Measuring Eco-efficiency by a LCC/LCA Ratio
An Evaluation of its Applicability

A case study at ABB

Master of Science Thesis in the Master Degree Programme;
International Project Management

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Abstract

The current situation with growing pollutions and industrial production put high demand on organisations environmental responsibility. Striving towards a sustainable development is an important assignment for the corporate world. In 1991 the World Business Council for Sustainable Development (WBCSD) established the concept eco-efficiency in order to sum up the business part of sustainable development. Eco-efficiency can be described as a continuous process of change in order to decrease environmental impacts with an enhanced value for products and services.

This master thesis is carried out with the purpose of measuring eco-efficiency and evaluating its applicability. A case study at ABB was executed with the aim of putting the eco-efficiency interpretation made by Steen (2004) into practice. The interpretation combines the two life cycle approaches LCC and LCA in a standardised index, $1-\frac{EDC}{LCC}$ and is presented as a percentage value in order to increase the understandability.

In the case study, two scenarios including the HXR500 electric motor and the ACS800 frequency converter are used. The first scenario is conducted in order to determine the eco-efficiency for the HXR500 motor's life cycle and in the second scenario, an eco-efficiency calculation is made for the HXR500 motor's life cycle operated by the ACS800 frequency converter. The product combination enhance the economic value and decreases the environmental impact and the aim with performing these scenarios is to evaluate how and if it is possible to make reasonable eco-efficiency comparisons.

Results from the study indicate that the standardised eco-efficiency index can serve as a valuable tool in order to evaluate eco-efficiency and can be used e.g. for monitoring progress, benchmarking and in purchase decisions. Nevertheless, it is difficult to evaluate if the index increases the understandability without obtaining great knowledge of the eco-efficiency concept. Important to notice is that evaluating eco-efficiency is still in an early phase and the method used in this study have not been put into practice to a great extent. Executing future studies in this area is therefore an important issue.

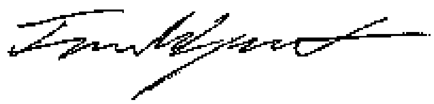
Additionally the study gave evidence to an obstacle when deciding the relevant value for the products using LCC. When making comparisons, an added value can be identified and it is important to take this into account in order to get an appropriate eco-efficiency value of the products compared.

Preface

This thesis is the last assay for the joint degree in M.Sc. in International Project Management at Chalmers University of Technology and Northumbria University in Newcastle upon Tyne.

The thesis has been carried out at the department of Environmental System Analysis and is part of the project Environment and Economy for CPM under supervision of the project manager and examiner Bengt Steen.

I would like to thank Lennart Swanström and Thomas Norberg at ABB for help with technical data during this master thesis. Further I would like to thank my examiner for support during this project and my colleague Guy Skantze that always were available for discussions during the entire work.



Fredrik Lyrstedt

Göteborg, October, 2005

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Introduction

The global system is growing rapidly i.e. population, industrial production, consumption of resources and thereby pollutions. However, there are limits to which the human population can use materials and energy and there are limits of how much waste that can be emitted without harming the earth, the people and the economy (Meadows, et. al., 1992). In the early 1970's Meadows, et. al. stressed the need for change in the current development and this in order to maintain a sustainable and safe resources base for future generations. This led to the recognition of current environmental problems and the term sustainable development was introduced in the World Conservation Strategy (IUCN, 1980). In 1987s report Our Common Future after the Bruntland commission the concept of sustainable development were thereafter spread by the definition:

> "Sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987)

During the recent years it has been an increasing demand for sustainable development, which has broaden the corporate responsibility to include environmental issues in all levels of its operations (Laestadius & Karlsson, 2001). There are crucial needs for instruments that can interpret sustainability requirements into working targets. One widespread interpretation of sustainable development is the three pillars of sustainability; it divides the definition into economic growth, ecological balance and social progress (WCED, 1987).

Unfortunately there is not a universal approach to reach sustainability but there are methods and concepts that can be used in the move towards a sustainable society. One concept is eco-efficiency, which combines two out of three pillars of sustainable development: economy and environment. Eco-efficiency can be described as a continuous process of change in order to make e.g. the exploration of resources, direction of investments and the orientation of technological development consistent with the future and present needs (Lehni, 2000). In the context of sustainable development and the corporate world eco-efficiency is becoming increasingly important.

This M.Sc. thesis is part of a project at the department of Environmental System Analysis (ESA) for the Competence centre for environmental assessment of product and material system (CPM) at Chalmers University of technology. The outcome of the project is intended to be some kind of method to monitor environmental costs and benefits for companies and their projects and products (Steen, 2005). This dissertation has its purpose to conduct a case study at ABB in order to evaluate how applicable the eco-efficiency concept is for measuring eco performance.

Goal and scope

Purpose

The aim with this study is to demonstrate the significance and the field of usefulness when measuring eco-efficiency, this by performing a case study at ABB. The case study's purpose is to put an eco-efficiency interpretation key into practice, the LCC/LCA ratio, and evaluating its applicability. The study is contributing to the existing knowledge base of environmental management and is putting the aspect of eco-efficiency interpretations in position.

Scope

The study performed in this report is considered from a company perspective. The company perspective covers both the manufacturer and the company that procure and use the product.

The products chosen in order to evaluate the eco-efficiency are the HXR500 motor and the ACS800 frequency converter from ABB. They were chosen in accordance with Björn Norberg at ABB and the reason for selecting these products were that both have easy accessible environmental and financial information. Additionally they are commonly used together in a product system and will be an object for comparison. The case study will determine the eco-efficiency in two different scenarios; figure 1 illustrates a simple flowchart of the system.

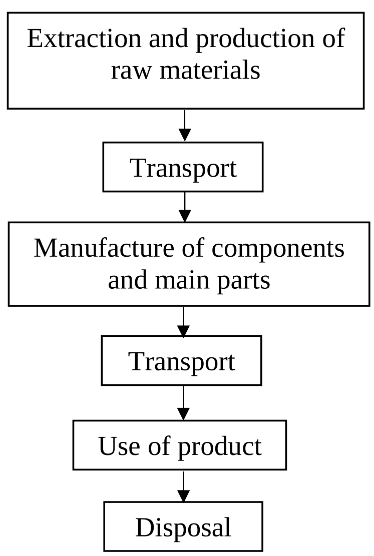

Figure 1.Simple flowchart of the system studied

The first scenario evaluates the eco-efficiency for the HXR500 motor's life cycle and the second scenario evaluates the eco-efficiency for the product combination's life cycle, the HXR500 motor with the ACS800 frequency converter. The product combination enhance the economic value and decreases the environmental impact and the aim with performing this scenario is to evaluate how and if it is possible to make a sound eco-efficiency comparison between the products.

The functional unit in the case study were set to 1kW of rated output power for the HXR500 motor.

Delimitations

The study only includes the eco-efficiency concept, alternative methods to measure environmental impacts in relation to financial performance has not been taken into consideration. The environmental in data is taken from existing LCA analyses and the LCC is based on estimations provided by ABB.

Research procedure

The research in this study is based on empirical studies and quantitative and qualitative theoretical research. The approach was useful in order to gain both the breadth and the precision of the studied context.

The result from the theories and the information, which the research gave was analysed thoroughly in order to draw reasonable conclusions. A comprehensively qualitative and quantitative data was gathered in the beginning of the study, this to get an extensive body of knowledge towards the studied topic (Rudestam & Newton, 2001).

The second phase was to collect data for the case study; this was done by interviews and qualitative data from ABB. In order to gain as much information as possible from the interviews they were semi-structured. They were primary focused in the extent of following a set of standardised questions, however they were also open-minded and this in order to get the interviewee’s own insight into certain proceedings (Wengraf, 2004). When it was necessary secondary data were gathered, such as information from relevant literature, this in order to make reasonable comparison of specific scenarios or relations that the research resulted in.

The case study approach was used in order to concentrate on a specific instance in an attempt to identify detailed processes (Remenyi, et.al. 2005) and it provided a detailed view of the current situation and opinions. According to Easterby-Smith et.al. (2003) the case study is particular appropriate when collecting both qualitative and quantitative data. The study is based on one explorative case, this to determine the feasibility of the research with in the context (Yin, 2003). The overall theory collected was important to the case study; it assisted to stipulating rival theories and specifying what was being explored (Yin, 2003).

Theoretical frame of reference

In this chapter the concept of eco-efficiency is described. Additionally, information of the functions and applications of eco-efficiency is provided together with an interpretation key for measuring the eco-efficiency of products and processes.

Eco-efficiency Objectives and purpose

In 1991 the Business Council for Sustainable Development (BCSD) were looking for a single concept in order to sum up the businesses part of sustainable development and the term eco-efficiency emerged (Lehni, 2000). It was an outcome from the report Changing Course, which resulted from the Earth summit in Rio de Janeiro where the term eco-efficiency was coined. Since then the World Business Council for Sustainable Development (WBCSD) has developed the eco-efficiency concept. The fundamental idea of eco-efficiency was to develop a concept in order to meet the need of sustainable development at a company level and include both economical and ecological efficiency (Schmidheiny, 1996), thereby the term "eco". Today it has been growing and been used in order to decrease the environmental influence in relation to its value and the concept is now well recognised in the business world (Lehni, 2000). The definition of eco-efficiency that today is most widely spread and which is gaining acceptance was coined by BCSD (Jollands et. al., 2004):

> "Eco-efficiency is achieved by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity"

Further eco-efficiency can be described as a management philosophy and business concept that simply means becoming more efficient makes good business. It focuses on business opportunities that allow companies to become more environmentally responsible and profitable, parallel to this it is expected to foster innovation and create growth and competitiveness.

The eco-efficiency concept goes throughout the whole organisation; it involves product development and manufacturing to marketing and distribution (Lehni, 2000). It is not limited within companies boundaries and is therefore valid for a products whole lifecycle, both upstream and downstream e.g. for a manufacturing plant.

In order to improve the eco-efficiency in companies there are several implementations that can be done. The WBCSD has identified seven elements that business can use to increase their eco-efficiency, this in order to achieve more value from lower inputs of material and energy with reduced emissions (Lehni, 2000). The elements are: reduce material and energy intensity, reduce dispersion of toxic substances, enhance recyclables, maximise use of renewables, extend product durability and increase service intensity.

The concept is comprised in three broad objectives (Lehni, 2000) where the seven elements are found in, the objectives are:

1. **Reducing the consumption of resources.** Minimising the use of energy, material, water and land. Increase the recyclability, product durability and closing material loops.
2. **Reducing the impact on nature.** Minimising emissions to air and discharges to water, waste disposal and the use of non-renewable resources.
3. **Increasing product or service value.** Providing more customer benefits e.g. through product functionality and flexibility, the customer receives the same or an enhanced function with less resources and materials.

Eco-efficiency can act as a useful tool for reporting and monitoring performance; additionally it may improve companies dialogue and communication with their stakeholders. This can e.g. be done by measuring and reporting eco-efficiency for its products or services. Beside these advantages DeSimone and Popoff (2000) has defined benefits, which can be described in five categories:

- Reducing the current costs of poor environmental performance
- Reducing potential future costs of poor environmental performance
- Reduced costs of capital
- Increased market share and improved or protected market opportunities
- Enhanced image

It is important to acknowledge that improving eco-efficiency does not necessary contribute to sustainability, e.g. improvements, enhanced value per impact, can still lead to a general increase in products or activities environmental impact (Lehni, 2000). An example of this is the SUV; it has a high eco-efficiency because of its great value in relation to its environmental impact.

