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Life Cycle Assessment Guideline for Protection Relay

615 series

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Ympäristöteknologia

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Tämä opinnäytetyö on tehty ABB Oy, Medium Voltage Producs Vaasan yksikölle. Opinnäytteen päätavoitteena on luoda ohjeet, joiden pohjalta elinkaari analyysit (LCA) suojareletuoteperheille tehdään. Osa aiemmin tehdyistä LCA:sta ei ole enää ajan tasalla, eikä niiden tekemiseen käytettyä tietokantaa ja työkalua ole enää päivitetty. 615 series tuoteperheestä opinnäytteenosana tehty LCA analyysi toimii esimerkkitapauksen.

Ohje perustuu ISO 14040 standardi sarjaa ja tätä standardia on käytetty pohjana ohjeille, joista käytetään myös nimitystä Product Category Rules (PCR). LCA 615 series tuoteperheelle on tehty PCR:n perusteella. Tässä työssä esitellään myös LCA prosessin eri vaiheita kuten (rajaus, inventaarioanalyysi (LCI), vaikutusten arviointi (LCIA) ja tulosten arviointi) ja elinkaaren eri vaiheet (valmistus, jakelu, asennus, käyttö ja hävitys).

Esimerkki laskennasta saadut tulokset on esitetty ja LCA -prosessin kulku on kuvattu. Opinnäytetyön perusteella voi sanoa, että huomiota tulisi kiinnittää erityisesti rajausvaiheeseen, joka luo pohjan koko elinkaarianalyysille. On myös tärkeää osata tehdä oletuksia ja päätöksiä työn loppuun saattamiseksi.

Avainsanat LCA, elinkaarianalyysi, LCI, PCR, Product Category Rules

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ABSTRACT

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This thesis is made for ABB Oy, Medium Voltage Products in Vaasa. The main goal of the thesis is to make Life Cycle Assessment (LCA) guideline for protection and control relay product families because the earlier made LCA studies are not valid anymore and the guideline, LCA tool and database are not up-to-date. During the new LCA guideline process product family 615 series LCA study is carried out as an example.

The LCA study is based on ISO 14040 standard series and the guideline so called Product Category Rules (PCR) is made based on these standards. The whole LCA process is explained for example different life cycle phases (manufacturing, distribution, installation, use and end of life phases) and steps (goal and scope, inventory analysis (LCI), impact assessment (LCIA) and result evaluation) are presented.

The results from the LCA study about 615 series are presented and the process is described. The main things that the LCA process has taught are that the goal and scope of the study is the key for the successful LCA study and with compromises, assumptions and decision making the LCA study will be finalized.

Keywords	LCA, Life Cycle Assessment, LCI, PCR, Product Category Rules

CONTENT

ABBREVIATIONS

AP	Acidification,
EACH	European Chemical Agency
EPD	Environmental Product Declaration
FINLCA	Elinkaarimetodiikkojen foorumi yritysten päätöksenteon tueksi
GWP	Global warming potential,
HW	Hardware
IED	Intelligent Electronic Devices
IPCC	International Panel of Climate Change
IPP	Integrated Product Policy
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCD	Liquid Crystal Display
LCI	Life Cycle Inventory Analysis
LCIA	Life Cycle Impact Assessment
NP	Eutrophication
ODP	Ozone Depletion
PCR	Product Category Rules
PLM system	Product Life Cycle Management System
POCP	Photochemical Ozone Creation

PSR	Product-Specific Requirements
PVC	Product Verification Center
PWB	Printed Wire Boards
R&D unit	Technology Center
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical substances
Relion®	Registered product name
REPA	Recourse and Environmental Profile Analysis
RoHS	The Restriction of the use of certain Hazardous Substances in Electrical and Electronic Equipment
SYKE	Suomen Ympäristökeskus
WEEE	Waste Electrical and Electronic Equipment Directive

1 INTRODUCTION

1.1 Introduction of the ABB

ABB was established in 1988 when Asea AB and BBC Brown Bowery AG merged to one company ABB. Only one year earlier Strömberg which was established in 1965 was acquired by Asea. Nowadays ABB Oy Medium Voltage Products in Vaasa, has almost 250 employees.

