DANTES

DEMONSTRATE AND ASSESS NEW TOOLS
FOR ENVIRONMENTAL SUSTAINABILITY

LCA study of current transformers

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1. INTRODUCTION

This LCA study report was prepared by ABB within the frames of the DANTES project that is co-funded by the EU Life-Environment Program. One DANTES project goal is to assess and demonstrate available sustainability tools such as Life Cycle Assessment (LCA) and to perform simplified as well as comprehensive LCAs. The aim of this report is to present the results from a LCA study on current transformers conducted at ABB Power Technology in Ludvika. ABBs core business is to supply products, systems and services related to power and automation technologies. More information about ABB can be found on: http://www.abb.com/

The goal of this LCA study was to analyze six models of IMB 145 current transformers and to introduce LCA as a tool in ABB Power Technologies in Ludvika. The target groups are decision makers who can influence the development and construction of the current transformers as well as everyone interested in using environmental arguments in marketing.

LCA is a tool to analyze the total environmental impact of a product from "the cradle to the grave". In recent years increasing attention has been given to the total environmental impact of a product, whereas before the focus lay on the manufacturing processes. The reason for this shift is that the environmental impact could often be greater for other life cycle phases, like raw material production, use of the product or waste treatment than it is at the product manufacturing stage. To achieve environmental improvements for a product system there is a need to analyze and consider different types of trade offs between all activities in the life cycle. An improvement which is positive for the environment at the manufacturing stage might for example be negative for the environment during the usage phase.

This report is conducted according to the recommendations and requirements given in the ISO 14040 series of LCA standards.

Section 2 gives a general background to the LCA methodology.
Section 3 describes the background and assumptions for this specific LCA study.
Section 4 describes the LCA study results.
Section 5 describes the conclusions from the LCA study.
Section 6 describes references to documents and other types of knowledge sources used in the study.

2. THE LCA METHODOLOGY- ISO REQUIREMENTS

Life Cycle Assessment, LCA, is a tool that could be used to compare the environmental impacts caused by different types of products or systems or to compare the impact from different life cycle phases for one product system. The LCA methodology consists of a step-wise procedure with which one can estimate the complex nature of environmental impact from a products' full life cycle phases (se fig 1).

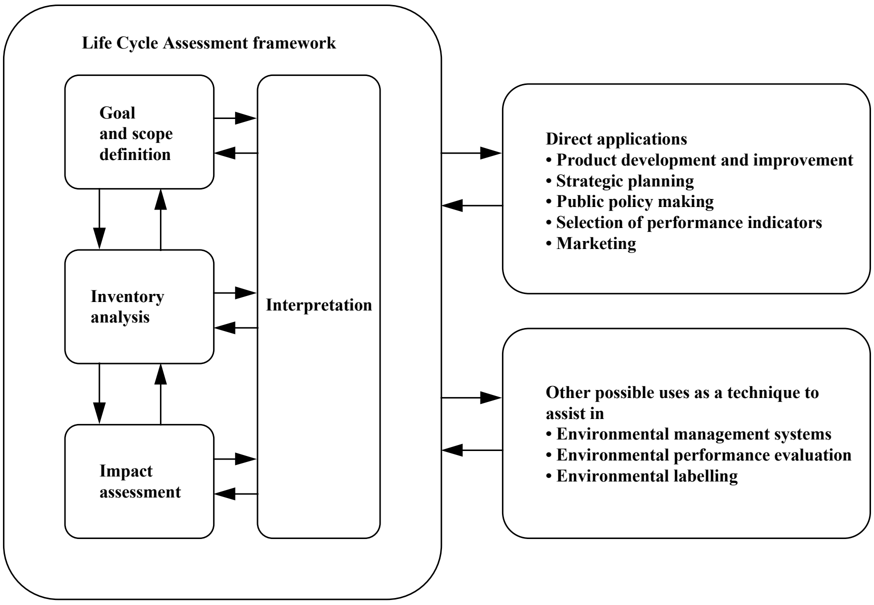

Figure 1. The LCA methodology and framework (Source: ISO 14040:1997)

A complete LCA consists of the following steps:

- Goal and scope definition
- Inventory analysis
- Impact assessment
- Interpretation

The depth and focus may shift from study to study depending on the goal and scope definition and hence can the results vary. Proper definition and documentation of goal and scope is therefore a very important groundwork before starting up an LCA study. The results should always be interpreted with the goal and scope definition in mind.