Further, eco-efficiency is not a fixed state that can be withheld, it is a process of change in which the direction of investments, the orientation of development, exploitation of resources and corporate change in order to enhance value while minimising waste, resources and emissions (Schmidheiny & Zorraquín, 1996). Eco-efficiency does not link all three pillars of sustainable development; it is establishing a link between the environmental and economical goals.

In order to balance all three pillars the social aspect needs to be taken into consideration. Responsible Entrepreneurship, where the social aspect is taken into consideration, is the next step, see figure 3, and together with eco-efficiency businesses can make a step forward in the attempt of achieving sustainability (Lehni, 2000).

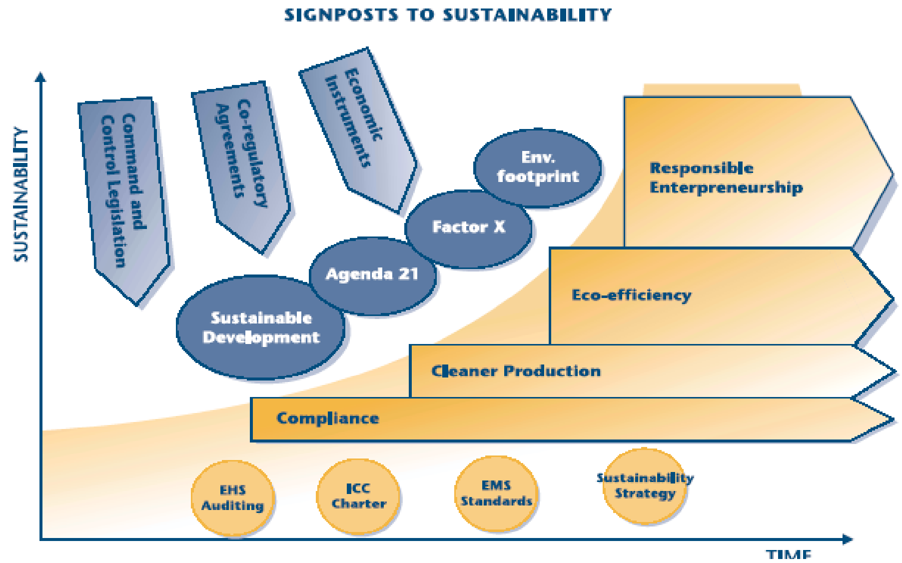

Fig. 3. Signposts to sustainability (Lehni, 2000).

Measuring eco-efficiency

Throughout businesses, setting targets and monitoring performance with indicators is an accepted management tool and it is important in order to evaluate corporate progress (Verfaillie & Bidwell, 2002). Consequently, for the eco-efficiency concept to become reality in organisations, Canada's National Round Table on the Environment and the Economy (NRTEE) (2001) claims that organisations must measure and monitor their performance, this in order to be able of setting targets for eco-efficiency improvements.

There are several reasons why companies choose to measure their eco-efficiency. Such reasons can e.g. be tracking and documenting performance, identifying cost savings and benefits, identification and prioritisation of opportunities for improvements (Holliday et. al., 2002). Further, it can act as a key instrument for change that can be used in order to estimate the environmental costs, energy and resource usage from the cradle to the grave (de Andraca & McCready, 1994).

Measuring eco-efficiency can also have advantages when deciding between alternative courses of action, reporting and communicating i.e. providing information of a firm's progress towards sustainability for stakeholders (DeSimone & Popoff, 2000). The eco-efficiency can be measured throughout the whole business spectrum. Selecting the correct boundaries and choosing the right indicators is therefore important depending where it is intended to be used. Figure 4 illustrate examples of the field of usefulness and that the indicators can be applied in many levels within an organisation (NRTEE, 1999).

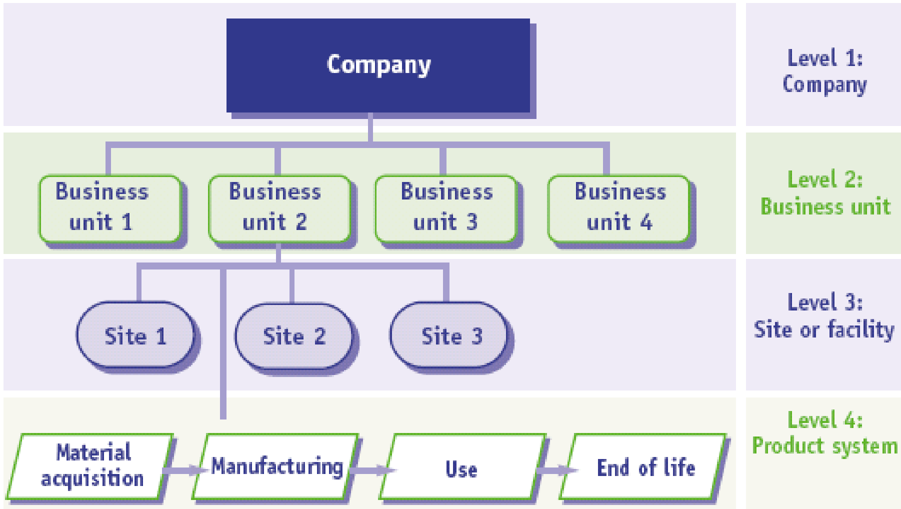

Fig. 4. Levels within a company where indicator can be applied (NRTEE, 1999)

The eco-efficiency indicators, which are one of the key attractions in eco-efficiency concept, can take numerous of forms depending on the function and audience (OECD, 1998). An indicator gives an important measured value for the specific area of evaluation and the main reason for companies to developing such indicators is to improve their eco-efficiency. E.g. an indicator that is relevant for most businesses is greenhouse gas emission. This indicator can include carbon dioxide ($CO_{2)}$, methane (CH_4), nitrous oxide (N_2O), hydro perfluoride (HF) and sulphur hexafluoride (SF_6). These emissions cover the gases specified in the annex A from the Kyoto Protocol (Verfaillie & Bidwell, 2002). One important issue for these indicators is the selection of boundaries; it can for a comprehensive evaluation include e.g. the emission from suppliers, the own business and the end users, in other words the whole life cycle for a product.

The WBCSD have made a framework in order to measure eco-efficiency that is intended to be flexible and easy enough to be used in the whole business spectrum (Verfaillie & Bidwell, 2002). As mention earlier the eco-efficiency brings together the two dimensions, ecology and economy. Therefore, an eco-efficiency index measures the environmental performance of a company or product with considerations to its financial performance. The index is a ratio between the environmental and financial variables (Sturm, et. al., 2004) and can be represented as:

$$\frac{\text{Product or service value}}{\text{Environmental influence}}$$

Increasing the eco-efficiency can be accomplished by providing more value with a decrease in the environmental influence or resource consumed for the evaluated product or service. An example of a well-known eco-efficiency ratio is the fuel consumption of a car expressed in kilometres per litre of used fuel.

When measuring eco-efficiency it is important that the measurement program are scientifically supportable, relevant, accurate and useful; therefore the indicators should be based on a set of defined principles (Verfaillie & Bidwell, 2002). The

WBCSD recommends that the indicators should be based on eight principles that can be adopted in any field of business when measuring the performance of an organisation or a specific product. The indicators should:

I. **Be relevant and meaningful with respect to protecting the environment and human health and/or improving the quality of life.** This is important in order to ensure that company's and stakeholders focus on high priority areas in their organisations.

II. **Inform decision makers to improve the performance of their organisation.** It is important that indicators help e.g. management to make sound environmental decision; i.e. how product designs can be modified in order to decrease environmental burden and enhance economical value.

III. **Recognise the inherent diversity of business.** Every company differ from each other and their environmental aspects and values depend on the specific business. It is therefore important that the measured indicator is relevant for the specific business.

IV. **Support benchmarking and monitoring over time.** In order to use the measure for monitoring performance over a time period it is significant that the indicators are related to both past and current issues. It is also important that the indicators are defined in that same way and not influenced by extraneous factors in order to use the measure for benchmarking.

V. **Be clearly defined, measurable, transparent and verifiable.** The definition, boundaries and methodology should be available for decision makers and for verification both internally and externally.

VI. **Be understandable and meaningful to identified stakeholders.** It is important that the indicators are clearly understandable for both decision makers and stakeholders. They should not be complex and this in order for easy usage.

VII. **Be based on an overall evaluation of a company's operations, products and services, especially focusing on all those areas that are of direct management control.** When determining the indicators, the evaluation should focus on areas, which the business can control and have direct influence on, e.g. the selection of material, resources and distribution.

VIII. **Recognising relevant and meaningful issues related to upstream (e.g. suppliers) and downstream (e.g. product use) aspects of a company's activities.** The indicators should consider the areas in which the company can control.

Gathering the data for an eco-efficiency measure can be complicated. In contrast to the financial/economical information needed, where there generally are well-established routines and methodologies, the environmental performance covers a various and often a complex mix of parameters for different impacts (Verfaillie & Bidwell, 2002). The functional value indicators provides a measure of the task for which a product or service perform for its end users.

The selection of boundaries, which can be a challenge for any organisation, is an important issue. In general the boundaries should be selected and based on the information need from the users. Within an organisation there are numerous of boundaries that needs to be defined, how these are selected have great impact on the selection and use of the indicators. Similar issues have been a hot topic for Life Cycle Assessment (LCA) and ISO 14040 can be a helpful guidance tool for this area (Verfaillie & Bidwell, 2002).

Interpretation of eco-efficiency

Attempts have been made to capture eco-efficiency in one single dimension, however in order to add up its several components it requires a weighting system (OECD, 1998). Interpretation of eco-efficiency data is an important issue when evaluating performance and reporting. The interpreted data can be a helpful tool in order to explain e.g. what figures mean in relation to peers and targets (Verfaillie & Bidwell, 2002). One important issue when reporting eco-efficiency is that both the environmental items and the financial/economy items cover the same activities and over the same time period; i.e. using a life cycle approach (Sturm, et. al., 2004). The life cycle approach can be impractical and expensive if the intended use is e.g. an annual report where extensive data needs to be gathered. On the other hand for specific products it provides very valuable information. Whether the use of an eco-efficiency interpretation is for an annual report or for a specific product it is important that the information have certain qualitative characteristics. Sturm, et. al., (2004) specifies four characteristics for an eco-efficiency measure:

I. **Understandability.** The information should be understandable for the users. Even though environmental information can be a complex matter it is important that these sorts of data are included in the information.

II. **Relevance.** The information should be able to influence users to confirming and evaluating past, current and future events.

III. **Reliability.** It is important that the eco-efficiency information is neutral, free from errors and bias, otherwise it will not be reliable and used.

IV. **Comparability.** In order to use an eco-efficiency measure for benchmarking and comparing results through different time periods, it is important that the work is carried out in a consistent way and that the method is changed when new scientific knowledge is developed.

