DANTES

DEMONSTRATE AND ASSESS NEW TOOLS FOR ENVIRONMENTAL SUSTAINABILITY

# LCA study of a HV Circuit Breaker


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# 1. INTRODUCTION

In the DANTES project one of the goal is to assess and demonstrate available sustainability tools such as Life Cycle Assessment. The aim of this report is to present the results from a LCA study of a High Voltage Breaker that was conducted by ABB within the frames of the DANTES project that is co-founded by the EU Life-Environment Program.

ABB´s core business is to provide power and automation technologies that enable customers to improve performance while lowering environmental impact. More information about ABB: http://www.abb.com.

The Life Cycle Assessment (LCA) for the LTB-D 145 kV high voltage circuit breaker is performed to make an Environmental Product Declaration (EPD). The report is conducted according to the recommendations and requirements given in the ISO 14040 series of LCA standards and the LCA fulfills the requirements of a certified EPD according to ISO TR 14025.

## 1.1 The LCA methodology

Life Cycle Assessment (LCA) is an environmental management tool to compare potential environmental impacts of different types of products or systems. The LCA methodology is a step-wise procedure that makes it possible to estimate the complex nature of environmental impact from all life cycle phases ("cradle to grave") of a product.

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. Proper definition of goal and scope is therefore an important groundwork before starting an LCA study.

The basic principle for the LCA methodology, illustrated in fig. 1, is to relate the inputs/outputs from the technical system over its' life cycle to environmental impact on the environment, i.e. environmental aspects.

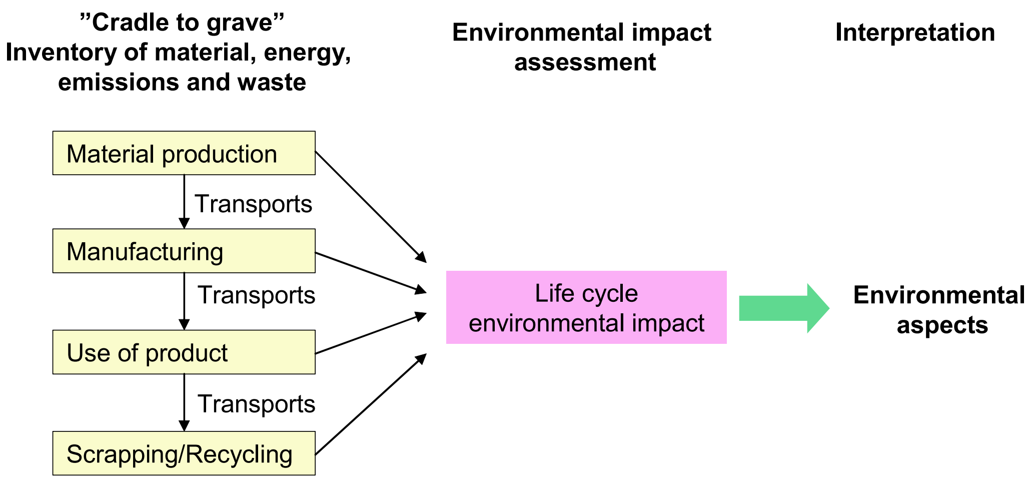


*Figure 1. Basic principle of the LCA method.*

The LCA results can be used for many purposes as example to compare different design alternatives and for environmentally sound material selection. Another common application of LCA is to compile customer information material like LCA based Environmental Product Declarations, EPD.

## 2. GOAL AND APPLICATION

The goal for this study is to perform a LCA for a LTB-D 145 kV High Voltage Breaker that fulfills the requirements of an Environmental Product Declaration (EPD).

The primary application for the result is

- to provide data for an EPD
- to identify arguments that can be used in marketing of the breaker
- to be used as a knowledge source and baseline in coming product development projects.

## 3. SCOPE

### 3.1 Functional unit

The functional unit is 40 years use of one live tank circuit breaker, a 3- pole LTB-D 145 kV including support structure and operating mechanism of type BLK. The schematic drawing in fig. 2 illustrates the studied product.

