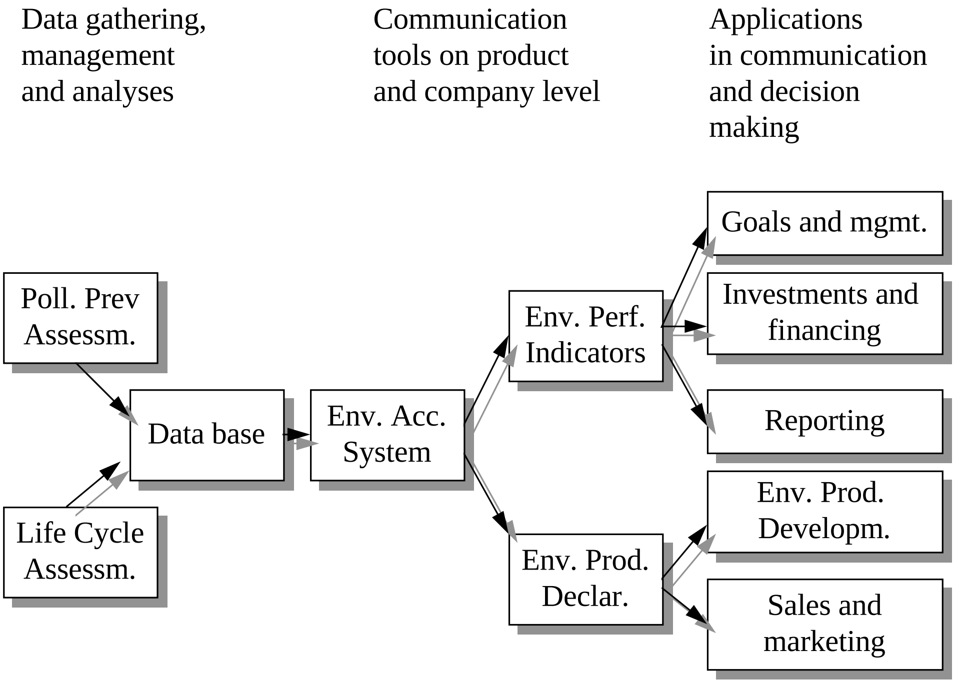

Figure 6. Principle structure of the relationship between different Environmental Management Tools and their applications in decision making and communication.

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A1. WHAT IS A LIFE CYCLE ASSESSMENT?

The following chapter gives more detail about LCA and LCA methodology than is given in the main part of this report. A detailed handbook for LCA can also be downloaded from http://www.leidenuniv.nl/cml/lca2/index.html

A1.1 Life Cycle Assessment

A Life Cycle Assessment of a product is defined as a systematic survey and assessment of environmental and resource affects throughout the whole of the life cycle of a product/product system.

A life cycle assessment is based upon a product system. It assesses the environmental impacts and resource use associated with the system throughout the whole life cycle of the product, «from cradle to grave».

Three central points in a life cycle assessment are:

- one examines the whole technical system required to produce, use and dispose of the product (system analysis), not just the product as such
- one examines the whole material cycle along the product's value chain, not just a single operation, or manufacturing process for a product
- one examines all of the relevant environmental and health affects for the whole system, not just for an individual environmental factor.

This gives a more holistic approach to health, environmental and resource problems than that we have witnessed before. Previously the focus has been upon individual factors, or processes.

Three central questions in a life cycle assessment:

- What are the most important environmental problems for a system?
- Where in the life cycle do the most important problems occur?
- What has the greatest potential to improve the product of a system, from an environmental effect perspective?

The methodological approach is based upon ISO standards ISO 14040-43.

An LCA is split up into 4 main elements:

1. Goal Definition and Scoping
2. Inventory Analysis
3. Impact Assessment
4. Interpretation

This is illustrated in Figure A1.1.