Calculating eco-efficiency

The eco-efficiency calculations that are made in this report are based on the method used in the Interpretation keys for environmental product declarations by Steen, et. al. (2004). In the interpretation key for Environmental Product Declaration (EPD) the ratio between Life cycle costing (LCC) and environmental damage costs (EDC) are described as a measure of eco-efficiency (Steen, et. al., 2004). In order to increase the understandability of the calculation it has been standardised; see equation 1, so that the eco-efficiency calculation is expressed in a percentage value. This implies in when e.g. a product receive 100% eco-efficiency the product would not contribute with any harmful impact to the environment.

$$1-\frac{EDC}{LCC} \qquad \text{(Equation 1)}$$

Important to acknowledge is that the costs of the product in the equation is an expression of the product value; more in detail the willingness to pay (WTP) for the product determines the relevant value. Notwithstanding, care has to be taken when using financial data in the denominator, which can lead to comparability issues over time; the financial data can easily be affected e.g. by price and shifts in value (NRTEE, 2001).

Life cycle costing

Life cycle costing (LCC) is an analytical tool or a method that belong to the group of life cycle approaches. Traditionally LCC has been used for decision-making involving acquisitions of products and capital equipment with high investments costs (Huppes et. al., 2005a). LCC is by definition of Rebitzer & Hunkeler (2005) all costs, both internal and external costs, that are associated with the life cycle of products and which are directly related to one or more of the actors during products life cycle.

There are three different types of LCC that can be distinguished, business LCC, environmental LCC and societal LCC. These types have different parameter settings and are used in different application contexts (Huppes et. al., 2005b). The business LCC, or conventional LCC, is most commonly used for internal and business related cost assessment, controlling and for purchasing decisions. The costs categories and the principles for measuring needs to be carefully agreed upon before the assessment starts, the functional unit is typically expressed in one unit of the product. In the environmental LCC, the product or system studied are generally less complex and is described by a functional unit in accordance with ISO14040; e.g. $1m^2$ of floor. In contrast to the business LCC it is not used for tender decisions or controlling reasons; the method is typically applied for investigating the economic and environmental impacts caused by a product or system. The costs estimations are more simplistic than in business LCC and the prices of the product or system is usually a way of describing its costs. In the environmental LCC, a LCA is normally used for steering and may be broaden to also include costs. The societal LCC covers both the internal and external costs, further it deals with costs from more than one perspective e.g. different stakeholders i.e. industrials, peoples and authorities view. This type of LCC are closer related to the conventional LCC rather then the environmental LCC.

The cost can be described as the cash or cash equivalent value for the products and services, which bring a future or current benefit for an organization (Huppes et. al., 2005a). When using a LCA or LCI together with LCC studies it is important that the system boundaries, functional unit, main assumptions and other aspects are aligned between the different methodologies (Schmidt, et.al., 2005), this in order to achieve symmetry between the methods.

There are five basic LCC stages, which probably are the most aggregated:

1. Research and development
2. Production of materials or components
3. Manufacturing
4. Use and maintenance
5. End-of-life management

Within the LCC one can differentiate between two types of costs: internal and external costs (Rebitzer & Hunkeler, 2005). The internal costs represent the costs that e.g. a producer, transporter or consumer are paying for; i.e. the manufacturing costs of a product and the use of it. The external costs, often called the externalities, are related to the monetised affects of social and environmental impacts. These costs are usually not directly charges to the consumer, company or government that are using or producing the product.

The LCC, which is used in the eco-efficiency calculations of this paper have most in common with the environmental LCC, the externalities are in the calculation taken into account in the environmental damage costs.

Environmental damage costs

The environmental influence that the WBCSD are using in their eco-efficiency calculations are in this paper replaced with the environmental damage costs (EDC). It is a monetary evaluation, which represents the environmental costs in environmental load units (ELU) that e.g. an evaluated product or system is contributing with in order to generate its functional value (Steen, 1999a).

The indicators for which the EDC are based upon are similar indicators that are measured in a LCA and presented in an Environmental Product Declaration (EPD). These are:

- Green house gases
- Acidifying gases
- Ozone depleting gases
- Gases contributing to creation of ground level ozone
- Emissions contributing to oxygen deficiency in water
- Consumption of non-renewable energy reserves

The indicators are expressed as equivalents, which mean that different substances are contributing to each specific indicator. The equivalents that are represented in the EDC are preferably based on data from a LCA analysis. LCA is a methodology that describes the quantity of natural resource use and pollutant emission from the “cradle”, where the materials are extracted from natural resources, through production, use and to the “grave”, the disposal. The LCA method has several advantages, e.g. it deals with environmental issues in a highly structured manner; it is a quantitative tool that can handle different types of environmental impacts at the same time. Additionally it is a systematic way of working and it enables communication about complex and large environmental issues (Baumann & Tillman, 2004).

Environmental Priority Strategies in product design (EPS)

In order to gather the EDC for the evaluated product or service the EPS system is used. It is a weighting method for the environmental impact of products during their entire lifecycle. The present version of the EPS system that is used in this study has been developed within CPM (Centre for the environmental assessment of Products and Material systems). In its origin it was developed for Volvo Car Cooperation by the Swedish Environmental Research Institute (IVL) to assist product developers and designers when evaluating e.g. which one out of two product concepts that have least environmental impact (Steen, 1999a). The EPS system can be described by a set of rules and definitions, in the EPS system these are in agreement with the standards of ISO14040 (Steen, 1999a), the principles are described below:

I. **The top-down principle**. In complex system there will always be issues that are not known or not possible to include because of limited resources, these must be dealt with in an economical way. The top down principle means two things:
   1. Issues that are close to decision are dealt with before giving basic information.
   2. Rough estimates are made first, the quality is later improved if experience from sensitivity analysis indicates that this is meaningful.

II. **The index principle**. Ready made impact assessments that are available in form of indices for materials and processes shall help the user of the EPS system to describe a products life cycle. The intention for these indices is to represent the weighted and aggregated environmental impact. The total environmental impact load in the EPS system is expressed in environmental load units, ELU, this is done in order to be able of evaluating e.g. decision of adding a material versus the whole.

III. **The uncertainty principle**. The EPS system as well as in LCA and life cycle impact assessment (LCIA) there are large uncertainties involved; e.g. the location of an emission is unknown and therefore the effects can not be estimated without great uncertainties. In LCA as well as in ISO 14040 and 14042 the term potential effects are used to indicate that there is an uncertainty between the life cycle assessment and the real impacts on the environment. The uncertainty principle means that the uncertainty should be accompanied with a quantitative index that represents the uncertainty of the result.

IV. **The default principle**. Using a default principle have several advantages; i.e. it fits well with the typical product development process, it can be used to communicate the environmental policy to the designers and the analytical process will be made faster than a complete LCA.

The environmental impacts that are evaluated in the EPS system are chosen from the Earth's Summit in Rio de Janeiro 1992, this in order to be compatible with the goals that were set. These environmental impacts are evaluated in one or several safeguard subjects, which are: human health, abiotic stock resources (e.g. fossil fuels and metals), ecosystem production capacity (e.g. crops, wood, fish and meat), bio-diversity and cultural and recreational (e.g. aesthetics and landscape scenery). The Willingness To Pay (WTP) in the OECD countries is chosen as a monetary measure in order to restore the safeguard subjects. There are two reasons for using the OECD values: 1) it is practical in the sense that it is measurable; 2) it is mostly the inhabitants from OECD that make decisions as designers (Steen, 1999a).

In a calculation of an ELU index the safeguard subjects has different subcategories for which the ELU is depending on. An illustration for calculating ELU for carbon dioxide is demonstrated in table 1.

Table 1. Calculation of ELU for CO_2 (Steen. 1999b)

	Charactarisation		Weghting	
Safeguard subjects	Global frequency x (or intensity)	(Contribution of 1kg to global emissions)x	Value of unit effect =	Sum
Human health	*(Affected persons/year)*	*1/(kg/year)*	*(Euro/person*year)*	*(ELU/kg CO2)*
Reduced life expecancy	5,40E+09	1,26E-16	85 000	5,78E-02
Severe morbidity	2,50E+09	1,26E-16	100 000	3,53E-02
Morbidity	2,50E+09	1,26E-16	10 000	6,55E-03
Severe nuisance			10 000	
Nuisance			100	
Ecosytem production	*(kg lost produce/year)*	*1/(kg/year)*	*Euro/kg produce)*	*(ELU/kg CO2)*
Reduced fish or meat prod.		1,26E-16	1	
Reduced crop prod.	6,00E+11	1,26E-16	0,15	1,13E-05
Reduced wood prod.	-3,20E-12	1,26E-16	0,04	-1,09E-04
Reduced water prod.			0,03	
Biodiversity	*(% of 1 NEX)*	*1/(kg/year)*	*Euro/NEX)*	*(ELU/kg CO2)*
Extinction of species	100	1,26E-16	1,10E+11	1,39E-03
Cultural values	*(not yet defined)*			
Abiotic resources	*(not applicable for emissions)*		0,0674	
			Sum	1,01E-01

Because the method mainly was developed with the aim of being an easy tool for companies' product development processes, care should be taken when using the system externally for other purpose. When using it e.g. for environmental declaration or purchasing decisions, obtaining great knowledge of the EPS system is therefore important in order to use it right (Steen, 1999a).

Case study

The electric motor was invented in the 1900th century and has thereafter been continuously improved and developed for new markets.

One important issue for the electric motor has always been its efficiency. Today approximately 65% of the total amount of the energy used in the industry is directly related to the extensive use of electric motors and the influence it has on the environment is an important issue for both the manufacturer and the users.

The aim of this case study at ABB is to measure the eco-efficiency of the HXR500 motor and evaluate how applicable the measurement is and the influencing factors that affect the eco-efficiency of the product. Additionally the case study will result in an analysis of how to make an eco-efficiency comparison between products.

ABB

The Swedish-Swiss ABB is a global leading power and automation technology company. They have a strong market positions in its core business that enable utility and industry customers to improve their performance while lower their environmental impact. ABB has a far-reaching history that goes back to the late nineteenth century with a distinguished record of innovation and technology leadership in many industries. The ABB group is organised in Power and Automation Technology and operates in over 100 countries with about 103,000 employees. Their goal is to create value for all stakeholders by meeting the needs of employees, communities and customers where they do their business (ABB, 2005).

Environmental work at ABB

ABB has always taken environmental issues seriously and is devoted to sustainable development (Lysell and Swanström, 2005). They are continuously striving to reduce their environmental impact e.g. developing energy efficient motors and automation systems. Sustainable development is integrated into all aspects of ABB's businesses and includes working in the three dimensions: social, economy and environment (Wisén & Karlson, 2002). Much of ABB's research and development is focusing both on new technologies as well as continuously improving existing products, this in order to reduce the environmental impact and particularly those that are related to CO_2 emissions.

ABB have a well-developed environmental management program and this area is one of their highest business priorities. ISO 14001 provides the framework and management tool for this program; this is done by e.g. applying environmental principles in all operations such as continuously improvements. Identifying environmental impacts, setting environmental objectives and targets as well as defining improvement plans are core elements of ISO 14001. Life cycle assessment is a powerful environmental management tool that ABB have been using in order to quantify the environmental impacts that their products have during their lifetime.

In the last ten years ABB have been in a successful co-operation with CPM and its international partners. During the first two years efforts were made on the development of scientifically based LCA tools and comprehensive databases containing comparable LCA analyses (Lysell and Swanström, 2005). During 2001-2004 ABB implemented LCA into its Gate Model, that is a tool to manage product development projects properly from a business perspective. The Gate Model put requirements on LCA use in the early stages in the development of new products and projects. The extensive use of LCA within ABB has resulted in an optimisation of the eco-efficiency design in products (Wisén and Karlson. 2002).