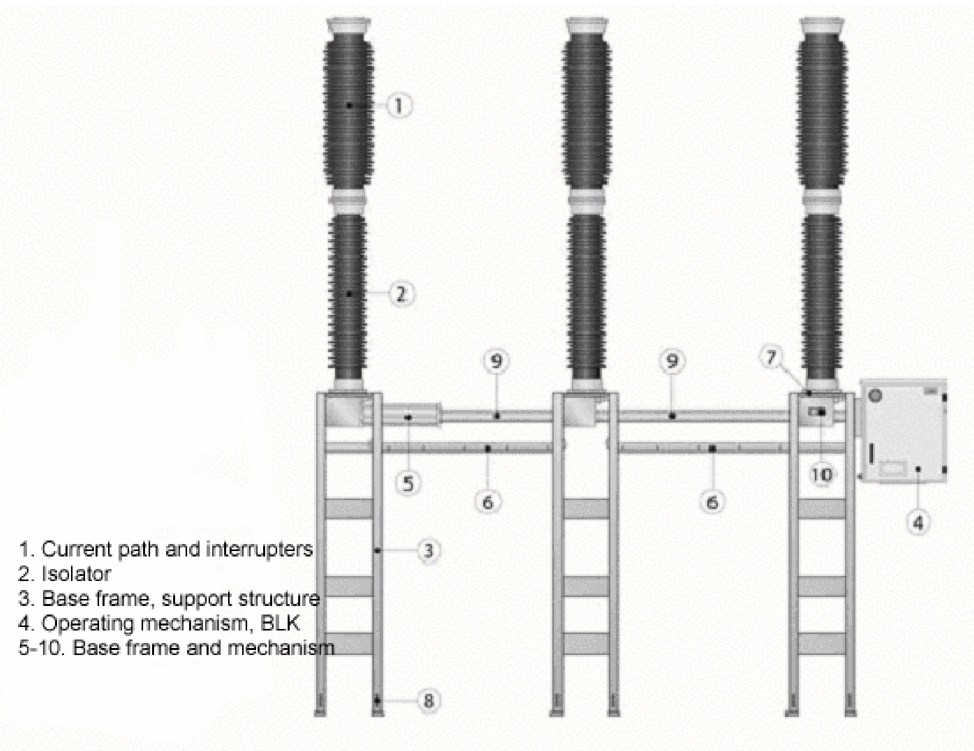


*Figure 2. The circuit breaker, LTB-D*

The breaker is produced in 2003. The product life time is 40 years with a running time of 8760 hours per year (24 h/day). The electrical performance is summarized in table 1.

Table 1. Electrical Performance

| | |
|---|---|
| Average load ($I_e$) | 50 % of rated current |
| Rated current ($I_n$) [1] | 3150 A |
| Rated voltage ($U_n$) [1] | 145 kV |
| Rated short-circuit breaking current ($I_{sc}$) [2] | 40 kA |

1) Specified according to IEC 60694  2) Specified according to IEC 62271-100

### 3.1.1 Life cycle boundaries

The life cycle boundaries and other specific conditions are defined in the Product Specific Requirements (PSR) 2002:3 for High Voltage Circuit Breakers and an overall description of the boundaries is illustrated in fig. 3.