To assure quality and consistency in LCA studies, a series of international standards (ISO 14040-43) have been developed to guide the practitioner in conducting and reporting a LCA study. The environmental impact of a product starts long before the product is used or even assembled. Already the mining of the material causes pollution, emissions and uses energy. Then there are transports and further refining of the material into a component/product, each step adding to the total environmental impact. The basic principle for the LCA methodology (see ISO 14040) is to relate the inputs/outputs from the technical system over its' life cycle to environmental impact on the environment (see fig 2).

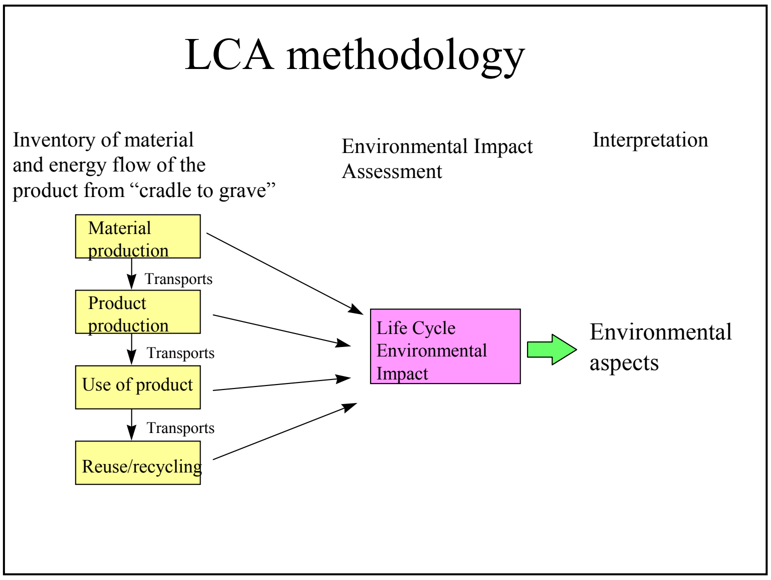

Figure 2. Basic principle of the LCA methodology.

The LCA results can be used for many purposes as for example to compare different design alternatives and to support environmentally sound material and design selection. Another application of LCA is to compile EPDs, Environmental Product Declarations to be used in e.g. customer communication.

2.1 Goal definition

When a LCA is performed one must clearly state the purpose of the study, for whom it is intended and how it is to be used. This information constitutes the goal and directly influences the layout of the study and forms a basis for deciding the scope.

This phase is an important groundwork of the LCA since it determines the scope and also the cost of all following activities. There are big differences between goals like “complete LCA of a product” and “identify main environmental aspects of a product” since the first often means a very large undertaking in time and costs.

2.2 Scope

The scope should contain information of e.g. the function of the product, the functional unit and system boundaries. It should also be defined well enough to ensure that the breadth and depth of a study are compatible with and sufficient to address the stated goal.

The choice of characterization and/or weighting method should also be stated in the scope. Equivalence of the systems being compared should be evaluated in a critical review if the LCA is to be used for external communication.

LCA is an iterative technique. Therefore, the scope of the study may need to be modified while the study is being conducted.

2.2.1 Functional unit (F.U)

A functional unit is a measure of the performance of the functional outputs of the product system. The main purpose of the functional unit is to provide a reference to which input and output data are normalized. This reference is necessary to ensure comparability of LCA results.