Developing products that deliver more from each unit of input with less environmental impact during their life cycle is a strategic approach for ABB; in other words increasing the eco-efficiency of the products makes them more competitive. The eco-efficiency work at ABB affects the entire business, from product design and material selection through manufacturing and distribution to product waste management.

Improving the efficiency of e.g. a motor is an important issue because the greatest environmental influence, which represents approximately 99% of the total impact, occurs during the usage phase. However in order to decrease the environmental burden it is more substantial to take a closer look on a complete system. Many motors that operate e.g. a pump are selected according to the maximum need and this cause that the selected motor often is oversized and inefficient. Using a frequency converter (variable speed drive), together with the motor will optimise the performance by effectively respond to the material flow, which results in improved process control and significant energy savings. The frequency converter is an electronic device that changes the motors supply frequency depending on the operational situation. AC drives are in the group of the most eco-efficient products on the market according to Wisén & Karlson (2002). E.g. using an AC drive instead of a throttle valve reduces the annual energy consumption with a large amount and thereby decreases CO_2 emission. ABB´s AC drives that have been delivered in the past 10 years for the speed control of pumps and fans alone, are estimated to have reduced electricity consumption by about 64,000 GWh per year worldwide. Savings have been achieved in all areas of industry in hundreds of different applications. The energy saved does not just have impact on the economy, the environmental impact decrease as well. Seen from a European mix of energy consumption the 64,000 GWh have reduced the CO_2 emissions with approximately 32 millions tons.

Scope of scenario one

According to Wisén & Karlson (2002) it is critical with easy to use and cost-efficient measurement tools that can be applied in various decisions situations related to management and product development. Important factors to consider with such tools are to enhance communication and increase the understanding of e.g. environmental data and results.

The evaluated motor in the first scenario is the AC 1278kW, 660 V motor operated by a throttle.

The functions of the product system

Typical applications of the machine include operating pumps, fans, blowers, compressors, conveyors, grinders, ship thrusters and AC generators.

The functional unit

Calculations and indicators are expressed in unit per kW of rated output power, which is in accordance with the Product Specific Requirements (PSR) for rotating electric machines (PSR 2000:2, 2000).

The product system boundaries

The boundaries for which the eco-efficiency calculation is based upon can be seen in figure 5. The actual use of the motor is not taken into consideration in the calculation; this imply in that the environmental impact and the costs only consider the motor and not the entire system that it is meant to operate in. The operation point for the motor was chosen in accordance with Björn Norberg at ABB, the calculation are based upon an estimated lifetime of 20 years when operating 8500 hours per year.

If the eco-efficiency were to be studied in a real scenario when it operates in a complete system, it would involve complex boundaries. First of all the system boundaries cannot be considered to be just the HXR500 model, the boundary must then involve some kind of operation assumption, e.g. the motor is operating a district heating pump. The eco-efficiency measure will then represent the whole system and extensive LCA and LCC data needs to be taken into consideration.

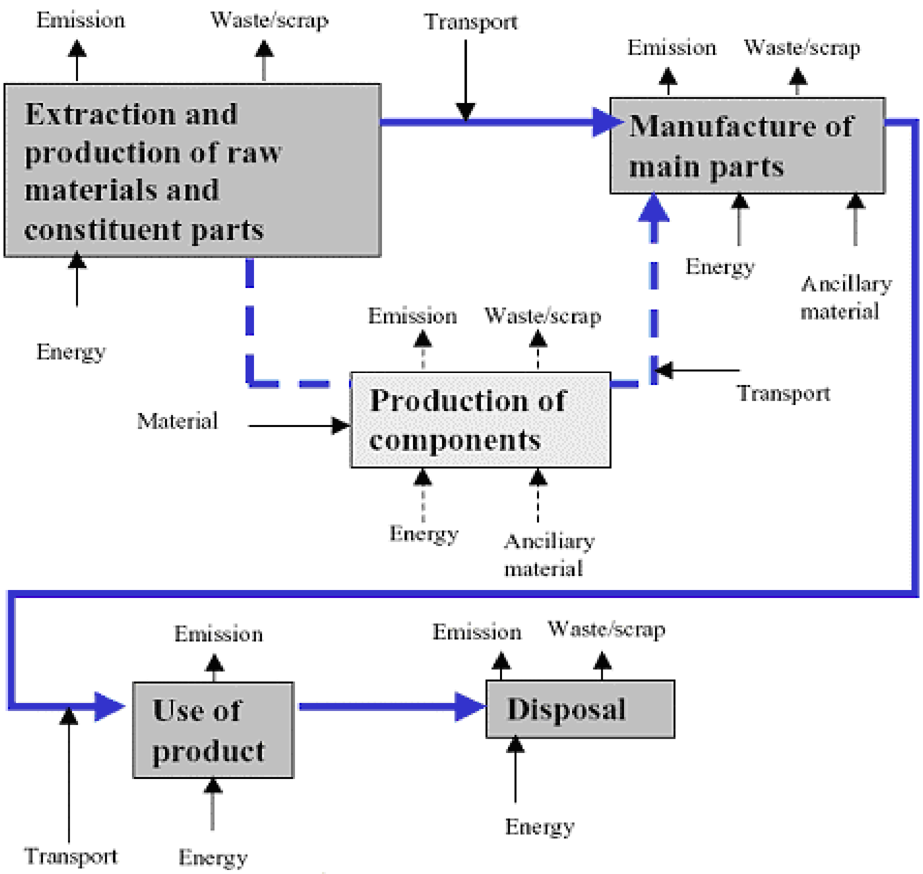

Figure 5. System boundary (PSR 2000:2, 2000)

Data requirements

The required data in order to calculate the eco-efficiency for the HXR500 model have been gathered from interviews at ABB and from product related information. The throttle does not contribute to an important environmental burden and the investment cost is insignificant whereby it is excluded in the calculation. In order to determine the environmental damage costs (EDC), LCA data is needed. In this case an available Environmental Product Declaration (EPD) for the HXR500 motor is used, which contains the environmental life cycle data. The complete EPD for the motor can be studied in appendix A. The data from the LCA that are described in the EPD covers all environmental aspects for extraction and production of raw materials, manufacturing of main parts, assembly of the machine, transportation and use of the product, dismantling, fragmentation, disposal and recycling of scrap at the end of the product's life (EPD HXR500, 2003). It is described in three stages, manufacturing-, usage- and disposal phase. The environmental burden in the usage phase that is described in the EPD only considers the losses or the "waste" that the efficiency of the motor contributes with. The remaining environmental impact that is not presented in the EPD is related to the benefit that the motor contributes with to the entire system, when it is in operation (Imrell, 2005). Therefore it required a recalculation of the data, in the usage phase, in order to obtain the relevant environmental burden for this study.

The necessary LCC data for the eco-efficiency calculation are: investment, usage, maintenance and disposal costs. The LCC for investment, maintenance and disposal were gathered from interviews with Thomas Norberg at ABB. The usage costs were calculated with information from PumpSave, (2005).

Limitations

In the case study an estimated operation point were chosen in agreement with Björn Norberg at ABB. This could be considered as an average operation point in the industries where the HXR500 model is used. Therefore the result and the eco-efficiency will vary depending on where and for what the motor is used for. Further, the financial data i.e. investments, maintenance and disposal costs should not be considered as precise values, they could easily vary depending on fittings and use. This limitation considers both scenarios.

Scope of scenario two

In the second scenario the ACS800 frequency converter operates the motor. All data for the motor are the same as in scenario one; therefore only the ACS800 frequency converter is taken into consideration in this description.

The functions of the product system

The frequency converters' function is to optimise the motor performance; this imply in that the function of the product system is the same as for the motor.

The functional unit

In order to successfully perform a comparison between the two scenarios it is important that the calculations and the indicators are expressed in same functional unit (unit per kW of rated output power).

The product system boundaries

The system boundary in the second scenario is practically the same as for scenario one. Besides the motor, this scenario includes the frequency converter and comprises manufacturing, use and disposal of the product.

Data requirements

The data for the ACS800 model is gathered in a similar way as for the HXR500. The information is based upon an available EPD for the ACS800, see appendix B, additionally, information were derived from PumpSave (2005) and interviews with Björn Norberg at ABB.

The LCC for the ACS800 model includes the three life cycle phases: manufacturing, usage and disposal. The usage costs is estimated to be the same as for the HXR500, in other words the costs that are included in the usage phase is the electricity costs for which the motor consumes.

Limitations

The actual benefits for using a frequency converter is very much depending on the operation load on the motor. If the motor for the most part is operating near nominal load it decreases the advantages for the frequency converter; therefore the result and the eco-efficiency will vary depending on where and for what the motor is used for.

Results

In this chapter the eco-efficiency calculation for the two scenarios will be presented.

In both scenarios the calculation are based on a Swedish mix of energy during the usage phase, which consists of: Natural gas 0.1%, Oil 0.4%, Combined heat and power 6.6%, Nuclear power 48.6%, Wind power 0.1%, Hydro-electric power 44.2% (SPINE LCI Database 2001). Because the motor is produced in Finland a Finnish energy mix has been used in the manufacturing phase. The average Finnish mix of energy consists of: Natural gas 10%, Hydro-electric power 31%, Nuclear power 40%, Oil 2 % and Coal 17% (EPD ACS800, 2003).

Scenario One

The scenario is divided into LCC and EDC and is described below.

Life cycle costs

The financial values for the products, which are presented in this report, are estimated and should therefore not be considered as precise figures.

The motor is operating 8500 hours per year with an estimated lifetime of 20 years. This results in that the motor, with an efficiency of 96.4% and output power of 1232kW, consumes 6,131,115 kWh per year (PumpSave, 2005). In order to attain the costs, which the motor contributes with while it is operating, the total amount kWh during its lifecycle is multiplied with the electricity cost, see equation 2, which is estimated to be 0.40 SEK per kWh (National Energy Information Centre, 2003).

$$\text{Usage costs} = \frac{6131115 * 20 * 0.40}{1232} \qquad \text{(Equation 2)}$$

The maintenance and the investments costs are estimated to be 500,000 and 560,000 SEK respectively (Norberg, 2005). In the disposal phase the large amount of material, which the motor consist of, have a certain value. Only the substantial materials are included, which are electric steel, other steel, cast iron and copper (EPD HXR500, 2003). Usually 90% of the copper can be sold and 80% for the remaining materials (Swanström, 2005). Together they have a value of approximately 149000 SEK (Nyström, 2005). The sum in table 2 is then divided with kW of rated output power, this in order to get the life cycle costs per functional unit.

Table 2. Life cycle costs

Life cycle costs	**SEK**	**SEK/kW**
Investment	560000	455
Usage	48985354	39761
Maintenance	500000	406
Disposal	-149000	-121
Sum	**49896354**	**40501**

Environmental damage costs

The data in the tables below describe the material and energy from nature and the emissions to air, water and the waste that the motor contributes with to nature. Table 3 presents data from the consumption of non-renewable resources during the different lifecycle phases. In order to understand the EDC calculation for the non-renewable resources an example is made below for Uranium.

When using a Swedish mix of energy, nuclear power contributes with approximately 48.6%. In SPINE LCI Database (2001) it is specified that the amount of uranium ore that is required to produce 1kWh of Swedish nuclear power is 0.602g.