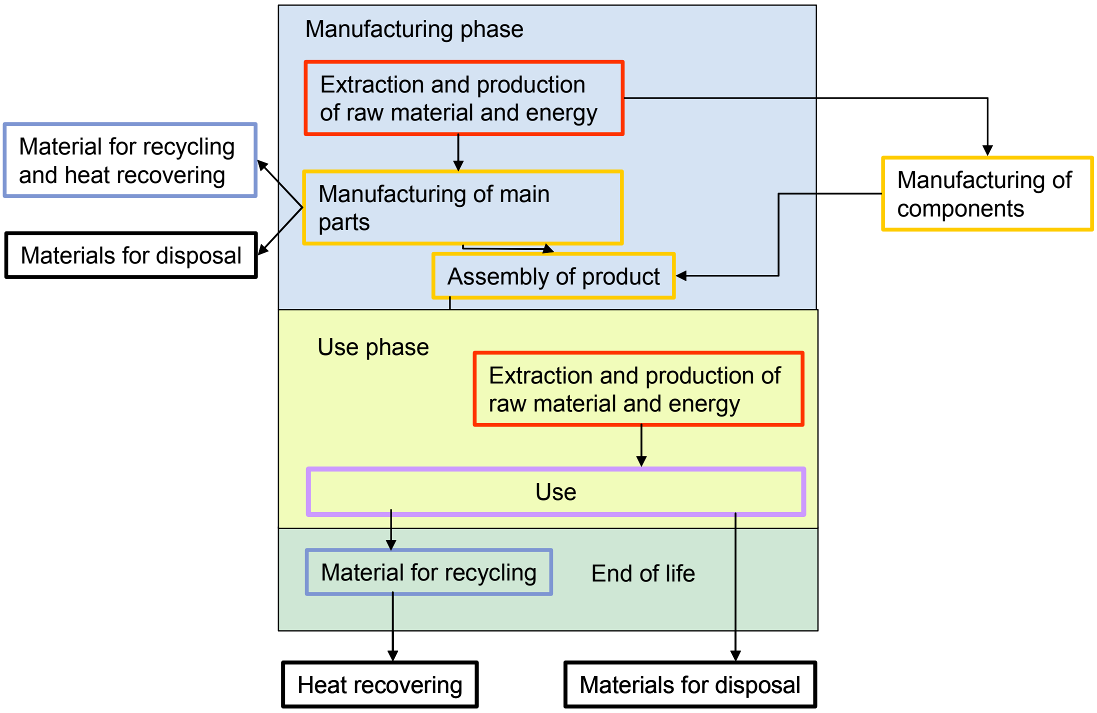


*Figure 3. Description of the life cycle boundaries of the system.*

### 3.1.2 Data Quality

Underlying data of material, energy and transports are given in the ABB EcoLab database 2001-11-19. Data sources for the most important materials:

- Aluminium: Mining to Aluminium EAA
- Copper: Mining to profile ICA- IME
- Electricity during use: Electricity Europe 1998 ETH
- Steel: Mining to steel IISI
- Plastics: APME (EPDM rubber-ETH and PTFE-EIME)
- Porcelain: Mining to porcelain IFÖ Ceramics
- $SF_6$: Production $SF_6$ Allied Signal

Site specific data are used for manufacture of main parts and assembly of the product. For porcelain, several suppliers are possible but data was only available from IFÖ ceramics in Sweden.

### 3.1.3 Allocation rules

- Energy consumption and emissions from manufacturing of the current path and interrupter are allocated based on the number produced, assuming that different models require the same amount of resources.
- Energy consumption at the manufacturing of the BLK mechanism was allocated by the supplier and, as no other information was given, it is assumed to be based on workshop area according to the questionnaire.
- Energy consumption at the manufacturing of other parts and assembling was allocated based on workshop area.

# 4. INVENTORY

## 4.1 Materials in the product

The main materials are steel, aluminium, copper and porcelain. $SF_6$ gas is used for insulation. Total weight is 1390 kg.
Detailed inventory data is not given in this report for confidentially reasons.

## 4.2 Manufacturing process and transports

*This is included in the study:*

- Extraction and production of raw materials for > 95 % of the materials used in the breaker.
- Transports of material. The distance is estimated to 200 km by lorry except when more detailed information was available.
- The energy consumption and emissions from the manufacturing main parts.

*This is not included in the study:*

- Manufacturing of components or other prefabricated parts used in the assembling of main parts.

## 4.3 Usage phase

*This is included in the study:*

- Transport of the product from ABB to customer is estimated to 500 km with lorry according to the PSR.
- SF6 topping-up is calculated according to the PSR:
- Electricity consumption during usage phase is calculated according to the PSR.

*This is not included in the study:*

- Energy and material used for the installation or other impacts from the installation
- Service and maintenance except $SF_6$ topping-up
- Energy consumption for motors, pumps and compressors is not accounted for as such devices are operating only for a fraction of the total lifetime.

## 4.4 End-of-life phase

*This is included in the study* according *to the PSR:*

- Recycling of metals is estimated to; aluminium 80 %, copper 95 % and steel 80 %.
- At dismantling 99 % of the $SF_6$ gas are assumed to be recovered whilst the remaining 1 % is considered to be lost.