Sales in ABB Oy, Medium Voltage Products have grown over 650% since 1990. In 2010 the turnover was 88 million euro. ABB's sales network covers more than 70 countries and more than 90% of the products are exported.

In Vaasa ABB has for example Technology Center (R&D unit), Product Verification Center (PVC) and Production unit. R&D unit is with more than 100 design engineers with knowledge and expertise in hardware (HW), embedded software, PC software, communication protocols, applications and algorithms. PVC improves the test methods and that way effects to the quality of the products and production systems. In the production there are 40 employees, in one to three shifts. Final assembly and testing of the products are the responsibilities of the production. Production works as a make to order manufacturing, so there is no stocking for products and the normal delivery time is two weeks. Main products of ABB Oy, Medium Voltage Products are protection and control IEDs. /2/

1.2 Description of 615 series

This Life Cycle Assessment (LCA) is made for the protection and control relays of the 615 series. 615 series is member of Relion® family which consists on 670/650 series, 630 series 615 series, 610 series and 605 series. Products of 615 series are REF615, RED615, REU615, RET615 and REM615. Members REF615, REM 615 and RET615 are shown in Picture 1.

Picture 1. Protection and control relays REF 615, REM 615 and RET615. /11/

REF615 is a feeder IED which is designed for control, protection, supervision and measurement for substations and industrial power systems. General applications for this device are earth-fault and over-current protection. Other features for this device are frequency protection, optional arc protection and phase voltage based measurements and protection. /19/

RED615 has two different basic functions to protect and to control. This IED is designed for utility and industrial power systems. /18/

REU615 is made for voltage protection and control. This IED can be used for voltage and frequency based protection schemes in industrial and utility power systems and distribution systems. With different configurations this IED can be used automatic voltage regulation of power transformers./22/

RET615 is designed for transformer protection and control. Basic functions for this IED are for example two-winding power transformer system with stabilized and instantaneous differential protection, earth-fault protection modes which can be chosen by user, back-up and thermal overload protection and optional arc protection./21/

REM615 is designed for motor protection and control. This IEDs functions are protection, measurement, control and supervision of asynchronous motors which are used in process industry and manufacturing. This relay has features like comprehensive motor start-up supervision and thermal overload protection

system, earth-fault and short circuit protection, voltage-based measurements and protection, energy and power measurement and optional arc protection./20/

All these members of Relion family 615 series have almost the same mechanical structure. All the basic parts are same only some printed wire boards (PWB) and software are different between these members./19/

1.3 Variants for LCA study

Two variants from REF615 have been selected for this LCA study to present the variation in whole product family. The First one is REF 615 Feeder Protection HBFCACABNNA1NN2XD which is so called “smaller variant” because it has lighter hardware construction. The second one is REF 615 Feeder Protection HBFFAEAGBCC1BCA1XD which is so called “bigger variant” because it has heavier hardware construction. /17/

Table 1. Description of bigger and smaller variants/17/

	Bigger variant	**Smaller variant**
Mechanical parts	Similar in both	Similar in both
Analog input module (PWB)	Two different analog input modules	One analog input module
Communication module (PWB)	One communication module	-
Power supply (PWB)	Input voltage • AC 100-249 VAC • DC 48-250 VDC Nominal frequency 50/60 Hz Binary Outputs 6	Input voltage • DC 24-60 VDC Nominal frequency 50/60 Hz Binary Outputs 6
Display Module	LCD size 128*128	LCD size 64*128

2 SITUATION NOW AND REQUIREMENT FOR LCA

2.1 Situation now

Previous LCA studies in ABB Oy, Medium Voltage Products in Vaasa location have been made in the beginning of 21st century for older product families like SPACOM and RED500. Many things have changed since the last LCAs. For example soldering is lead-free, suppliers have changed from local to global and transportation methods have changed and developed.

LCA studies haven't been made for the new product families like Relion 610 series, 615 series and 630 series. Last time the LCAs were made by consult by using EcoLab with Spine database. This component database is not up-to-date anymore and that is why it can't be used as a LCA tool nowadays.