In an LCA the F.U is what we relate all the environmental impact to. The F.U is set according to the goal of the study. Usually this is a function or a specific product that is clearly defined. If the F.U is to deliver 1 kWh electricity all material and energy flows should be allocated to this unit. The results of the study are presented as impact per F.U.

2.2.2 System boundaries

System boundaries are set based on the goal of the study and divided into technical, geographical and time-related boundaries. To assure comparability and fairness in the study's different phases several factors such as cut off criteria, data and cost constraints must be considered in the planning of the study.

Cut off's and allocation principles should be motivated, clearly stated and assumptions explained. The study must make information transparent and the results clear and without hidden assumptions. A reader should be able to trace the origin of a conclusion when presented with the material used in the study.

2.2.3 Comparability

In comparative studies, the equivalence of the systems being compared should be evaluated before interpreting the results. Highlighting of weak data sources, rough estimations, difficult assumptions and parameters that by their nature have to be qualified guesses (for example usage in the future).

Differences in functionality should be described and explained as this might have impact on the results. Questions on how to estimate the impact of new legislation, geographical differences, difficulties in retrieving information and unclear data sources should be discussed.

Together with "alternatives not studied" the comparability discussion are important to give the study credibility by indicating weak parts, how these have been dealt with and describing what could be done to improve the study.

2.3 Inventory analysis (ISO 14041)

This phase involves data collection and calculation procedures to quantify relevant inputs and outputs of a product. This is in general a resource demanding and "calendar time consuming" step of a LCA study. Since an LCA has the aim to give a picture of an entire life cycle of a product the amount of information grows rapidly. A useful software tool - connected with a database consisting of relevant material and environmental data - to analyze the information gathered in the inventory is necessary. In this study the EcoLab software (www.port.se) with an ABB specific database (developed in cooperation with Chalmers Technical University http://www.imi.chalmers.se/) have been used.

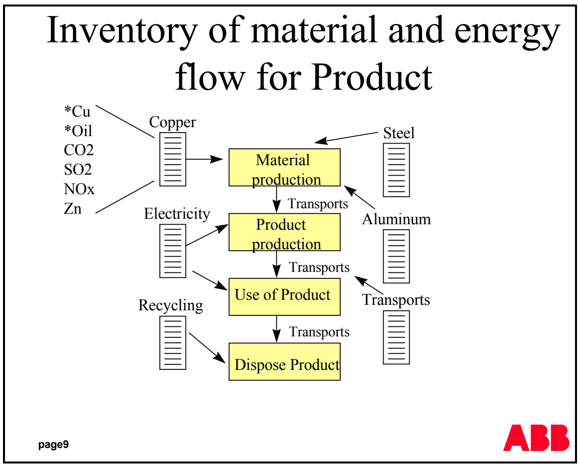

Figure 3. In the Inventory analysis the different raw materials, energy carriers and transports are summarized. The energy and emissions to produce these are then also added.

At this stage one could stop the analysis and use the results as a quantitative measure on emissions, energy and material resource use. This Life Cycle Inventory, LCI, profile gives straightforward information on the quantity of emissions and resource use that is caused by the F.U.

2.4 Impact assessment (ISO 14042)

The two impact assessment steps characterization and weighting could be used. The characterizing step is more objective than the weighting step, since the various environmental effects are then not weighed together.

2.4.1 Characterization

In the characterization step the environmental impacts caused by resource uses and emissions is aggregated into different environmental effect categories. Examples of (more than 15 conceivable) categories are:

- Greenhouse effect (Global Warming Potential, GWP), mainly caused by carbon dioxide emission. This is a commonly used category since the climate effect is in focus today depending on e.g. the Kyoto protocol.
- Acidification (AP, Acidification Potential), mainly caused by sulfur dioxide and nitrogen dioxide emissions.
- Ozone layer depletion (Ozone Depletion Potential, ODP), mainly caused by CFC gasses, "Freons".