### 4.5 Life cycle flow tree

The life cycles flow tree from Ecolab is shown in fig.4

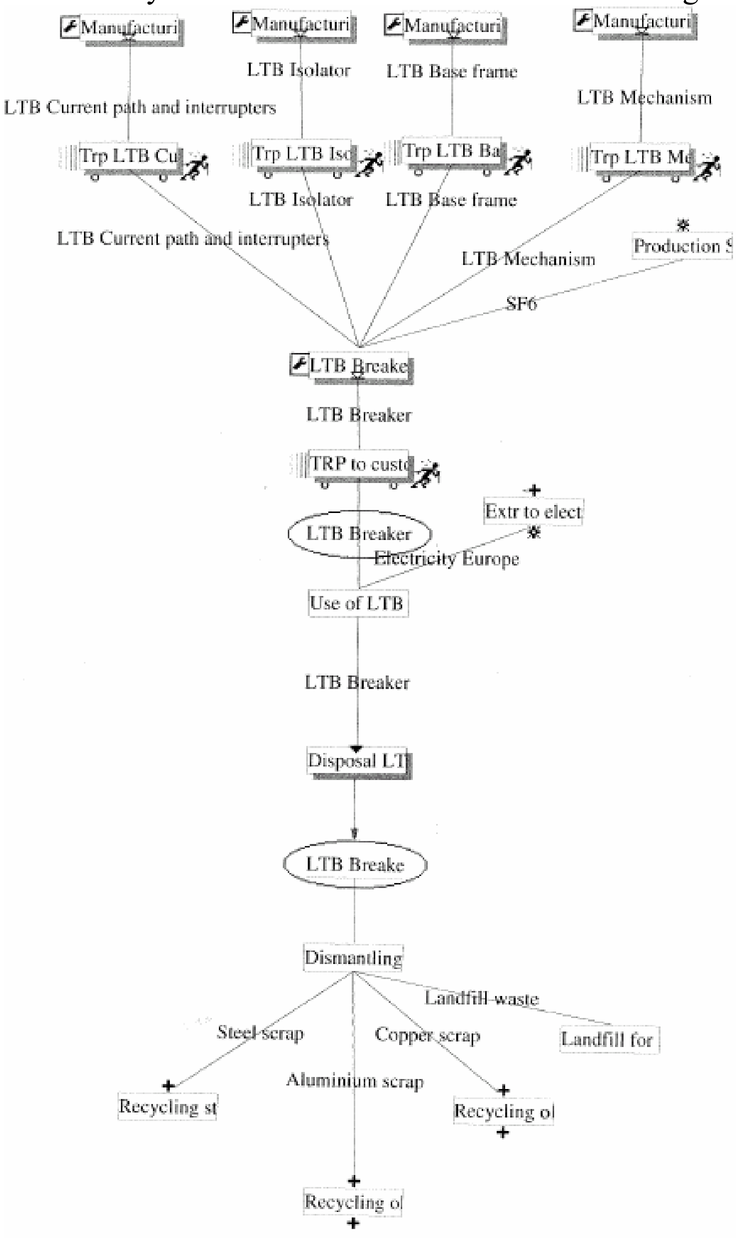


*Figure 4. The life cycle of the LTB breaker illustrated as a flow tree.*

## 5. RESULTS

The evaluation was done according to GWP (Global Warming Potential) since this is a commonly discussed effect for products in the "energy field".
The weighting method Ecoindicator 99 has also been used on parts of the result. The result from this method confirmed that the choice of GWP as an indicator of environmental impact was correct.

### 5.1 Environmental impact during the life cycle of the LTB breaker

In fig. 5 the environmental impact from the life cycle phases is shown as Global Warming Potential. It is emission of carbon dioxide from energy consumption and leakage of SF6 during the usage phase that stands for the main part of the impact. The validity of using the GWP was checked by applying also the weighting method Ecoindicator 99 and this gave the same results and conclusions, see fig. 6.