The uranium ore that is used in Sweden to produce the nuclear fuel consist of 0.7% uranium (SPINE LCI Database, 2001). Hence the total amount uranium per kWh that the motor uses during the usage phase is, see equation 3:

$$\left(\frac{0.602}{1000}\right) * 0.07\% = 4.2E^{-6}\text{kg/kWh} \qquad \text{(Equation 3)}$$

The amount used kWh during the estimated lifetime for the HXR500 motor is approximately 122,500,000 kWh. Multiplying the amount kWh with the amount uranium that it takes to produce 1kWh gives 514kg uranium. The number used in the calculation is per kW of rated output power and the total amount uranium is therefore divided by 1232kW, which result in 0.42kg/kW. The Environmental Load Unit (ELU) for uranium is 1190 per kg (Steen, 1999b) and this results in that the Environmental Damage Cost (EDC) for uranium is 499 Euro per kW. The complete utilisation of non-renewable resources for the motor can be seen in table3.

Table 3. Consumption of non-renewable resources [kg/kW] (EPD HXR500, 2003)

Non-renewable resources	Manufacturing phase	Usage phase	Disposal phase	Entire life cycle	EUR/ kW
Coal	8.79	0.77	-3.08	6.5	0.3
Iron	6.3	0	-4.16	2.1	2
Uranium	0	0.42	0	0.4	499
Oil	3.56	12.03	-2.31	13.3	7
Natural gas	1.33	0.31	-0.04	1.6	2
Copper	0.98	0	-0.89	0.1	19
Aluminium	0.001	0	-0.001	0	0
Manganese	0.01	0	0	0	0.1
			Sum	**24**	**529**

Besides the consumption of the non-renewable resources, the motor contributes with other environmental burdens, i.e. greenhouse gases that affect the global warming and photochemical oxidants that affect the oxygen deficiency in water. The entire list of the environmental load and the aggregated EDC can be seen in table 4.

Table 4. The entire environmental load for the HXR 500 (EPD HXR500, 2003)

Environmental effect	Equivalent unit	Manufacturing phase	Usage phase	Entire life cycle	SEK/kW
Global warming potential GWP	kg CO_2	44.55	2744	2789	2816
Acidification potential AP	kmol H+	0.01	0	0	0.01
Eutrophication	kg O_2	1.13	74	74.9	0
Ozone depleting potential ODP	kg CFC-11	0	0	0	33
Photochemical oxidants POCP	kg ethylene	0.03	2	2.4	7
Consumption of non-renewable resources	kg			24	4944
				Sum	**7800**

As can be seen in table 4 almost the entire environmental load that the motor contributes with is directly related to the extensive energy consumed.

In the figures EDC are expressed in SEK, because the EDC originally is calculated in Euro the amount is multiplied with the currency for one Euro, which is 9.35 SEK (Dagens Industri, 2005).

When the LCC and the EDC are known, the eco-efficiency for the motor can be calculated, see table 5, using the equation $1 - \frac{EDC}{LCC}$.

Table 5. Eco-efficiency for HXR500

Life cycle costs	40501 SEK
Environmental damage costs	7800 SEK
Eco-efficiency	**81%**

Scenario Two

Because the eco-efficiency calculations are made in the same way, only the figures that differ from scenario one will be presented.

Life cycle costs

The LCC is still based upon a lifetime of 20 years when operating 8500 hours. Because a frequency converter operates the motor, the motor efficiency will decrease with approximately 1% (PSR 2000:7, 2000) due to losses. The motor with frequency converter and a changed efficiency from 96.4% to 95.4% and output power of 1232kW, consumes 2,897,409 kWh per year (PumpSave, 2005). The frequency converter contributes with a reduction in electricity needed by 3,233,706 kWh per year.

In order to estimate the costs that the motor contributes with while it is operating, the total amount of kWh during its lifecycle is multiplied with the electricity cost; see equation 4, which is estimated to be 0.40 SEK per kWh.

$$\text{Usage costs} = \frac{2897409 * 20 * 0.40}{1232} \qquad \text{(Equation 4)}$$

The maintenance and the investment costs are estimated to 500,000 SEK and 560,000 SEK for the HXR500 motor and 1,000,000 SEK in investments, with 500,000 SEK in maintenance for the ACS800 frequency converter (Norberg, 2005). In the disposal phase the material, which the frequency converter consist of, have a certain value. This value is added together with the disposal value of the motor. Together they have a value of approximately 157,000 SEK (Nyström, 2005). The sum in table 6 is then divided with the functional unit kW of rated output power.

Table 6, Life Cycle Costs

Life cycle costs	SEK	SEK/kW
Investment	2660000	2159
Usage	23130223	18775
Maintenance	1000000	811
Disposal	-157000	-130
Sum	**26633223**	**21615**

Environmental damage costs

The data in the figures below describe the material and energy from nature and the emissions to air, water and the waste that both the HXR500 and ACS800 contribute with to nature. Table 7 presents data from the consumption of non-renewable resources during the different lifecycle phases. The emissions during the manufacturing and disposal phase for the frequency converter and motor is added together in order to get the total amount that they contribute with. During the usage phase the emissions that has been taken into consideration are the emissions that are related to the consumed energy. The total amount of used kWh during the estimated lifetime for the ACS800 frequency converter and HXR500 motor is approximately 57,000,000 kWh.

Table 7. Consumption of non-renewable resources for the ACS800 and HXR500 [kg/kW] (EPD HXR500, 2003; EPD ACS800, 2003)

Non-renewable resources	Manufacturing phase	Usage phase	Disposal phase	Entire life cycle	EUR/ kW
Coal	10.33	0.36	-3.91	6.75	0.34
Iron	7.25	0	-4.93	2.32	2.23
Uranium	0	0.2	0	0.2	234.59
Oil	4.14	5.68	-2.45	7.37	3.73
Natural gas	1.55	0.15	-0.08	1.62	1.78
Copper	1.22	0	-1.08	0.14	29.69
Aluminium	0.131	0	-0.091	0.04	0,01
Manganese	0.01	0	0	0.01	0.06
			Sum	**18.46**	**272**

Besides the consumption of the non-renewable resources, the motor and frequency converter contributes with other environmental burdens. The entire list of the environmental load and the aggregated EDC can be seen in table 8.

Table 8. The entire environmental load for the HXR 500 and ACS 800 (EPD HXR500, 2003; EPD ACS800, 2003)

Environmental effect	Equivalent unit	Manufacturing phase	Usage phase	Total lifecycle	SEK/ kW
Global warming potential GWP	kg	46.43	1295.7	1342.13	1355
Acidification potential AP	kmol H+	0.01	0	0.00	0.01
Eutrophication	kg O_2	1.22	34.83	36.05	0.00
Ozone depleting potential ODP	kg CFC-11	0	0	0.00	15.92
Photochemical oxidants POCP	kg Ethylene	0.03	1.11	1.14	3.37
Consumption of non-renewable resources	kg			18.46	2547
				Sum	**3922**

As can be seen in table 8 almost the entire environmental load that the frequency converter and motor contributes with is directly related to the energy consumed during the usage phase. The eco-efficiency for the product combination of the HXR500 motor with the ACS800 frequency converter can be seen in table 9.

Life cycle costs	21615 SEK
Environmental damage costs	3922 SEK
Eco-efficiency	**82%**

Table 9. Eco-efficiency for HXR500 & ACS800

Analysis

The purpose with the analysis is to determine the sensitivity of the outcomes when changing parameters that may affect the eco-efficiency, this in order to determine the most important parameters that affect the motors eco-efficiency. Further on, the analysis will determine how to make a sound eco-efficiency comparison between the two different scenarios; is it sufficient to present the eco- efficiency percentage value or is more information needed?

Parameters that will be changed and studied are:

- **Electricity**, how does the electricity affect the eco-efficiency, i.e. where it is produced?
- **Efficiency**, what affects does a change in motor efficiency have on the eco-efficiency?

Comparisons between first and second scenario

As can be seen in the result, the eco-efficiency for both scenarios is nearly the same, 81% and 82% respectively.

One of the reasons why the eco-efficiency in the second scenario, when using a frequency converter together with the motor, is nearly the same as for the single motor has to do with the approach of using LCC as an expression for the product value. When the LCC is reduced the environmental burden per the products functional costs will increase as a result from the method used. This approach of considering the eco-efficiency can be justified by that all economic activity has a negative impact on the environment (Jollands & Patterson, 2004), a decrease in manufacturing costs will lead to an increase in operational income. An other way of explaining this can be done with the rebound effect, which imply in that an increase in efficiency contribute with more and better products with less resources required. It emphasise that progress has a reverse side, an increase in efficiency cannot be regarded as valuable unless the benefits are used wisely in the economy. E.g. if the benefits from a more efficient production leads to an increase in products produced, the total amount of resources will continue to increase or be unchanged even though less input is required per unit (Sanne, 2000).

Using this approach when evaluating the eco-efficiency can thus be perceived as critique for using efficient products, on the other hand the result has also to do with the system boundaries in the evaluation. If both scenarios were studied from a real operation scenario, e.g. the motor is operating a fan in order to cool a system, it would imply in that the actual value of the product for the plant could be estimated more accurate. Evaluating the eco-efficiency for the whole plant would then illustrate an increase in eco-efficiency when using the ACS800 drive together with the HXR500 motor. Because of these circumstances discussed above, the percentage value cannot serve as an accurate index when making comparisons between the two products.

The LCC in the eco-efficiency calculation is supposed to identify the value of the product for a company/user. However, when making a comparison between the first and the second scenario the LCC will not be a sufficient measure as it was done in the result chapter. This because the value added have not been taken into consideration. In a comparison between two products that is contributing with the same function, e.g. making a fan rotate or making a pump to start transporting a fluid, the products effectiveness when performing this function has to be taken into account.

In scenario one and two, the function for the HXR500 and the HXR500 operated by the ACS800 is the same; never the less the motor with the frequency converter is performing the function more energy efficiently, which leads to a decrease in operating expenses. This can be seen in chart 1 and has to be considered when making a comparison between these two products.

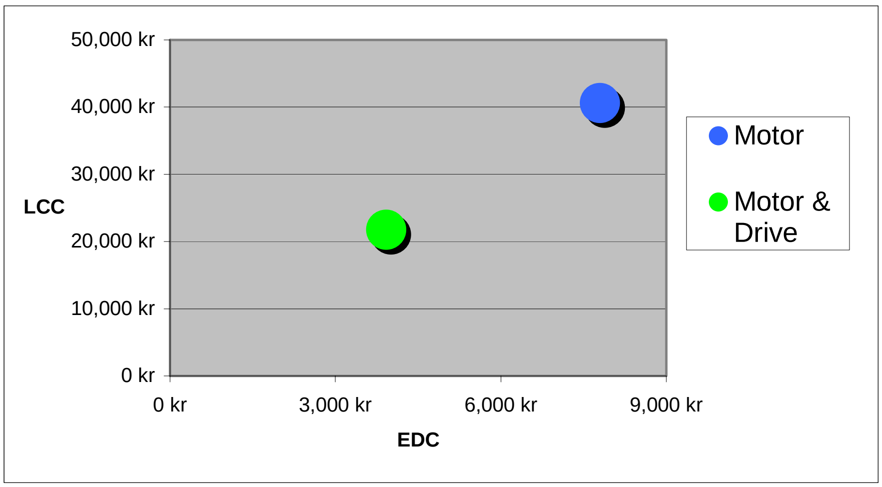

Chart 1. Relation between LCC and EDC

Therefore, the difference between the LCC for the motor and the motor combined with a frequency converter can be seen as the value added for the company/user (VAc) and the difference in EDC can be regarded as the value added for the society (VAs). The VAc represents the reduction in operation cost and the VAs is the decrease in environmental burden. In order to establish the relevant value for the motor with the frequency converter the VAc and the VAs is added to the functional value see equation 5. Additionally the enhanced value of the product because of the disposal value of the products may also be required in order to present the relevant value. The HXR500 motor is in this case observed as a value reference product.

$$40622 + 18876 + 3878 + 121 = 63618 \qquad \text{(Equation 5)}$$

The new value for the motor and drive, see chart 2, can then be used in order to re-calculate the eco-efficiency. The intended use of the new value is to evaluate the difference in eco-efficiency between scenario one and two and make a sound eco-efficiency comparison.