Product-Specific Requirements (PSR) is not up-to-date anymore. This document was a guideline for these earlier LCA studies PSR was based on ISO 14025 standard.

2.2 Requirements for new LCAs

A new guideline is needed because of all the changes that have happened to LCA tools, suppliers and soldering etc. during the past years. Even the PSRs have changed and are now called Product Category Rules (PCRs) and it is based on ISO 14040 and 14044 standards. /1/

For a successful LCA study is crucial to create this new guideline PCR with all rules, definitions and margins. LCA study is worthless without proper impact assessment and result evaluation. These two steps include not only quantitative analysis, but also more profound explanations including examples which bring these quantitative values closer to real life.

LCA study starts with PCR but also a LCA tool and inventory analysis is needed. New tool and PCR should be up to date and easy to use also in the future. This new PCR should also indicate when to update LCA reports. /11/

3 THEORETICAL BACKGROUND OF LCA

3.1 LCA Life Cycle Assessment and demand for LCA analysis at the moment

LCA is a tool which can be used for making an assessment about products environmental impact affects. LCA is based on collected information which covers products all steps during its life time (extraction and production of raw materials, manufacturing of main parts, assembling of product, use of product and recycling of materials). LCA consists of four main steps: goal and scope, inventory analysis, impact assessment and result evaluation.

LCA is focused on environmental aspects and that is why social and economical aspects are not taken in account into LCA study. A complete LCA study is based on a functional unit which determinates the result of the study because all the steps are connected to the functional unit. /5/

In ABB Oy, Medium Voltage Products, to some LCAs are not valid anymore and new ones have not been carried out. LCAs have become more acute in the past few years in Finland among companies. Example SYKE (Suomen ympäristökeskus) has had in years 2009-2011 a large LCA project FINLCA (Elinkaarimetodiikkojen foorumi yritysten päätöksenteon tueksi) which purpose has been to inform companies about different kinds of LCA methods and offer information and experience, which companies can use for decision making. /16/

3.2 Roots of LCA

In the past LCA had had many names like Ecobalances, Recourse and Environmental Profile Analysis (REPA) and Environmental Profile, before it become LCA. This name was given to this analysis in the 1991 and first ISO 14040 standards was issued in 1997 by International Organization for Standardization. Development of LCA process is described in Figure 1.

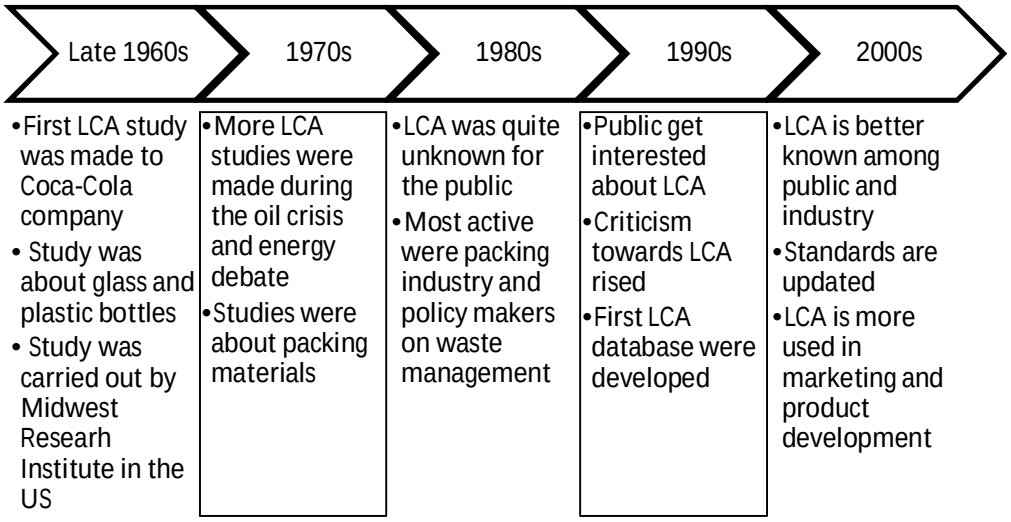

Figure 1. Development of LCA process./3/ /16/

3.3 Standards behind LCA

LCA is based on many standards of the ISO 14040 series. In the ISO 14040 presents the main facts about LCA and ISO 14044 is more like guideline for LCA. There are also other ISO standards related to LCA like ISO/TR 14047 which is about the life cycle impact assessment and ISO/TS 14048 which is related to data documentation format. /16/