The individual substances have different characterization factors depending on their contribution to the environmental effect. For instance CO_2 (carbon dioxide) has a GWP factor of 1 and CH_4 (methane) has a GWP factor of 35.

At this stage one could stop the analysis and look at the environmental effects caused by the different products or phases in a product's life cycle. Characterization is used as one main evaluation principle in EPDs, Environmental Product Declarations. It is also the most used evaluation principle in ABB, and then especially GWP factor, since ABBs products are related to energy transformation and energy use, and consequently the climate problem. This however does not mean that ABB products are free from other types of impacts. All evaluations and interpretations must therefore be done with care and conclusions must not be made to quick and simplified. The GWP factor is used as the main evaluation principle in this LCA study.

2.4.2 Weighting

The last but also most subjective, and according to ISO optional step, is to weight the results together into one single score. Methods where all impact categories are weighted together into a single score is by definition always subjective. Weighting methods should therefore be used with care and with a clear understanding of the assumptions and limitations that is built into all weighting methods.

Published weighting methods are designed in very different ways and are based on e.g.:

- Regional emission reduction goals (country and/or political)
- Willingness to pay for protection of safeguard objects
- Environmental quality goals
- Cost to reduce pollution

One weighting method is the EPS method (The Environmental Priority Strategies in product design). The EPS method is based on the society's willingness to pay for protection of the five safeguard objects; human health, biological diversity, biological production, resources and aesthetic values.

2.5 Interpretation (ISO 14043)

According to ISO 14043 the interpretation phase of an LCI study comprises three steps:

- Identification of the significant environmental aspects based on the results of different phases of LCA/LCI.
- Evaluation which shall include elements such as completeness check, sensitivity check and consistency check.
- Conclusions, recommendations and reporting on the significant environmental issues.

When interpreting the results it is important to consider the limitations and assumptions of the LCA study. As always, in the end the results are depending on how the information is used and how well the problem has been identified, i.e. it depends on the goal and scope definition.

A common LCA application is to identify environmental aspects to be used in product development projects and marketing.

Life cycle interpretation is also a process of communication designed to give credibility to the results of the more technical phases of the LCA, namely the inventory analysis and the impact assessment, in a form that is both comprehensive and useful to the decision maker. For example, motivate a more energy demanding production process if it leads to greater environmental gains in the usage or dispose phase.

2.5.1 Level of uncertainty

Usually in a LCA study the level of uncertainty depends largely on the experience and the ability of the practitioner to estimate the level of accuracy of input data. Educated guesses and understanding of the dynamics of the system set the references.

In order to know the quality of the results one might use different types of statistical methods. One preliminary assumption (before a more thorough statistical analysis is conducted) could be that the expected sum of all errors is zero. It is realistic to think that we overestimate as often as we underestimate. A statistical calculation could show what the probability would be that this assumption has an error larger than for example 20%. In this study no such statistical methods have been used.

3. LCA OF IMB CURRENT RANSFORMERS 145, GOAL AND SCOPE DEFINITION

3.1 Goal definition

3.1.1 Goal

The goal for this LCA study was to evaluate six models of current transformers from an environmental point of view. The goal was to get an overview of the environmental impacts over the full life cycles for these alternatives and to analyze the differences between the models. All life cycle phases and main steps are included but the goal was not to go deep into all conceivable details in the product life cycle.

3.1.2 Intended Application

Several applications could be thinkable as example:

- to build up knowledge on the LCA methodology at ABB Power Technogy in Ludvika as a starting point for future similar studies.
- to be used as a knowledge source and baseline in coming product development projects.

- to be used for identifying arguments that can be used in customer communication.

3.1.3 Intended audience

All interested at ABB Power Technology in Ludvika.