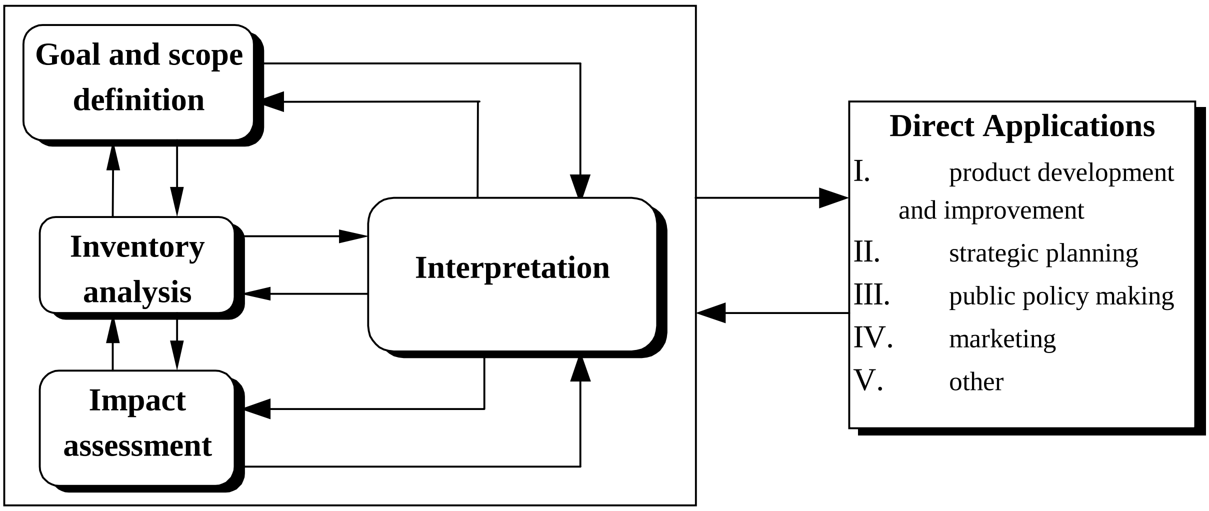

Figure A1.1 The main structure of an LCA (ISO 14040).

Each of the phases shown here can be broken down into parts, which are further described in the following sections of this report. In a complete life cycle assessment all four elements are included.

A1.2 Goal Definition and Scoping

The first element in a life cycle assessment is goal definition and scoping. This is made up of three parts, which have a decisive affect on the results of the assessment:

- problem specification
- definition of the system boundaries/product tree
- definition of the functional unit

Problem specification

As in every project, it is important to define the objectives for the life cycle assessment. This stage may have a large influence on methodology and data quality requirements, it is therefore very important to formulate the problem as precisely as possible. Some examples are:

∗ To increase the knowledge about the total environmental and health impacts of a product system, throughout the product life cycle.

∗ To compare two or more products or processes with respect to environmental and health impacts throughout the life cycle.

∗ To evaluate the potential for cost effective improvements of product systems based on life cycle information.

* To evaluate products, processes, materials, distribution systems, waste management systems etc. with respect to specific emissions, waste generation, etc.

System Boundaries

A life cycle assessment is based upon a product system, i.e. a technical/economical system which makes it possible to convert inputs (raw materials, energy, etc.) into a product with respect to:

- producing the product
- distributing the product to the users
- using the product
- ensure correct disposal of the product
- understanding all transport between the different units in the system.

In a life cycle assessment one studies all of the interactions between the technical/economical system and the ecological systems, concerning both inputs (energy and raw materials) and outputs (waste, pollution to air and water, energy loss etc.).

In order to compare the results from different products and different analyses it is important that the system boundaries are set on a similar basis, i.e. that one has similar criteria for the boundaries of a product system. In many life cycle assessments there is a documented difference in results for two products, first and foremost because the product systems are defined differently.

Things which should be taken into consideration when setting the system boundaries can be broken down into two groups:

- Criteria for which elements should be included, or excluded from the assessment, (e.g. all the material inputs that are greater than 1 weight %, 1% of the energy use, or 1% of the relevant environmental impacts should be included)
- Criteria for what data quality there should be for the data gathered. (e.g. how old can the data be, which geographical area shall they apply to, the technical boundaries for the data, site specific data, precision, assumptions that can be made, etc.)