The purpose of LCA according to the ISO 14040 standard is to help recognize opportunities to make products more environmentally friendly at different stages of their life cycle. LCA can be a tool for decision making and it can be an indicator for marketing. According to ISO 14040 standard, LCA includes the whole life-cycle (extraction and production of raw materials, manufacturing of main parts, assembling of product, use of product and recycling of materials) and it is focused on environmental aspects and impacts. The whole LCA process should be an open process because it is complicated and hiding thing makes it more difficult. Comprehensive LCA takes account variables and aspects of environment, human health and natural resources but still approach of LCA study is scientific. All the information and reporting should be done so well that the whole study can be duplicated. /5/

ISO 14044 defines the requirements and guidelines for LCA. All the parts of the LCA which are presented in ISO 14040 are explained in details in this standard. All the phases and steps are described and explained and PCR can be written by using this standard. /6/

ISO14047 standard gives instructions for reporting the impact assessment of LCA. Instructions for impact assessment can be found from ISO 14042 standard. So the whole LCA processes are divided in different standards. /7/

3.4 Directives related to LCA

ABB's final product is the IED and that is categorized as an electrical and electronic devise. EU directives that are related to electrical and electronic devises are RoHS (The Restriction of the use of certain Hazardous Substances in Electrical and Electronic Equipment), REACH (Registration, Evaluation, Authorisation and Restriction of Chemical substances), EcoDesign and WEEE (Waste Electrical and Electronic Equipment Directive). /8/

RoHS-directive

Meaning of this RoHS-directive (2002/95/EY and 2011/65/EU) is to protect human health and the environment and also improve utilization of electrical and electronic waste by environmental friendly way. RoHS-directive forbids and limits the use of five hazardous substances lead, mercury, cadmium, hexavalent chromium, PBB and PBDE. in electrical and electronic devices. Products that are made according RoHS-directive can be appointed by insistence declaration of EU and in the future by CE-marking. Responsibility of manufacture is to create technical documentation about the product. /23/

REACH

European Community Regulation REACH (EC 1907/2006) is about chemicals and safe use of chemicals. Meaning of REACH is to protect human health and the environment. It is also meant to improve enhance innovation and competitiveness among the EU chemicals industry. Main idea behind REACH is that

manufacturers and importers have to gather information about properties of their chemical products. These properties of chemical products will be registered in a central database run by the ECAH (European Chemical Agency) and the information allows safe handling of the chemicals. /4/

EcoDesign-directive

EcoDesign-directive (EU/2008/1249) improves sustainable development by preventing energy economy and protection of environment. Directive defines design, research and development of electrical devises. The goal of the directive is to integrated environmental aspects and life cycle thinking to design phase of the product. /10/

WEEE directive

WEEE directive (2002/96/EY) relates to some electrical and electronics devises at home use and in company use. The basic idea behind this directive is to collect the electrical and electronics devises out of the landfills by organizing separately collection for these devises. WEEE directive also guides the designing so that in the future electronic and electrical devises are easier to reuse and recycle. WEEE also determines that producer in many cases seller is responsible for the organizing of the waste collection for electronic and electrical devises. /8/

Main idea behind all the regulations and directives is to decrease product's environmental impact during its life time. Integrated Product Policy (IPP) is the preferred direction in the EU Environmental Policy concerning production. Principles for IPP are life cycle thinking, co-operation between different parties during product's life cycle and constant improvement of the products. /8/

3.5 Life cycle phases of LCA

Different life cycle phases are manufacturing, distribution, installation, use and end of life phases. Framing of the LCA study is done by these phases. The whole process is shown on the Figure 2.