3.2 SCOPE

Six different types of IMB 145 current transformers were analyzed. These are abbreviated according to the following “translation key”:

- **IMB type 1** - IMB 145, porcelain insulator, new cooler, rated continuous thermo current 3150 A.
- **IMB type 2** - IMB 145, porcelain insulator, gas cushion, rated continuous thermo current 2400A.
- **IMB type 3** - IMB 145, polymeric insulator, new cooler, rated continuous thermo current 3150 A.
- **IMB type 4** - IMB 145, polymeric insulator, gas cushion, rated continuous thermo current 2400 A.
- **IMB type 5** - Previous generation IMB 145, porcelain insulator, cooler, rated continuous thermo current 3150A.
- **IMB type 6** - Previous generation IMB 145, porcelain insulator, gas cushion, rated continuous thermo current 2400A.

In the following analyses it is only relevant to compare IMBs with equal load in Ampere. This means that IMB type 1,3 and 5 is compared with each other and IMB type 2, 4 and 6 with each other.

3.2.1 Function of the current transformers

The main tasks for current transformers are:
- Transform current from high levels to levels suitable for relays and meters.
- Insulate the feeding circuit from high voltage system.
- Make possible standardizing of relays and meters.

3.2.2 Functional unit

All emissions, material and energy uses are allocated to the functional unit that is 40 years use of one IMB.

3.2.3 Evaluation

The evaluation was done according to the GWP (Global Warming potential) principle since this is a commonly discussed effect for products in the electric power industry. Additionally the climate effect is on the global agenda depending on e.g. the Kyoto protocol. This statement is however only valid since the IMBs do not contain hazardous materials, else it could also have been necessary to use other evaluation principles in addition to GWP, like eco toxicity.

To confirm the selected valuation principle the weighting method eco-indicator 99 was also used on parts of the result. This gave very similar results confirming that it was OK to use GWP as an indicator on total environmental impact.

3.2.4 System boundaries

A photo of IMB type 1 can be found in fig 4.

Figure 4. The studied product Current transformer IMB

3.2.4.1 Physical

This is included in the study:

- The construction materials and components used during the assembly in Ludvika. The ambition was to cover >95 % of the components/ materials.
- The process energy used in Ludvika to assembly one IMB is 556 kWh electricity, 1,2 kg oil and 7,3 kg gas.
- Transports from material and component manufacturing to Ludvika are included in the study. Most transport is conducted by lorry, but the transports of some materials from Canada and India also includes transports by ship.
- Transport of the product from Ludvika to customer was estimated to be 500 km. (To a harbour for further transport abroad).
- The OECD electricity mix was used to calculate the environmental impact. The average operational load was assumed to be 10% of

the rated continuous thermo current. This low percentage is justified by the facts that 1) Utilities tend to standardize the highest operational load for the system for all current transformers purchased but the average highest load is substantially smaller, 2) The peak load of the system only occurs during a few peak hours, 3) A substantial amount of current transformers are connected to branches which see no load currents or share the system current with other branches during many service situations.

- Recycling of metals at end of life was estimated to be 80% for aluminium, 95% for copper and 80% for steel.
- It was estimated that the transformer oil was incinerated after disposal of the product.
- The insulator and sand goes to landfill after disposal of the product.
- Data for the polymeric insulator was retrieved from ABB Plast. The other inventory data for materials were generic data taken from ABBs LCA database.

This is not included in the study:

- Manufacturing of components at suppliers (except for the polymeric insulator).
- Energy used or other impacts during installation of the product.
- Effects of possible accidents and other non-planned activities.

3.2.5 Temporal

Usage is assumed to be 40 years with 8 760 h of use per year (i.e. constant use).

3.2.6 Geographical

All material used is assembled in Ludvika, except for the polymeric insulator that is assembled at ABB Plast in Piteå. Transports of materials and components from the supplier to ABB in Ludvika are included in the study.

3.2.7 Disposal

Steel, copper and aluminium are assumed to be recycled to a degree of 80, 95 and 80 % respectively. It is assumed that the other materials (except the oil that is assumed to be incinerated) are transported to a safe landfill in the nearby area. This safe landfill is assumed not to leak any substances to the surrounding. However, some emission to the air due to the degradation of organic materials is accounted for.