These are all things which can affect the final result and they should, therefore, be included when the purpose for the study is defined.

Functional Unit

The functional unit is the unit which defines a products performance in relation to a particular users needs. If considering cement and concrete, the functional unit can be, for example, 1000 kg cement, or 1 m3 concrete. This functional unit says nothing about the use of the product. If one shall compare different products, it is important that the functional unit reflects the function of the product. In this case a relevant functional unit could be 1 km of road, including maintenance over a given time period.

The functional unit will also determine the material flows of raw materials and products, up stream and down stream from the user phase. For example, the functional unit of 1 km of road, including maintenance over time period of 50 years, defines how much raw materials and resources are needed to produce, maintain and dispose of the product. The material flow analysis shows which flows are large and important, and which on a weight basis, are of less importance in relation to data gathering for the production of raw materials. Figure A1.2 shows different approaches to the choice of functional unit if one wishes to assess cement as a road surface from a life cycle perspective.

All mass and energy flows are normalised with respect to the functional unit.

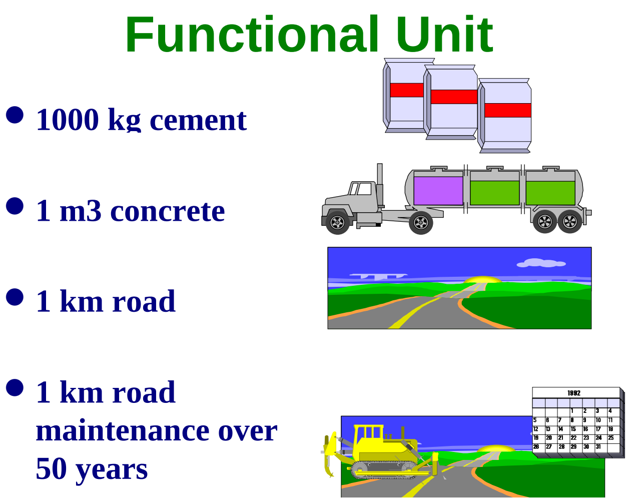

Figure A1.2 Different Approaches to the functional unit for cement as a road surface

Choice of the correct functional unit will, in many analyses, have a central role in relation to the results of a comparative study. A functional unit is an expression for how effective a product is at fulfilling the requirements of the user, preferably quantified in relation to the amount of product required to meet these requirements.

A1.3 Inventory Analysis

In the inventory analysis phase data for energy and material use, emissions to air and water and waste are inventoried for the whole life cycle. The data collected are normalised in relation to the functional unit. The emissions, quantities of waste and energy use are calculated for each unit in the system.

A central methodological problem which can arise during the inventory analysis is how the environmental and resource effects should be allocated in the cases where a process produces several products. The problem occurs when one product is included in the assessed system, while the other is not. There are several ways to in which allocation can be performed. It can be done on a mass basis, according to the economical value of the products, biological allocation (resource requirements), 50/50- allocation etc. (Lindfors et al., 1995). ISO 14041 (1997) recommends that allocation should be, to the greatest possible degree, avoided, or minimised, for example by expanding the system boundaries. When allocation cannot be avoided, allocation should be made on the basis of the physical, or economical relationship between the products.

A1.4 Calculation and Assessment of Environmental Impacts

When assessing environmental impacts one often uses literature data and average data based on products with unknown origin. An assessment of environmental impacts in an LCA will not normally be based upon site specific data and conditions. An LCA cannot, as a rule, assess anything other than the <u>potential impacts</u> a product system can have on its surroundings. This is an important point for understanding the principles and methods for the assessment of environmental impacts in a life cycle assessment. An LCA attempts to assess the <u>maximum</u> impacts a system can have on its surroundings, for all types of impact.