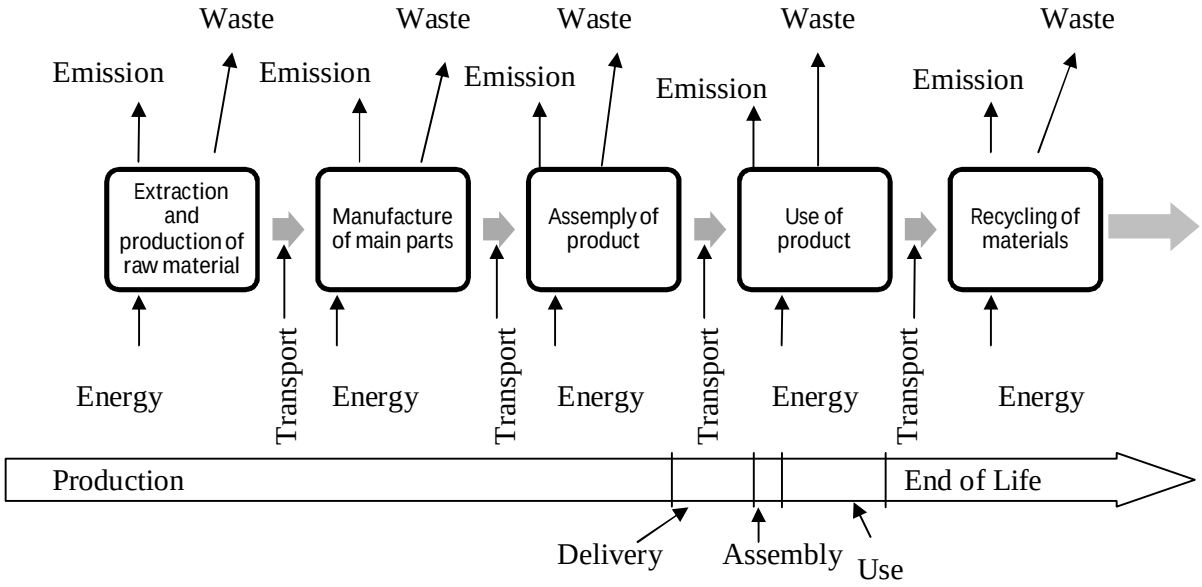

Figure 2. Describtion of steps and phases of the LCA. /1/

Manufacturing includes the following steps: extraction of raw materials, production of main components, assembly of final product and transportations between all the steps and finally to the warehouse. All the steps include inputs (like raw material, energy and water) and outputs (like emissions to air, water and soil, wastes and side and final products).

Delivery includes delivery from warehouse to final destination where the product will be used.

The installation includes the installation of the product. This step takes account of all the materials and energy needed and all the emissions caused in this phase.

Use includes energy consumption of the product, emissions to the air, water and soil caused from this step. Also maintenance and all the materials and energy needed include in this phase.

End of life consists on transportation to the waste disposal (landfill or incineration without energy recovery) or to the waste valorisation (recycling, reuse and incineration with energy valorisation) depending on the product. This step

includes emissions to air, water and soil and also possible side products made from recycled product. /1/

3.6 Steps of LCA

LCA consists of four steps goal and scope, inventory analysis (LCI), impact assessment (LCIA) and result evaluation. In goal and scope framing, level of details, result evaluation, excluding of data and scope are defined. In inventory analysis information is collected according to definitions of goal and scope. Next step is impact assessment where results are formed so that they can be compared with other results. And in the last step result evaluation, the results will be set in form that can be used for example in the decision making and marketing communication.

3.6.1 Scope

Scope is the guideline of LCA because it determines the product, functional unit, system boundaries, allocation rules, impact categories, information requirements, assumptions, limitation, quality requirements of data and requirements for the final report. All the decisions on the LCA are based on the scope. The one of the most important factors effecting the results is to accurately determine and set the limits to the functional unit, because functional unit is related to all steps and it defines how input and output are connected to each others.