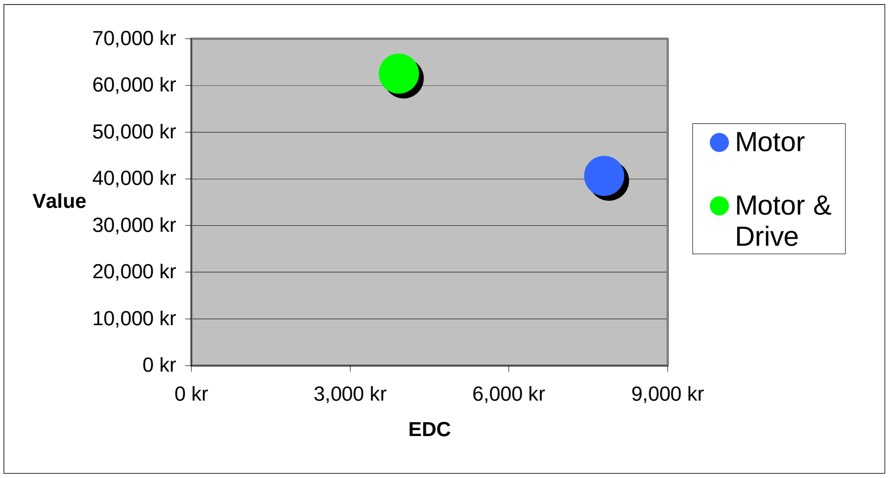

Chart 2. Relation between value and EDC

The difference can be calculated, see equation 5, by subtracting the measure for the motor and the frequency converter with the measure for the motor, the increase in eco-efficiency when using a frequency converter will then be illustrated. In table 10 the new eco-efficiency value is shown when comparing the two alternatives.

*Table 10. Eco-efficiency for HXR500 & ACS8*00

Value	63618 SEK
Environmental damage costs	3922 SEK
Eco-efficiency	**94%**

$$94\% - 81\% = 13\% \qquad \text{(Equation 5)}$$

The increase in eco-efficiency is approximately 13 percentage units; however it is important to understand that this new eco-efficiency measure not should be confused with the origin index for the HXR500 and ACS800. It presents the difference in eco-efficiency for the products compared.

Energy source

In the calculations that were made in scenario one and two a Swedish mix of electricity were used. Because the Swedish mix primarily consists of nuclear- and hydropower it does not contribute with CO_2 emissions in the same amount that e.g. a European mix of electricity does. The eco-efficiency calculation was therefore recalculated with European mix of energy; this in order to determine what affect a different energy mix has on the eco-efficiency. The European mix consists of: Nuclear power 34.6%, Coal 28.1%, Natural gas 14.8% and Oil 7.7% (SPINE LCI Database, 2001), there are also a certain amount energy produced from e.g. hydropower and wind mills, these sources are not included because they do not contribute with any significant emissions. The tables below illustrate the change for the indicators and eco-efficiency.

Table 11. Comparison between different electricity mix

Environmental effect	Equivalent unit	European energy mix	Swedish energy mix
Global warming potential GWP	kg CO2	50535	2816
Acidification potential AP	kmol H+	10	0.01
Eutrophication	kg O2	0	0
Ozone depleting potential ODP	kg CFC-11	161	33
Photochemical oxidants POCP	kg ethylene	59	7
Consumption of non-renewable resources	kg	5084	4944
	Sum	**55848 kr**	**7800 kr**

As can be seen in table 11 the European mix of energy is approximately contributing 20 times as much in CO_2 than the Swedish mix does. This is of course not something that is surprising in any way, it just give evidence to that the Swedish energy mix have a less environmental burden compared to the European mix. The interesting issue is what affect this has on the eco-efficiency. In table 12 the eco-efficiency for the motor is presented when it operates with different energy sources.

Table 12. Eco-efficiency comparison between different electricity mix

Energy mix	**European**	**Swedish**
Value	40742	40742
Environmental damage costs	55848	7800
Eco-efficiency	**-37%**	**81%**

In this scenario it can be clearly seen that the externalities have a great impact on the eco-efficiency. The electricity prices for the industry in Sweden and Europe, which the calculations are based upon, are nearly the same (National Energy Information Centre, 2003); therefore the electricity cost per kWh is not changed.

Does then the eco-efficiency measure of –37% imply in that the motor during its life cycle is less eco-efficient when it operates on European mix of energy? The motor itself is not less eco-efficient, in relation to manufacturing and disposal, however the energy situation where it is in operation have a negative impact. Important to notice is that when an eco-efficiency evaluation is made in a region, which give a negative value in eco-efficiency it is still useful. It can be used in the same extent in every country; a negative value does not decrease the use i.e. for benchmarking or trend analysis. As can be seen in table 12 the value added has not been taken into account, with exception of the disposal value. However if a company had the possibility to choose between different electricity sources and want to make an accurate comparison, which alternative that would be most eco-efficient, the value added has to be considered.

Motor efficiency

The electric motor is one of the most energy consuming products and is contributing with approximately 65% of the energy consumption in the industry. Increasing the motor efficiency, which is a measure of how well a motor converts the energy into useful work, can therefore make a big difference in the annual energy consumption, (ABB Automation Group, 2001).

The calculation below has its purpose to determine how a change in motor efficiency affects the eco-efficiency.

The HXR500 motor that been used as an example in this study has an efficiency of 96.4%. In table 13 an estimated efficiency of 93% has been used in order to distinguish what affect it has on the eco-efficiency, if a motor with an efficiency of 96.4% is used instead. Since a comparison is made between two products it is important that the value added is taken into consideration. The change in motor efficiency causes such a situation and therefore the same re-calculation has to be made as in the comparison discussed above, see equation 6.

$$VAc = 43379 - 40742 = 2637 SEK /_{Kw}$$
$$VAs = 8048 - 7800 = 248 SEK /_{Kw}$$
(Equation 6)

Table 13. Comparison between different motor efficiency

Efficiency	93%	96,4%
Value	43379	46264
Environmental damage costs	8048	7800
Eco-efficiency	**81%**	**83%**

As can be seen in table 13 the change in motor efficiency does not cause a significant change in the eco-efficiency, on the other hand when making the same comparison with an European mix of energy instead of Swedish it have greater affect, see equation 7 and table 14.

$$VAc = 43459 - 40742 = 2717 SEK /_{Kw}$$
$$VAs = 59771 - 55848 = 3923 SEK /_{Kw}$$
(Equation 7)

Table 14. Comparison between different motor efficiency

Efficiency	93%	96,4%
Value	43379	50019
Environmental damage costs	59771	55848
Eco-efficiency	**-38%**	**-12%**

Discussion

Moving towards sustainability is an important issue for both the society as a whole and for organisations. It is important to notice that businesses by itself cannot guarantee e.g. that the use of natural resources is in line with the earth's carrying capacity, however adopting eco-efficiency and responsible entrepreneurship can have a positive contribution of achieving such goals (Lehni, 2000).

Even though eco-efficiency is not a new concept in businesses today it is still in its developing phase, e.g. there is not an accepted method that is widely spread for measuring eco-efficiency among different organisations. For a new methodology to become accepted and put into practice in businesses it either needs to be necessary, i.e. legislated for reporting purpose, or motivated and/or involve money. Moreover it is essential to possess considerable knowledge of how to use the concept and what it stands for.

The WBCSD (2002) stress the importance of that there is an approach to measure eco-efficiency that is flexible enough to be widely used in the full business spectrum. This approach has both pros and cons; on one hand it is valuable to have a measurement that is flexible to be widely used; however when different methodologies are used it can cause difficulties when comparing different products or businesses. If the measurement is not done in a consistent way, i.e. using the same indicators and methodology, the result cannot serve as a legitimate index when making comparisons. Of course making comparison is not the only intended use for an eco-efficiency measure. Using different indicators and methodologies can still act as an important monitoring tool; e.g. evaluating an organisations eco progress and performance in a time spectrum.

Reporting results and trends is an essential ingredient in management systems, both internally to management and externally to stakeholders (Lehni, 2000). If the eco-efficiency concept should gain ground in organisations an international standardisation of the concept might be required. According to NRTEE (2001) it could become as an accepted standard and routine as indicators for financial performance reporting currently are. A standard for eco-efficiency do not automatically imply a decrease in its flexibility it can e.g. act as a guidance policy similar to PSR. Such guidance policies can result in less complicated comparison if it is known that every evaluation is done in similar way; creating a standard is not an easy task though.

Additionally, in order for eco-efficiency interpretations to become successful and useful in e.g. guiding policies it is important to pay attention to four issues according to Jollands & Patterson (2004). These are the true meaning of eco-efficiency and the meaning of the indicators, which most suitable indicator to use and possessing knowledge about the strengths and weakness of eco-efficiency indicators.

How well does the eco-efficiency method used in this report stand in comparison with the guidelines recommended by the WBCSD? The different indicators used in the calculations give comprehensive information; e.g. it can be used to distinguish high priorities areas in order to make decisions of what to improve in order to decrease the environmental burden. The calculation can be used for different products and services and act as a monitoring and benchmarking tool, on the contrary when it is used for benchmarking care has to be taken. It is important when e.g. two products are compared towards each other that the work is carried out in a consistent way (WBCSD), e.g. the selection of boundaries have great impact on the calculations and can be difficult to determine. In additional e.g. economic, political, environmental and natural resource constraints may be different in different regions within same business sectors (NRTEE, 2001). This can clearly be recognised when a comparison is made for the electric motor when it operates in different countries and with different energy source.

When using an economical indicator, i.e. LCC, in the calculation it can be very sensitive to market changes that usually are outside an organisations direct control. E.g. if the currency or the electric price changes it has a considerable affect on the eco-efficiency results; therefore when using the results for e.g. monitoring progress or benchmarking, recalculations might be required in order to get a trustworthy comparison.

Verfaillie & Bidwell (2000) specify the importance that indicators used for eco-efficiency should be clearly defined, measurable, transparent and verifiable; which is relevant for the trustworthiness of the results. The indicators used in the equation for this paper are based on well-established and accepted methods and because it is based on a life cycle approach it is useful for users when evaluating both current and future events. However there has been critique for the EPS system, which is used in order to establish the EDC. Steen (1999a) state that a debate has been going on for several years that the transparency will be lost if the environmental information is described in a one number concept, like an index. However the problem is more of a communication issue according to Steen (1999a). When people who are not directly involved or experts in LCA are going to cite results of LCA they often leave out background information, therefore if a “one number” index is available this would be the easiest way to report it.