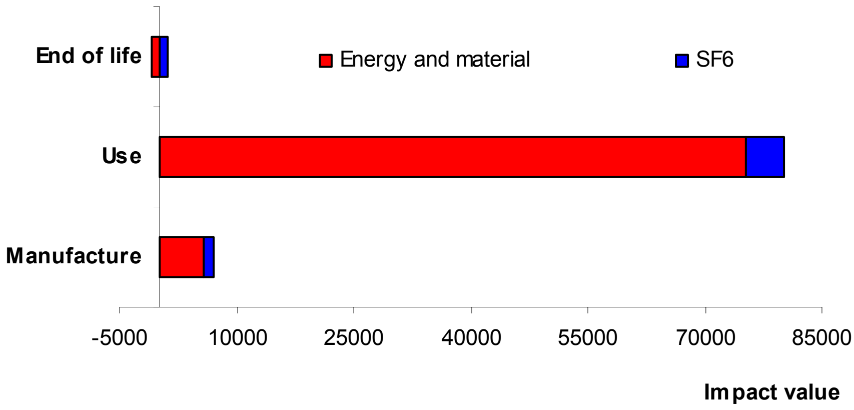


*Figure 5. Life cycle impact as Global Warming Potential.*

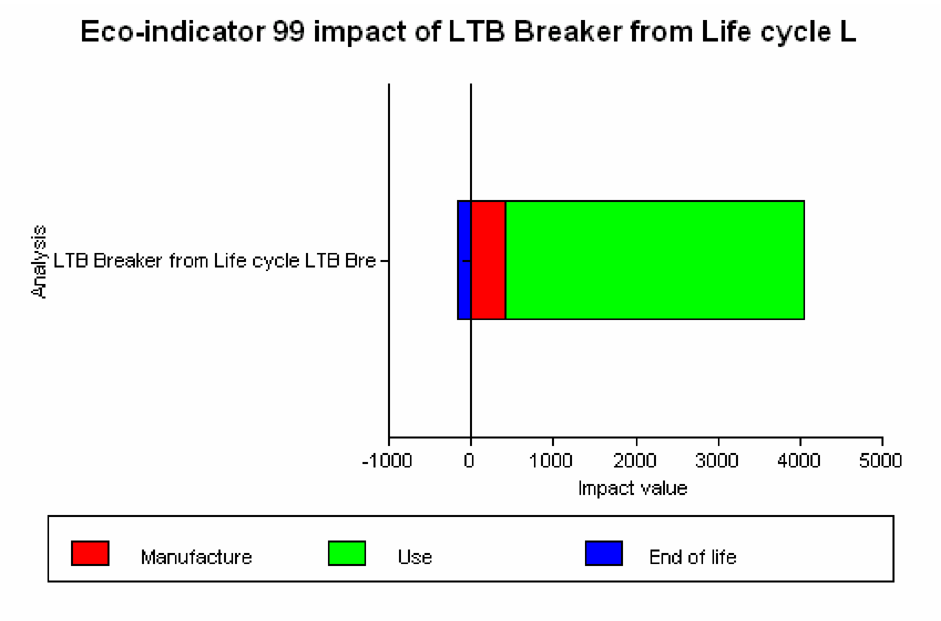


*Figure 6. Life cycle impact using Ecoindicator 99 weighting method.*

It is energy consumption during the usage phase that dominates the environmental impact. Losses are responsible for 70 %. The rest is shared by the thermo-stated heater (10 %) and the anti-condensation heater (20%).
Another observation is the importance of recycling the metals. The materials impact can be credited by recycling and this is facilitated if it is easy to dismantle the breaker and separate the different materials. Recycling of material reduces the impact from the manufacturing phase by 12 %.

## 5.2 Environmental impact from the manufacturing phase

Although the usage phase dominates the environmental impact, the material selection, manufacturing processes and transports should not be ignored. Manufacturing of base frame and isolators have the largest environmental impact. This is due to the production of porcelain and aluminium that is energy consuming and results in $CO_2$ emission. Leakage of $SF_6$ during the assembling of the breaker and emission of HCFC-22 during PTFE production will also affect the impact as can be seen in fig. 7.

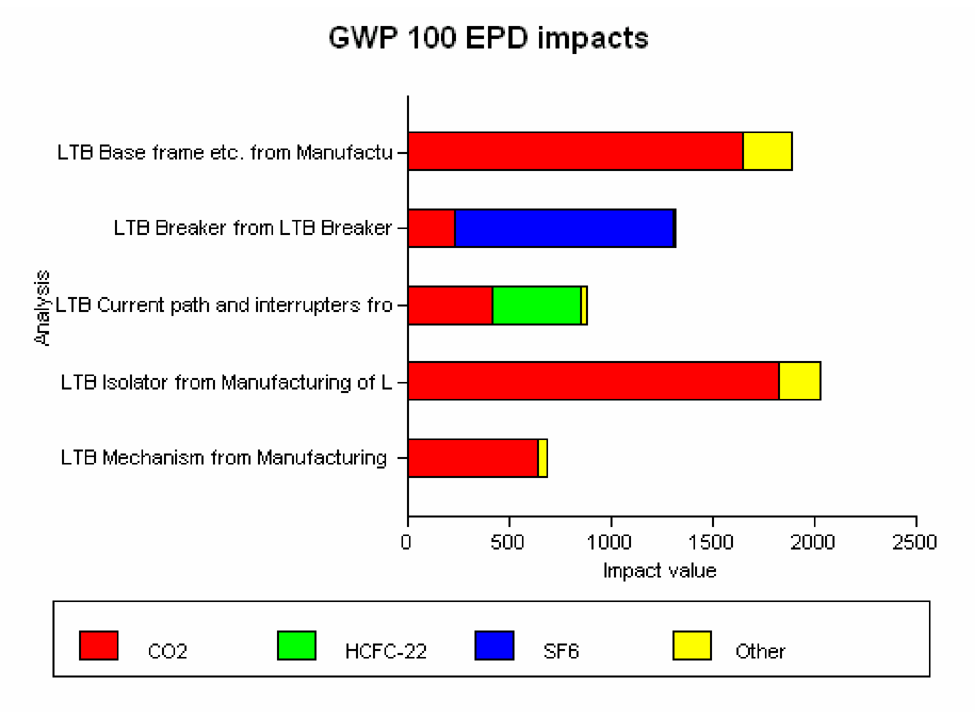


*Figure 7. Environmental impact (Global warming) from the manufacturing phase and assembling of the LTB breaker including production of raw material.*