System boundaries

LCA process system boundaries define which unit processes are included in study and which physical systems have to be modeled. In the system boundary step it is necessary to take into account for example the raw material supply, inputs and outputs of main processes, delivery and transportation, electricity and heat consumption in production, wastes and product disposal and recovery of product (reuse, recycling and energy recovery). /5/

System boundaries have to be viewed from many different perspectives like geographical and time boundaries, boundaries for natural system relations and

technical system of boundaries. Geographical aspect has to be included because for example different parts of life cycle occur in different parts of the world and the effects of different pollutants vary in different places. Time boundaries define if the study is looking forward or backwards in time and this depends on the goal of the study. Study looks backwards if caused impacts are studied. If the study is about what might happen it will look forward in the time. Boundaries for natural system relations define when life cycle begins. Sometimes it might be difficult to separate technical and natural system from each other. /3/

Cut-off criteria

Cut-off criteria mean things that can be excluded from the LCA study. The basic idea of LCA study is to make as complete inventory analysis as possible but there are still many uncertain things like transportation of employees, production and maintenance of capital goods and personnel restaurants and some other things which can be excluded from LCA study because these are just impossible to define and analyze. /3/

Allocation

Allocation problem means situation were more than one product is produced in a one process or many different products are collectively treated in same time in the waste treatment process. /3/ Allocation should be done to the different products and for that reason the products must be separated from the total mass. In allocation of unit process sum of inputs and outputs should be same before and after allocation. There are three different allocation procedures. First one is that whenever possible avoid allocation for example dividing the unit process to sub-processes. Second procedure is to reflect the underlying physical relationship between input and output dividing it between different products and functions. And the third procedure is to reflect other relationships between the input and function and product. Inventory analysis is made based on the balances between input and output and the allocation should be based on this balance. /6/

Data quality requirements

Data quality requirements are defined in goal and scope of the LCA study. Data quality should take account following things: age of the data and time period when the data is collected, specific technology or technologies, variability of measured data, percentage amount of measured and estimated data from the total amount of data, representative of the data, consistency, where the data is come from, uncertainty of the data and reproducibility of the data. Also missing data must be documented and quality of the data should be assessed by both quantitative and qualitative aspects. /6/

3.6.2 Inventory analysis

LCI is the phase which gathers all the information together. This step is essential for collection and calculations of inputs and outputs. While catering the information to boundaries might have to be changed. Information collection can be divided according to boundaries in four main group physical inputs (energy, raw materials and additional materials), products (wastes, main and side products), emissions (air, water and soil) and other environmental aspects. Result calculations include validation, connecting the information to main process and functional unit and calculations of energy and fuel streams. /5/ In validation the validity of the data is checked for example by comparison with other data sources and energy and mass balances. /3/

Calculation

When all the data have been collected the calculation process can begin. The calculation process has five steps:

1. Normalize the data. This means that collected data is linked to inputs and outputs in activities. In this step it is not necessary to relate the data to the functional unit.
2. Link the activities to flowchart by using the functional unit. This is done by relationships between mass balances for the individual activities in the flow chart and solving the equation.

3. Calculate the flows to match system boundary. In this step the functional unit will be representing the related flow.
4. Sum up the emissions to the environment and the resources used during the life cycle of the product.
5. Document the results and calculations.
   /3/

3.6.3 Impact assessment

LCIA is based on LCI. It is a subjective inspection which includes process modeling and assessment of impact categories. Elements of LCIA can be separately and accuracy determined. LCA can include all the LCIAs elements separately. Quality inspection includes all assumptions and other decisions which have to be reported just like everything else in LCA and LCIA. LCIA alone is not adequate study for environmental impact assessment. /5/

LCIA describes the environmental impact of the inventory analysis result. The idea behind LCIA is to make the results more comprehensive, environmentally relevant and easier to understand. Another purpose is to make the results more reliable. The general categories used in LCA are considering human health, used resources and ecological consequences. These three categories are usually divided to subcategories like global warming, acidification, eutrophication, ozone depletion and photochemical ozone creation. Categories should include all the relevant and major environmental problems, but still the list of categories should be short enough. Double-counting of impact needs to be avoided and the calculations should have scientific value. Describing the environmental impact is not easy because different ways of modelling gives different kind of results and different environments reacts different ways. /3/