The use of an eco-efficiency measure has in this report only included calculations of a product; however the use of interpreting eco-efficiency has a much wider spectrum. It can serve very useful when monitoring progress for an entire business. This would of course include more extensive boundaries and information gathering, nevertheless if a framework for the specific company is made, it can be used and monitored without any significant workload. In work done by Skantze (2005) an evaluation is made at Akzo Nobel using the same methodology used this report, this in order to decide which process that were most eco-efficient for combustion of process water. This is a practicality example that eco-efficiency can serve as a guideline for decision makers when deciding between different alternatives.

The environmental data used to calculate the EDC for the products in the case were mainly gathered from available environmental product declarations. This approach proved to be a useful data source in order to collect data for the eco-efficiency calculations; nevertheless knowledge is needed for how the data in the specific EPD is presented. In the PSR for electric rotating machines it is specified that during the usage phase the products environmental impact should only consider the loss of energy as determined by operational efficiency (PSR 2000:7, 2000). For that reason it is important when using information in an EPD to be aware of what environmental burden that the manufacturer imply with in the different phases. If the eco-efficiency calculation for the HXR500 motor entirely were based on the data and the approach used in the EPD the result would change drastically. It would then only represent the environmental burden caused by the efficiency.

Producers, purchases and wholesalers experience an increasing demand for environmental information, in order for them to make objective comparisons between products and services (Leire & Thidell, 2005). One of the intended uses of environmental product declarations was to solve or facilitate such decisions. However studies made on EPD denote that the level of information provided is perceived as too complex to be used for e.g. investment decisions (Leire & Thidell, 2005). The information needs to be interpreted in order to enhance transparency and understanding of the results. Interpreting the data together with financial information into an eco-efficiency index can then be beneficial in order to make sound environmental comparisons in e.g. purchase decisions.

Communicating results to stakeholder requires that all understand and the ‘same language’ (Vogtländer, et.al., 2002). The question is then if it is sufficient with a one number index, such as the percentage value that was presented in the results, or is more information needed. In one of the guidelines from WBCSD they stress the importance of understandability and even though environmental information can be complex it is important that such data are included. In order to increase the understandability of the result from an eco-efficiency calculation the EDC and the financial value for the evaluated product may serve valuable. E.g. when communicating information to stakeholders who do not obtain great knowledge about eco-efficiency, such information together with a percentage index might therefore be necessarily.

Conclusions

The purpose with this study is to evaluate the field of usefulness when measuring eco-efficiency by putting an interpretation key into practice.

Results from the case study indicate that the interpretation of eco-efficiency when using the standardised equation $1-\frac{EDC}{LCC}$ can serve useful in order to evaluate eco-efficiency. The method shows an increase in eco-efficiency of approximately 13 percentage units when a comparison is made of the HXR500 motor with the more eco-efficient product combination, using the motor with the ACS800 frequency converter. This give evidence that the interpretation is valid e.g. for purchase decision, monitoring performance and benchmarking of products. However, it is difficult to decide whether or not the index presented as a percentage value is sufficient when communicating the eco-efficiency without extensive knowledge of the concept.

An outcome of the case study when calculating the eco-efficiency gave evidence to an obstacle when using the LCC approach as an indicator for the product value. The difficulty was to determine the relevant value of the products when making a comparison. E.g. a motor, which have preferable life cycle costs compared to a different product, will provide the company/user with an increased value. The same added value can be identified for the EDC if the compared product have less environmental burden. For that reason the added value needs to be taken into account in the calculation in order to make sound eco-efficiency comparisons.

A general conclusion is that the eco-efficiency concept can function as a powerful tool in organisations environmental management systems and while successively measuring the eco-efficiency performance it can complement the strive towards sustainability. Additionally, it is important to notice that it can be difficult to determine the feasibility of the LCC/EDC index by executing one case study. It is therefore interesting with further investigation of the method and how to communicate eco-efficiency results in a suitable approach.

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Appendix A

Environmental Product Declaration

AC machine type HXR 500, 1278 kW power

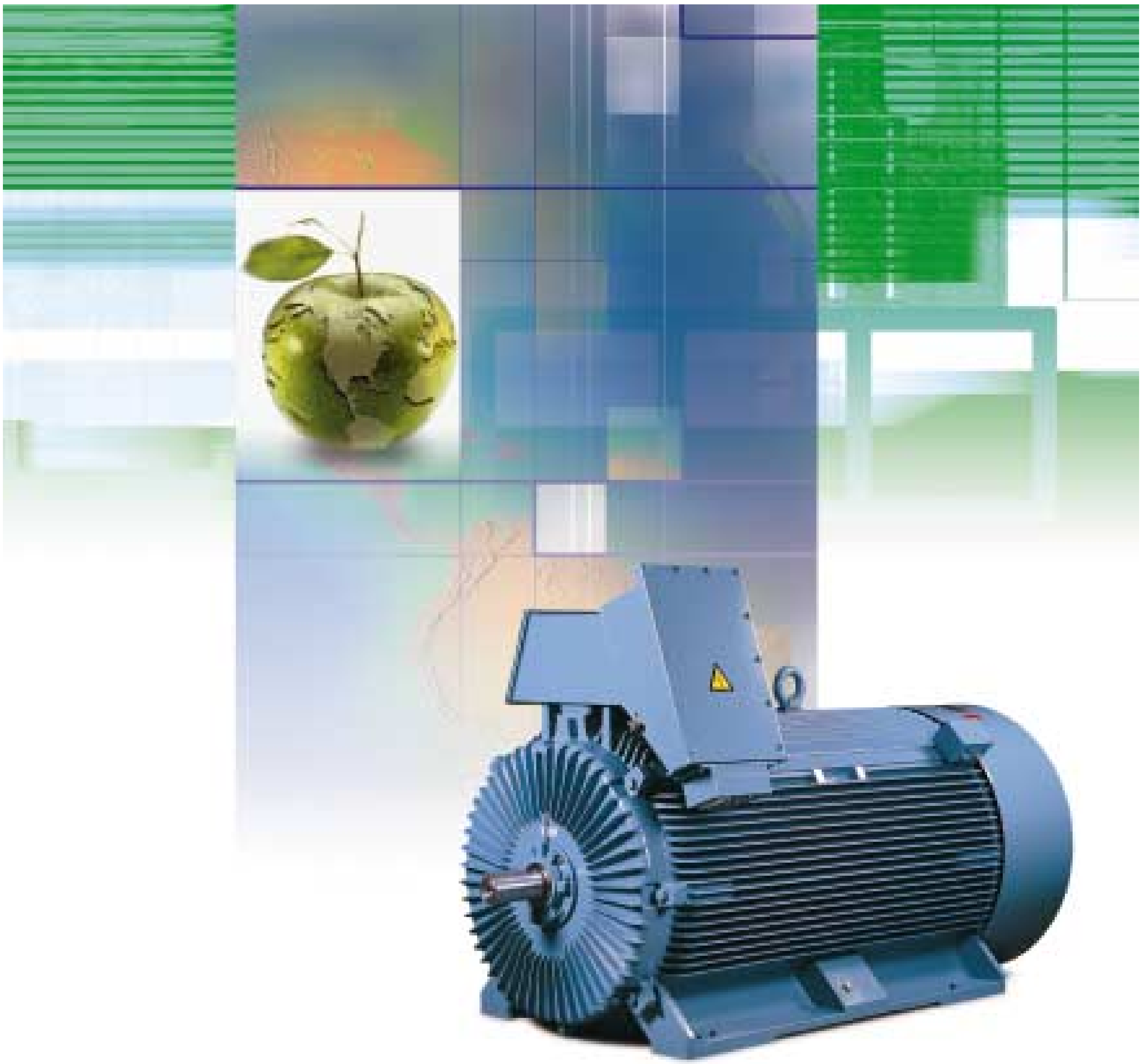

ABB Automation

Organizational framework

Manufacturer

ABB Industry Oy/Machines Group
P.O. Box 186
FIN-00381 Helsinki
Finland

ABB Industry Oy/Machines Group Helsinki is part of the Motors & Machines ***Business Unit***, comprising fourteen manufacturing locations around the world. The business unit belongs to the Automation Power Products ***Business Area***, part of ABB's Automation segment.

Environmental management
The ISO 14001 international environmental management standard has been implemented and the Helsinki factory has been certified since 1996. Lifecycle assessment is applied continuously to all product development.

The Helsinki factory was awarded the ISO 9001 quality certificate in 1994 in recognition of its commitment to maintaining the high quality of its AC Machines.

Product description
HXR machines have shaft heights ranging from 315 mm to 560 mm. The range of rated output is 100–2250 kW, and voltage ranges from 380 V to 11 500 V. Typical applications of the HXR machines include pumps, fans, blowers, compressors, conveyors, grinders, ship thrusters and AC generators. This document applies to the HXR 500 model, a 1278 kW, 660 V product.

Material for the product is used according to the following table:

Type of material	kg/product	kg/kW
Electrical steel	6484	5.07
Other steel	1294	1.01
Cast iron	2344	1.83
Aluminium	1.6	0.00
Copper	1254	0.98
Insulation material	46	0.04
Wooden packing material	70	0.005
Impregnation resin	31	0.02
Paint	16	0.01

Environmental performance

The data and calculations are in accordance with the Product-Specific Requirements (PSR) for Rotating Electrical Machines dated April 2000, which specify the following baselines for the LCA calculation.

Functional unit
The functional unit for the LCA is 1 kW of rated output power.

System boundaries
The lifecycle assessment covers all environmental aspects for extraction and production of raw materials, manufacturing of main parts, assembly of the machine, transportation and use of the product, dismantling, fragmentation, disposal and recycling of scrap at the end of the product's life. It includes consumption of material and energy resources as well as emissions and waste generation.

Calculations are based upon an estimated lifetime of 25 years when operating 6500 hours per year. A Finnish mix of energy has been used to calculate energy consumption during manufacturing and a European mix of energy to calculate energy consumption during use and disposal.

The operational point chosen for the usage phase is 1278 kW, 1500 rpm and efficiency 96.4 %. The operational point in reality will vary considerably depending on the specific application.

Allocation unit
The factor for allocation of common environmental aspects during manufacturing (such as manufacturing waste) is calculated as the rated output power of the product in relation to the total annual production volume of the factory.

Resource utilisation	Manufacturing phase unit/kW	Usage phase unit/kW	Disposal phase unit/kW
Use of non-renewable resources			
Coal kg	8.79	1662.00	-3.08
Aluminium (Al) kg	0.001	0.00	-0.001
Copper (Cu) kg	0.98	0.00	-0.89
Iron (Fe) kg	6.30	0.00	-4.16
Manganese (Mn) kg	0.01	0.00	-0.00
Natural Gas kg	1.33	114.90	-0.04
Uranium (U) kg	0.00	0.06	-0.00
Oil kg	3.56	174.19	-2.34
Use of renewable resources			
Wood kg	0.06	0.00	0.00
Hydro Power MJ	0.21	0.00	0.00

Energy consumption and losses	kWh/product			kWh/kW		
Energy form	**Manufacturing phase**	**Usage phase**	**Disposal phase**	**Manufacturing phase**	**Usage phase**	**Disposal phase**
Electrical energy	8414	7 755 497	537	6.58	6068.46	0.42
Heat energy	2785	–	–	2.18	–	–

The average Finnish electricity mix is defined as being 10 % gas, 31 % hydro, 40 % nuclear, 2 % oil and 17 % stone coal. Average European electrical energy is defined as being 10 % gas, 15 % hydro, 36 % nuclear, 10 % oil, 19 % stone coal and 10 % lignite coal. The resultant resource utilisation is shown in the table above.