The assessment of environmental impacts in an LCA consists of the following three elements:

- *Classification:*
  relating resource use, waste, emissions and content of environmentally dangerous components to the relevant impact categories.
- *Characterisation*
  quantification of the contributions of the different emissions to the different impact categories (e.g. conversion of NOx, HCl (g) etc. to SO_2-equivalents)
- *Valuation*
  Performing a valuation of the different emissions, or impact categories.

Classification

In the classification step all the inputs, outputs and energy flows are linked with the environmental impact categories where <u>primary effects</u> can arise, from a known dose-response relationship. In the methods for life cycle analysis there are summaries which show what types of environmental impacts should be assessed (Nordic Council of Ministers 1992, SETAC 1993b, Lindfors et.al 1995b).

The classification step is consequently a qualitative assessment of what type of environmental impacts are relevant for later quantitative assessment.

Characterisation

The next step involves all the contributions to the environmental and resource impacts, which have been found to be relevant in the classification step, to be quantified. This quantification should, as far as possible, come from known physical, chemical and economical models. In this step the uncertainty level in the LCA increases significantly. This is because of the fact that for many types of impact large uncertainty dominates the calculation factors based on dose/response-conditions. Many impacts also lack accepted factors for calculation of impacts from emissions. The environmental impacts which today have the best foundation on which to perform a valuation, seem to be use of renewable and non-renewable resources, global climate effects, ozone depletion, acidification and eutrophication of lakes and water courses. The calculations for other categories are, in many cases, both uncertain and difficult to compare. Examples of the contributions of different emissions to environmental impacts are given in Table A1.1.

In this LCA such calculations of potential environmental impacts from emissions, as described above, are not performed.

Table A1.1: Different emissions' contributions to potential environmental impacts and the effects they can have.

Emission	Environmental Impact	Potential Environmental Effects
CO_2-emission N_2O-emission CH_4-emission CF_4/C_2F_6	Global climate change	Temperature rise in the atmosphere (green-house effect and climate change). This can have serious problems for the ecosystem.
SO_2-emission HCl-emission NO_x-emission	Acidification	Death of fish and forestry, corrosion damage, damage to buildings, release of heavy metals with effects on animals, vegetation and health
VOC-emission CO-emission NO_x-emission	Photochemical oxidation	Reduction of the ozone layer, acute toxic effect, negative effect on photosynthesis.
Tot N, water Tot P, water BOD_5	Eutrophication	Localised over growth effects with increased algae growth.

In addition to this, assessments of the use of non-renewable resources (e.g. fossil fuels) and production and hazardous wastes are performed.

Valuation

In many cases it will be desirable to produce an aggregated assessment of the different environmental impacts from a product system. Either this, or ranking the different environmental impacts against each other according to importance, is often required. This sort of valuation will always contain an element of subjectivity and the choice of values used as valuation parameters can never be based on a strong scientific foundation. The valuation step is therefore, one of the steps in an LCA, which has advanced the least in terms of methodological development, it is also the most debated.

In the meantime, it will be of little merit for a company not to produce a finite prioritisation of which initiatives ought to be considered/carried out in order to improve a product system from an environmental perspective. To make such a prioritisation one must prioritise between environmental impacts. This must be done because an improvement of a system in one way can reduce one type of impact (e.g. acidification equivalents), while increasing another (e.g. eutrophication of lakes and water courses).

In order to fulfil the need for an aggregated assessment different types of environmental indicators have been developed. These are partly based on ecological conditions and partly on the values of society. Examples of these are:

- Environmental Priority Strategies (the EPS system)
- «Ecoscarcity» approach
- normalisation against national emissions

These are described as follows:

<u>«Ecoscarcity» approach</u>

This model comes originally from Austria, and is developed based on national environmental requirements *(Ahbe, 1990).* The method includes a direct valuation of energy use and physical and chemical effects on the surrounding environment. In other words the results of the inventory analysis are multiplied directly with valuation factors. The valuation factors are expressed in so called "eco-points". The valuation factors for the different environmental effects are drawn up from examining the relationship between "actual flow" and "critical flow" over a year, within a specific area. All use of this method so far has used a country as the geographical boundary for the critical and actual flows. Furthermore the critical flows have been set as the same as the political targets for the country for which the method is being used.