Following elements should be included to the LCIA phase: selection of impact categories, characterization models and category indicators, classification (sorting out the inventory parameters by the type of environmental impact) and characterization (types of environmental impacts are calculated by relative contribution of the resources and emissions). /6/

Impact categories

Acidification, AP

Emissions of nitrogen oxides and sulphur dioxide cause acidification. These oxides react in the atmosphere with water vapour forming acids. These acids fall down to the earth by rain and snow or by dry deposition. Acidification potential is expressed by kg of SO_2 per functional unit.

Eutrophication NP

Eutrophication is caused by nutrients mainly phosphorous and nitrogen which come from fertilizers and sewage outfalls. In water nutrients cause the growth of algae and other vegetation. The degradation of organic materials uses oxygen from the water and causes fish kills. Eutrophication potential is presented by kg of phosphate per functional unit.

Global warming potential, GWP

Affect to the global warming is calculated by release of different gases. The indicator expressed by kg of CO_2 per functional unit. The potential describes the green house effect of the emission for the effect of greenhouse gases over 100 years according to IPCC (International panel of climate change).

Ozone depletion, ODP

This indicator describes the breakdown effect of the ozone layer. The effect of the ODP is presented as by kg of R11 (CFC-11/Freon) per functional unit.

Photochemical ozone creation, POCP

Photochemical ozone depletion describes the change of ground-level ozone concentration. The effect of the POCP is expressed by kg of ethane per functional unit. /1/

3.6.4 Result evaluation

The goal of the study is to generate results which are based on goal and scope. Conclusions made based on LCA calculations should explain the limitations and offer recommendations about the life cycle of the product and its environmental impact. The results present potential environmental impact and the form of the results can be conclusions or recommendations which help decisions making. All the results should be presented clearly, consistent and finally. /5/

The ISO standards don't describe the evaluation method of the results, they only describe the structure. There are many different ways to present the results like these two. The first way to present the results is to decide the format of result presentation on the base of the results. The second way is to format the result presentation of the result by a particular analytical purpose for example using the step of the life cycle which is most polluting. /3/

The stepwise aggregation of information can be presented by inventory level, the characterization level and the weighted level. Stepwise aggregation of information can be presented like in Figure 3. The inventory level consists from inventory parameters which are selected by analyst. These parameters are often included in main text part. The results are often presented as a bar diagram. In characterization level the results are presented more like total results which allows aggregation of the information of all parameters to fit in one diagram. In the weighting level the results can be compared. This step is not necessary if the results can been clearly seen on the characterization level.

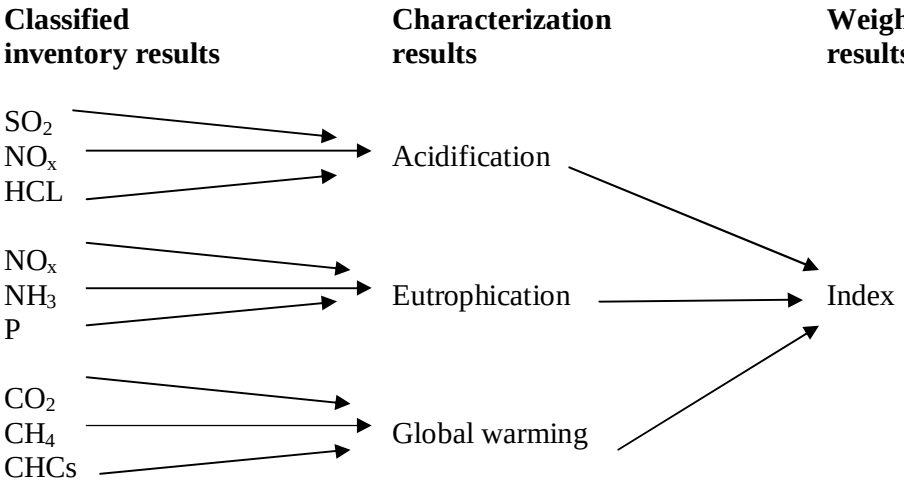

Figure 3. Stepwise aggregation of information presented by three different levels. /3/