3.2.8 Data quality

The data quality for each data set can be found in the ABB database 2003-10-27. This data are judged to be of relatively high quality (compiled in cooperation with Chalmers Technical University) and are mostly average values and to some extent also literature data.

3.2.9 Sensitivity and error analysis

No numerical sensitivity or error analyses were conducted. However, the relevance of the results is validated based on earlier experiences.

3.2.10 Peer review

No peer expert review from a third part has been conducted.

3.2.11 Inventory data

Detailed inventory data for e.g. materials are not given in this report for confidentially reasons. The product weights are between 380 and 670 kg depending on model. The main materials are steel, aluminium, porcelain and transformer oil.

4. RESULTS AND DISCUSSION

GWP, Global Warming Potential, is used as evaluation method if nothing else is stated.

The results for the six models are judged to be comparable since most of the materials and used processes are very similar for all six models. The limitations and assumptions used in this study are judged to not impact the results and conclusions in a significant degree. These qualitative statements are based on experiences from conducting and interpreting a large number of LCAs within ABB.

4.1 Life cycle impact

In section 4.1 the impact over the full life is examined.

4.1.1 IMB type 1, 3 and 5

The environmental impacts during the life cycle of IMB type 1, 3 and 5 can be found in fig. 5. The three life cycle phases are manufacturing, use and end of life.

- The manufacturing phase includes production of the materials from mining or oil extraction to construction material, transports from material production to Ludvika and process energy use in Ludvika to assemble the IMBs.
- The use phase includes the energy use (for losses) and 500 km lorry transport of the IMB to a harbor for further transport to a customer abroad.
- The end of life phase includes recycling of the metals, incineration of and landfill of the other materials.

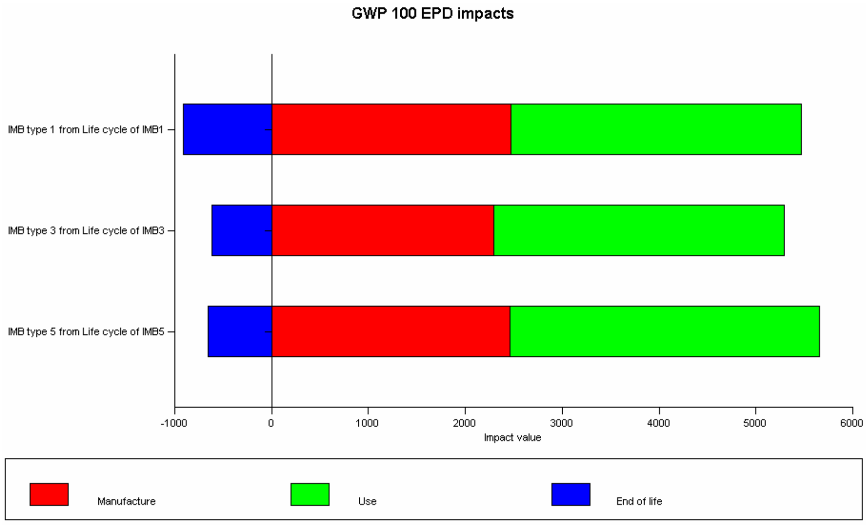

Figure 5: Life cycle impact (in GWP) of IMB type 1, 3 and 5

A first conclusion from this figure is that the impact from the use of the product during 40 years and the impact from the material are relatively equal. Of the "cradle to gate", i.e. mainly the material impact, approximately 30% of the materials can be "credited back" if the metals are recycled as stated in the goal and scope section. To understand the absolute number of the climate effect from IMBs we can compare with a common understood activity, car driving. If we assume that the car emits 220 g/CO2 emissions per km the total impact over a full life cycle of IMB 1 correspond to approximately 20 700 km of car driving. (4557 kg of CO2).

A second conclusion is that there is no significant difference between the IMB type 1 and 3 compared to the previous generation model IMB type 5.