The method uses political targets as a basis for calculation of valuation factors. This is meant to reflect the attitudes of the governing authorities. If a company takes these attitudes into account in the environmental development of its products, it will be prepared for implementation of governmental measures, such as emissions related taxes.

Valuation factors in eco-pints have already been calculated for a large number of environmental effects based on Norwegian political targets and actual emissions *(Baumann and Rydberg, 1994).* The limit to complete adaptation of this method to Norwegian conditions lies in the extent to which there are quantified political targets for the environmental impacts which haven't yet got eco-points calculated for them.

<u>The EPS system</u>

EPS is a system for a one-step quantitative evaluation of environmental impacts. It was developed in collaboration with Swedish industry (first Volvo) to use in environmentally friendly product development *(Steen and Ryding, 1992).* Total environmental impacts are given in "Environmental Load Units" (ELU). Environmental impacts are evaluated in relation to five "safeguard subjects", based on the willingness to pay to keep, or restore these subjects; or in the case of resources - on the environmental effects of sustainable substitution processes:

- Human health
- Biodiversity
- Production (biological production values, but also industrial values)
- Resources
- Aesthetic values.

Although not all elements are integrated it is clear that EPS assigns a higher value to global and long term effects. The main effects considered in EPS are the use of mineral resources, energy resources and global warming. Regional impacts (such as NOx, SOx, all water acidifying agents) are almost without weight. Therefore, an activity which uses metals, or fossil energy is bound to come out with a worse ranking than an activity which does not have such impacts *(Braunschweig et al. 1994).*

<u>Normalisation against national emissions</u>

From the report "The State of the Environment in Norway 1996" *(Rübberdt et al, 1996)* an overview of national emissions and waste data is obtained. In addition to this, data on annual national use of fossil fuels and electricity is obtained from Statistics Norway. The emissions throughout the life cycle for the two product systems are compared with total national emissions figures to obtain an expression of the importance of the emissions.

A1.5 Interpretation

In the last draft version of the standard (spring 1998), ISO suggested to exclude the improvement step from the methodology. The reason for this is that LCA is an information tool, which gives input to different decision making processes. For this reason one uses different methodological approaches which are not contained in the LCA method, to use the information provided by the LCA.

This phase of life cycle assessment is when synthesis is drawn from the findings of the inventory analysis and impact assessment in line with the defined goal and scope. Interpretation and communication of the results in relation to the goal and scope of the study, as well as reflection on the results of any sensitivity and uncertainty analysis is undertaken here.

As shown previously, an important aim for a life cycle assessment is to provide a better foundation for decision making in the product system improvement process. The life cycle assessment can provide a much more holistic picture of where in a product system the largest environmental impacts arise. It can therefore be a basis for assessing where the greatest potential for environmental improvement lies.

There has been a large Nordic project for environmentally sound product development, where 25 large Nordic companies have co-operated to develop methods, decision making tools and educational programs on this subject. A large amount of case studies projects were performed to produce more environmentally sound products. The foundation for the methods is a general model for integrated product development which comes from the Technical University of Denmark *(Myrup-Andreasen and Hein, 1986).* The experience gained from this project has, amongst other things, led to the development of a hand-book for environmentally sound product development *(Hanssen et. al 1995)*. In this hand-book information and data from life cycle assessments of products are integrated into the different phases and decision making steps in the product development model.

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A2. PRODUCT DEVELOPMENT

A2.1 Environmentally sound product development

To achieve more sustainable industrial products it is vital to integrate environmental aspects into the product development processes at an early stage. They should also be more directly integrated into the product development process. Environmentally sound product development is an approach where the customer's requirements, environmental loads and costs are integrated. Such an integrated process will make it easier for the developing team to make improvements with respect to environmental loads throughout the life span. It will also reduce the total life cycle cost for the customer at the same time as fulfilling the customer's needs and requirements concerning the product's functionality.