The environmental impact from transports and the materials in the LTB breaker is illustrated in Figure 8.
$SF_6$, porcelain, aluminium, steel and PTFE are the main contributors. Transports stands for a relatively small environmental impact.

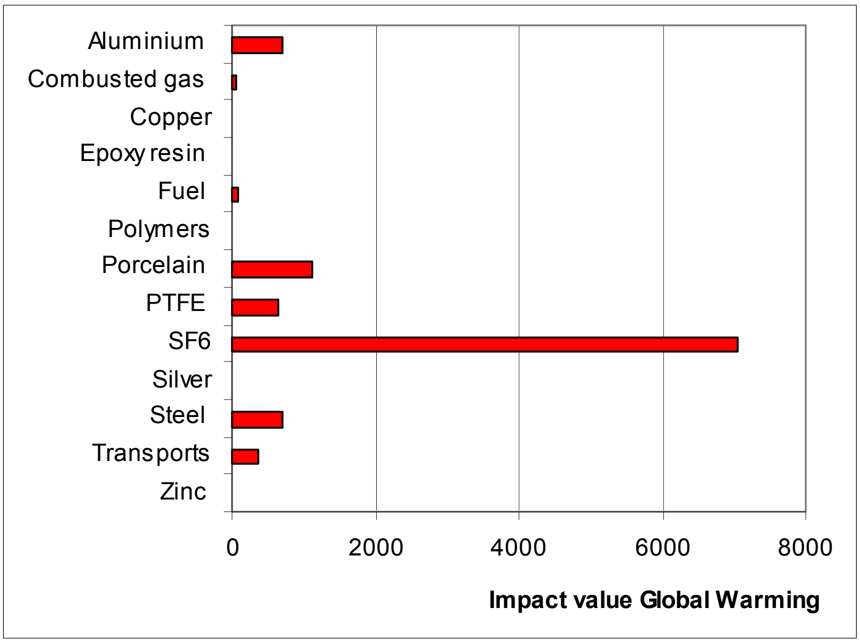


*Figure 8. The environmental impact as global warming from materials and transports.*

# 6. INTERPRETATION

## 6.1 Interpretation

According to ISO 14043 the interpretation phase of a LCA study comprises three steps:

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

## 6.2 Significant issues

A comparison between the environmental impacts using different impact categories for evaluation is given in table 5. Most of the environmental impact occurs in the use phase and comes from the use of electricity due to losses and heating. The ozone depletion potential is an exception since this cathegory is affected by the emissions that mainly occurs during the production of raw materials.

Table 5 Impact on environmental categories

| **Environmental impact category** | **Impact Manufacturing** | | **Impact Use** | |
|---|---|---|---|---|
| Acidification (mol $H^+$) | 700 | 5% | 13430 | 95% |
| Global warming potential (kg $CO_2$) | 6050 | 7% | 81350 | 93% |
| Nutrification potential (kg $O_2$) | 83 | 8% | 890 | 92% |
| Ozone depletion potential (kg CFC-11) | 0,037 | 76% | 0,012 | 24% |
| Photochemical Ozone Creation Potential (kg $C_2H_2$) | 0,85 | 6% | 13 | 94% |

## 6.3 Sensitivity check

No numerical sensitivity or error analysis was conducted.

# 7. CONCLUSIONS

- The usage phase dominates the environmental impact of the breaker.
- Epoxy is, together with SF6, on ABB´s restricted list of hazardous material.
- Easy dismantling and separation of materials will facilitate recycling and decrease the environmental impact from the materials.
- SF6 has an extremely high influence on the global warming potential, therefore, a minimum of leakages and a secure gas recovery at dismantling are of outmost importance.

# 8. REFERENCES


- The Swedish Environmental Management Council "Product Specific Requirements. High Voltage Circuit Breakers"
  PSR 2002:3, version 1.0, 2002-06-05.
- EcoLab software v 5.3.2.h including ABB´s database.
- ABB web.site http://www.abb.com
- Dantes web site, http://www.dantes.info