The validity of the GWP results was checked by applying the weighting method Eco indicator 99. The result confirms that the selected GWP evaluation principle seems to be relevant to use since the Eco indicator evaluation give a very similar result pattern as the GWP evaluation, see fig 6, and compare this with fig. 5.

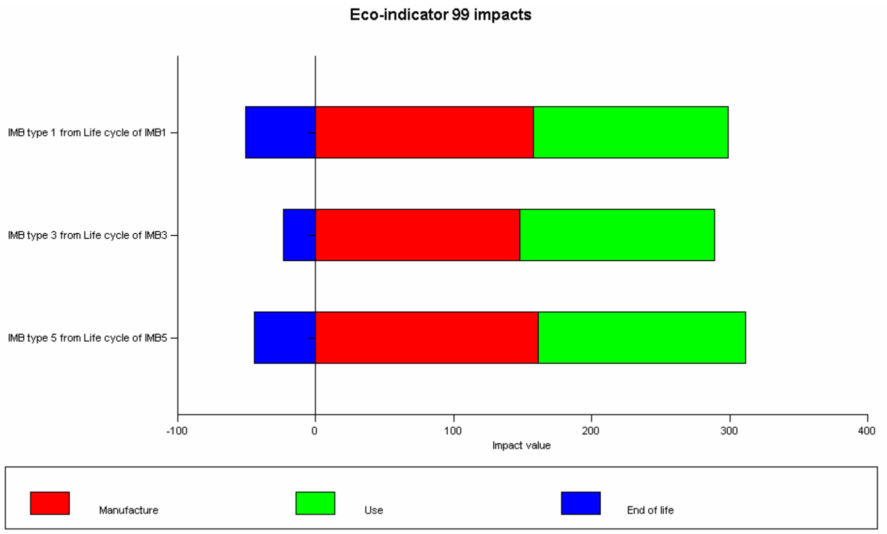

Figure 6: Life cycle impact of IMB type 1, 3 and 5 using the Eco indicator 99 weighting method.

The impact from all transports in the life cycle is very small compared to other activities (approximately 1 % of the total life cycle impact), see figure 7.

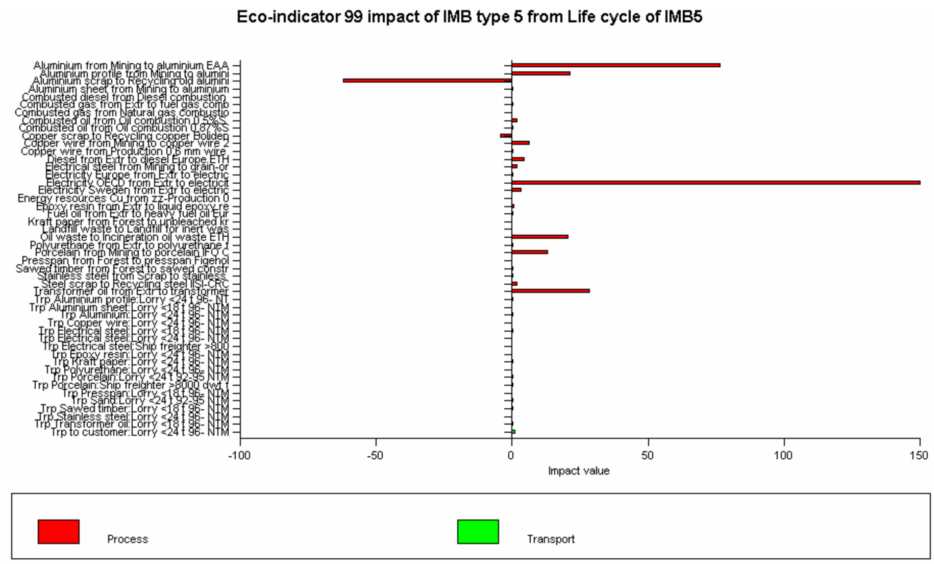

Figure 7: IMB type 1, transports compared to other activities.