- **Quality Function Deployment (QFD):** systematic analysis of customers' needs and requirements such as:

- functionality of the product
- economic aspects related to purchase and use of the product
- environmental aspects

The ultimate reason for buying a product is that the product fulfils the needs of a customer. The challenge for a manufacturer is to identify the product's main requirements and transform them into the product's properties, in such a way that their product is preferred to a competitor's product.

Quality Function Deployment is a method for systematic analysis of customer requirements and relationships between quality requirements and the product structure. The relationships between customer requirements and the technical parameters of the total product are analysed.

- **Life Cycle Assessment (LCA):** describes and assesses the environmental performance through the life span of a product to identify:

- what are the most important environmental loads arising during the life span of the product
- where in the life span of the product do the environmental loads occur
- what are the most efficient aspects on which to focus, with respect to product changes or development of new products.

The LCA describes and assesses the environmental performance throughout the life span of a product. All activities from the production of the product, the use of the product and discarding the product are included.

- **Life Cycle Cost (LCC):** calculation of the total cost related to purchasing and using of the product to identify:
    - the most significant aspects for the customer (purchase, maintenance, disposal...)
    - potential for development of, or changes to, the product.

Whereas investments in equipment are always analysed over a period of time, e.g. 10 years according to depreciation and tax rules, this is very seldom the case with products. The most important economic factor is thus the purchasing price, and the life cycle costs are very seldom calculated. Products with different life spans are seldom compared with respect to operation costs, maintenance costs, service costs, costs related to failure and costs related to purchasing of new products during a given time period, due to different life spans of the products. Short-term economic considerations may end up with the selection of a low quality and a low purchasing price product.

Within Systems Engineering, there are well established methods for calculation of life cycle costs of products. Based on the structure and the life time processes of a product system it is possible to calculate life cycle costs per functional unit for different products. Life cycle costs for different products can therefore be compared on a fair basis.

QFD, LCA and LCC are regarded as information tools, where information about customer needs and requirements, environmental loads and the cost for the customer are structured throughout the life cycle.

A2.2 Analysis Of The Product Range

Life cycle analyses (LCAs) are suitable for use as tools to assess the environmental properties of products. In the opening phase of the product development process it is of interest, from an environmental perspective, to assess which products are interesting to improve. With a review of the product range the company can obtain an overview of which products it will be most effective to improve. Figure A2.1 shows how LCA can be used in this context.

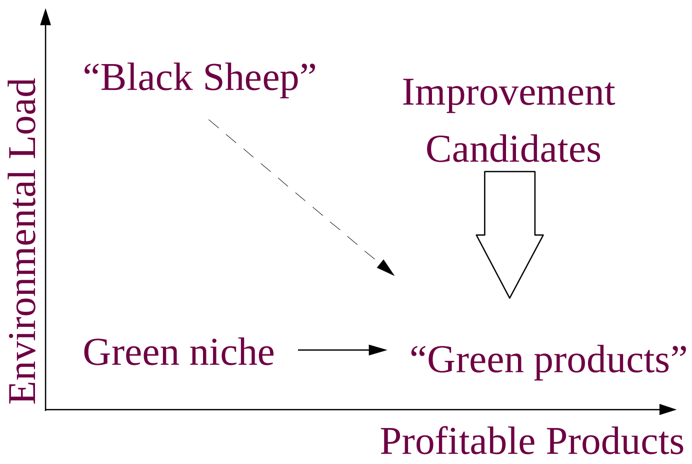

Figure A2.1 Profitability in a Life Cycle Perspective as a Function of Environmental Load

As in the figure above, experience has shown that products that have relatively high environmental impacts and are profitable are the most interesting for improvement purposes. The company is likely to have less strategic interest in further development of products that have high environmental loads and low profitability.

An LCA together with a profitability analysis will be a good instrument to show how the products fit into such a 'landscape'.