Waste	kg/kW
Hazardous waste after manufacturing phase	
Oil emulsions	0.024
Various	0.013
Hazardous waste after usage phase	
Various	0.013
Regular waste (to landfill)	
During manufacturing phase	0.065
At disposal phase	0.337

The classification data for emissions are as below:

Environmental effect	Equivalent unit	Manufacturing phase	Usage phase	Total lifecycle
Global warming potential GWP	kg CO_2/kW	44.55	3050.70	3081.39
Acidification potential AP	kmol H+/kW	0.01	0.60	0.61
Eutrophication	kg O_2/kW	1.13	38.24	39.11
Ozone depletion potential ODP	kg CFC-11/kW	0.00	0.00	0.00
Photochemical oxidants POCP	kg ethylene/kW	0.03	0.70	0.73

Additional qualifying factors

Recycling and disposal
The main parts of the product can be recycled. Some parts need to be fragmented to separate different types of material. A list of parts and components that can be fragmented and recycled can be obtained from the manufacturer. See references.

Usage phase in relation to the total
It must be noted that the environmental impact during the usage phase is the most important. As an example, the GWP of the usage phase is approximately 70 times greater than the GWP of the manufacturing phase.

Category of impact	Usage in % of total
Global warming GWP	99.00 %
Acidification AP	98.42 %
Eutrophication	97.77 %
Ozone depletion ODP	–
Photochemical oxidants POCP	96.22 %

References
- 3BFP 000 016 R0101 REV A, LCA report
- PSR 2000:2 for Rotating Electrical Machines
- HXR 011 G en 9706, Installation and Maintenance Manual
- 3BFP 000 018 R0101 REV A, Recycling and Disposal
- MSR 1999:1 Requirements for Environmental Product Declarations, EPD from the Swedish Environmental Management Council

The above-mentioned documents are available upon request.



GLOSSARY

Acidification, AP: Chemical alternation of the environment, resulting in hydrogen ions being produced more rapidly than they are dispersed or neutralised. Occurs mainly through fallout of sulphur and nitrogen compounds from combustion processes. Acidification can be harmful to terrestrial and aquatic life.

Eutrophication: Enrichment of bodies of water by nitrates and phosphates from organic material or surface runoff. This increases the growth of aquatic plants and can produce algal blooms that deoxygenate water and smother other aquatic life.

Global warming potential, GWP: The index used to translate the level of emissions of various gases into a common measure to compare their contributions to the absorption by the atmosphere of infrared radiation. GWPs are calculated as the absorption that would result from the emission of 1 kg of a gas to that of the emission of 1 kg of carbon dioxide over 100 years.

Lifecycle assessment, LCA: A management tool for appraising and quantifying the total environment impact of products or activities over their entire lifecycle of particular materials, processes, products, technologies, services or activities. Lifecycle assessment comprises three complementary components: inventory analysis, impact analysis and improvement analysis.

Ozone depletion potential, ODP: The index used to translate the level of emissions of various substances into a common measure to compare their contributions to the breakdown of the ozone layer. ODPs are calculated as the change that would result from the emission of 1 kg of a substance to that of the emission of 1 kg of CFC-11 (a freon).

Photochemical ozone creation, POCP: The index to translate the level of emissions of various gases into a common measure to compare their contributions to the change of ground-level ozone concentration. POCPs are calculated as the change that would result from the emission of 1 kg of a gas to that of the emission of 1 kg of ethylene.

Printed on triple blade coated Galerie Art Silk, awarded with Nordic Swan Label for low emissions during production.

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3BFP 000 014 R0101 REV A

Appendix B

Environmental Product Declaration

Drive^{IT} Low Voltage AC Drive
ACS800 frequency converter, 630 kW power

Organisational framework

ABB Oy, Drives in Finland forms part of ABB's Automation Technologies division. The company develops, manufactures and markets drives for ABB Group customers world-wide and is responsible for several key product groups, including variable-speed AC drives and drive systems for speed control of electric motors.

Environmental management

The ISO 14001 international environmental management standard has been implemented and the Helsinki factory is certified since 1996. Life cycle assessment (LCA) is applied continually to all product development.

Product description

ABB Oy, Drives comprises the following product series

- ACS100 power range 0.12 to 2.2 kW
- ACS140 power range 0.12 to 2.2 kW
- ACS160 power range 0.55 to 2.2 kW
- ACS400 power range 2.2 to 37 kW
- ACS600 power range 1.5 to 4,300 kW
- ACS800 power range 1.1 to 5,600 kW

This document applies to the ACS800-07-0750-7 model which is a 690 V, 630 kW product with protection class IP 21.

Material according to the table below is used for the product:

Type of material	kg / product	kg / kW
Steel	433	0.687
Iron	134	0.212
Copper	153	0.242
Aluminium	77	0.121
Plastics	16	0.025
Other materials	30	0.046

Environmental performance

The data and calculations are in accordance with Product Specific Requirements (PSR) for Variable Speed Electric Drives, which specifies the following baselines for the LCA calculation.

Functional unit

The functional unit for the LCA is 1 kW of rated output power.

System boundaries

The life cycle assessment covers all environmental aspects for extraction and production of raw materials, manufacturing of main parts, assembly, transportation and use of the product, dismantling, fragmentation and disposal and recycling of scrap after end of life. It includes consumption of material and energy resources as well as emissions and waste generation.

Calculations are based on an estimated lifetime of 15 years when operating 5,000 hours per year. A Finnish mix of energy has been used for calculating energy consumption during manufacturing and an OECD mix of energy for calculating energy consumption during use and disposal.

Allocation unit

The factor for allocation of common environmental aspects during manufacturing (such as manufacturing waste) is calculated as used working hours in relation to the total annual production volume for the manufacturing at ABB Oy, Drives and mass for the manufacturing at the suppliers.

Resource utilization

	Manufacturing phase unit / kW	Usage phase unit / kW	Disposal phase unit / kW
Use of non-renewable resources			
Coal kg	1.46	553	-0.79
Aluminium (Al) kg	0.12	0.00	-0.09
Copper (Cu) kg	0.23	0.00	-0.18
Iron (Fe) kg	0.90	0.00	-0.73
Manganese (Mn) kg	0.00	0.00	0.00
Natural Gas kg	0.21	64.5	-0.04
Uranium (U) kg	0.00	0.02	0.00
Oil kg	0,55	57.8	-0.13
Use of renewable resources			
Hydro Power MJ	0.03	107	0.00
Wood kg	0.01	28.4	-0.00

Energy consumption and losses

	kWh / product			kWh / kW		
Energy form	Manufacturing phase	Usage phase	Disposal phase	Manufacturing phase	Usage phase	Disposal phase
Electrical energy	717	1,539,000	-	1.13	2,443	-
Heat energy	391	-	-	0.62	-	-

Electricity mix which was used in the manufacturing phase is defined as being 10 % gas, 31 % hydro, 40 % nuclear, 2 % oil and 17 % stone coal. The average OECD electrical energy is defined as being 13.2 % gas, 15.7 % hydro, 23.2 % nuclear, 7.3 % oil, 32.5 % stone coal, 6 % lignite coal, 1.5 % biomass & waste and 0.6 % other. The resultant resource utilization is shown in the table above.

Waste

	kg / kW
Hazardous waste	
During manufacturing	-
At disposal phase	0.04
Regular waste (to landfill)	
During manufacturing phase	0.02
At disposal phase	0.06

The classification data for emissions are as follows:

Environmental effect	Equivalent unit	Manufacturing phase	Usage phase
Global warming potential GWP	kg CO_2 / kW	5.88	1,549
Acidification potential AP	kmol H+ / kW	0.00	0.27
Eutrophication	kg O_2 / kW	0.09	18.0
Ozone depletion potential ODP	kg CFC-11 / kW	0.00	0.00
Photochemical oxidants POCP	kg ethylene / kW	0.00	0.26

Additional qualifying factors

Recycling and disposal

The main parts of the product can be recycled - some parts need to be fragmented to separate different types of material. A list of parts and components that can be fragmented and recycled can be obtained from the manufacturer. See references.

Usage phase in relation to the total

It should be observed that the environmental impact during the usage phase is the most important. As an example, GWP for the usage phase is approximately 260 times larger than GWP for the manufacturing phase.

Category of impact	Usage as % of total
Global warming GWP	99.66 %
Acidification AP	99.71 %
Eutrophication	99.57 %
Ozone depletion ODP	99.94 %
Photochemical oxidants POCP	99.69 %

References

- LCA report, 3AFE 64695908
- PSR 2000:7 for Variable Speed Electric Drives
- ACS800-07 Drives, 500 to 2800 kW Hardware Manual, 3AFE 64731165
- ACS800 frequency converter, Environmental Information, Recycling Instructions, 3AFE 64557815
- MSR 1999:2 Requirements for Environmental Product Declarations, EPD from the Swedish Environmental Management Council

The above mentioned documents are available upon request from ABB Oy, Drives.

Glossary

Acidification, AP.
Acidification originates from the emissions of sulphur dioxide and oxides of nitrogen. In the atmosphere, these oxides react with water vapour and form acids which subsequently fall down to the earth in the form of rain or snow, or as dry depositions. Acidification potential translates the quantity of emission of substances into a common measure to compare their contributions to the capacity to release hydrogen ions.

Eutrophication.
Nutrients (mainly nitrogen and phosphorus) from sewage outfalls and fertilised farmland accelerate the growth of algae and other vegetation in water. The degradation of organic material consumes oxygen resulting in oxygen deficiency and fish kill. Nutrification potential translates the quantity of emission of substances into a common measure expressed as the oxygen required for the degradation of dead biomass.

Global warming potential, GWP.
Some of the gases in the earth's atmosphere (in particular water vapour and carbon dioxide) have an ability to absorb infrared radiation. They do not prevent sunlight reaching the earth's surface, but they do trap some of the infrared radiation emitted back into space causing an increase in the surface temperature. Global Warming Potential, GWP100, translates the quantity of emission of gases into a common measure to compare their contributions - relative to carbon dioxide - to the absorption of infrared radiation in 100 years perspective.

Life cycle assessment, LCA.
A management tool for appraising and quantifying the total environment impact of products or activities over their entire life cycle of particular materials, processes, products, technologies, services or activities. Life cycle assessment comprises three complementary components - inventory analysis, impact analysis and improvement analysis.

Ozone depletion potential, ODP.
Ozone forms a layer in the stratosphere protecting plants and animals from much of the sun's harmful UV-radiation. The ozone levels have declined as a consequence of CFCs and halons released into the atmosphere. A depletion of the ozone layer will increase the UV-radiation at ground level. Ozone depletion potential, ODP, translates the quantity of emission of gases into a common measure to compare their contributions - relative to CFC-11 (a freon) - to the breakdown of the ozone layer.

Photochemical ozone creation, POCP.
Photochemical ozone or ground level ozone is formed by the reaction of volatile organic compounds and nitrogen oxides in the presence of heat and sunlight. Ground-level ozone forms readily in the atmosphere, usually during hot summer weather. Photochemical ozone creation potential translates the quantity of emission of gases into a common measure to compare their contributions - relative to ethylene - to the formation of photochemical oxidants.

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