From fig 7 it can also be seen that the materials giving the major impacts are from aluminium, porcelain and oil. Incineration of oil stands for a significant amount of the impact from the oil.

4.1.2 IMB type 2, 4 and 6

The environmental impacts during the life cycle of IMB type 2, 4 and 6 can be found in fig. 8.

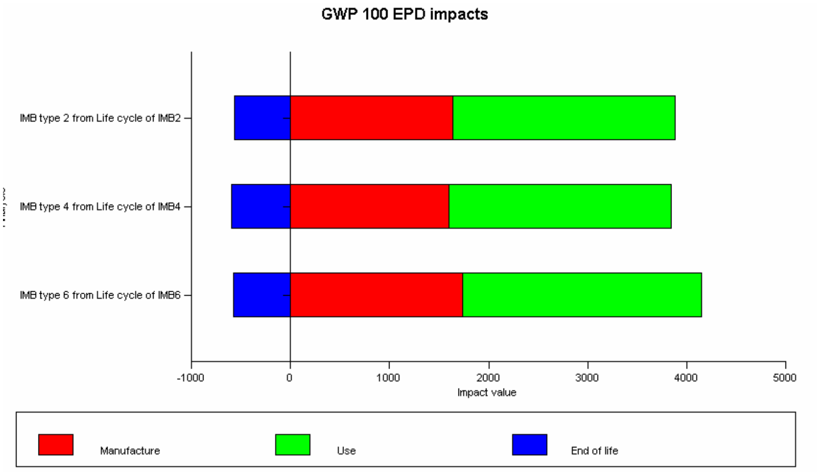

Figure 8: Life cycle impact (in GWP) of IMB type 2, 4 and 6

Exactly the same conclusions can be drawn as already been discussed under 4.1.1.

5. CONCLUSIONS AND RECOMMENDATIONS

This LCA study provides valuable knowledge about the life cycle environmental impact caused by IMB 145. The result could be used in ABB Power Technology in Ludvika when planning and designing new current transformers or when other types of decisions related to the product is taken. In addition this knowledge could be used when communicating the environmental impact for current transformers to customers and other stakeholders.

The following conclusions can be drawn from this study:

- The environmental impact of an IMB 145 during its expected 40 year life time corresponds to the use of fuel for 20 700 km car driving with a car consuming approx. 1 liter per 10 km.
- Operation of the IMB 145 during the product use phase and the impact from the materials stands for equal parts of the life cycle environmental impacts. Approximately 1/3 of the material impact can be credited by recycling of metals.
- No major difference between the six models has been identified.
- All transports in the supply chain together stand for a relatively small amount of the life cycle impact.
- IMB 145 designs that facilitate easy separation and recycling of metals should be one part of the designers’ requirements.
- Easy to use tools like LCA Light could be very useful in product development projects. The results from this study could give the valuable input and also serve as an object of comparison and “base-line” for such screening LCA studies.

6. REFERENCES

ABBs web site, http://www.abb.com

CPM, Competence Center in Environmental Assessment of Products and Material Systems, http://www.cpm.chalmers.se.

DANTES web site, http://www.dantes.info

EU Life Environment programme web site, http://europa.eu.int/comm/environment/life/home.htm

ISO/TC 207 Environmental Management Standardisation, International Organisation for Standardisations, http://www.tc207.org/home/index.html.

ISO 14040:1997. Environmental management- Life cycle assessment- Principles and framework. International Organisation for Standardisations.

ISO 14041:1998. Environmental management- Life cycle assessment- Goal and scope definition and inventory analysis. International Organisation for Standardisations.

ISO 14042:2000. Environmental management- Life cycle assessment- Life cycle impact assessment. International Organisation for Standardisations.

ISO 14043:2000. Environmental management- Life cycle assessment- Life cycle interpretation. International Organisation for Standardisations.