Depending on situation the results can be presented in different ways like dominance analysis, contribution analysis and decision maker analysis. In dominance analysis is investigated which part of the life cycle gives the biggest environmental impact. Contribution analysis differs from dominance analysis because instead of activities the environmental impact caused by contributes of environmental loads is analyzed. The environmental impacts that can be controlled are appointed in decision maker analyses. /3/

3.6.5 Report and Critical review of the LCA study

Report should be adequate accurate for example all the information, results, methods, assumptions and limitations needs to be marked. Reporting for the third part needs also detailed report example description of data quality, variables and environmental mechanisms and relations to LCI. Basically the report should include everything that is done in LCA study. /5/

In ISO14044 is more specific instructions for reporting. /6/ Reporting the LCA study will show how comprehensive the study is. The report must be so accurate that the reader can understand the difficulties and assumptions that have made

during the LCA study. The structure of the report can be for example the following:

1. Goal and scope definition
2. Description of process
3. Inventory
4. Impact assessment
5. Data quality and sensitivity analysis
6. Critical review of LCA
7. Evaluation of results
8. Conclusions
9. References
10. Appendix

/9/

The main question is if the LCA has met the expectations? Does it include methods, information, result evaluation and report? Critical review has to be defined in scope. What have to do in study? What things are included and in what level the details are? And who are participating? The critical review ensures that classification, characterizing, normalization, grouping and material weightings are adequate and right documented. /5/

3.7 Different types of LCAs

There are different types of LCA. The two most common are accounting and change-oriented. Accounting type of LCA tells what kind of environmental impact the product has. The change-oriented LCA type compares possible alternatives what the product can cause to the environment. /3/

These two have also other names. The accounting is called attributional life cycle assessment and change-oriented is called consequential life cycle analysis. Most of the LCA studies are based on attributional life cycle analysis. This method concentrates only main flows which are directly related to investigated life cycle. By this method future can be predicted by making assumptions of investigated

flows. Critical parts of attributional life cycle assessment are boundaries and allocation methods. In consequential life cycle analysis unit processes that can change after some decisions are taken in account in study. This method produces information for decision making for situations when process in changing. Difficulties in this method are to recognize changing flows and uncertainty of raw materials and lack of information. Both have their good and bad features and in some cases it might be good to use both LCA methods in the same. /3/, /16/

4 PROCESS DESCRIPTION OF LCA PROCESS IN ABB

4.1 PCR, Guideline for LCA

The whole LCA study of 615 series is based on Product Category Rules which replace the old guideline Product-Specific Requirements. This new PCR is based on ISO 14040 and ISO 14044.

PCR includes the goal and scope of LCA study and it defines everything in the LCA studies which are made in ABB Oy, Medium Voltage Products. The whole PCR can be found appendix 1.

4.2 Stages of product's life-cycle

The LCA study in the ABB includes four steps: extraction and production of raw material, manufacture of main parts and product, use of product and recycling of materials which are shown in figure 4.

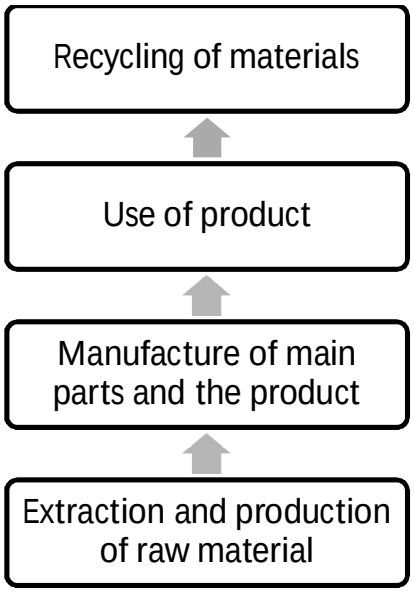

Figure 4. Four steps of life-cycle

Extraction and production of the information on raw materials is based on the information in the LCA tool's general information from the GaBi database. The information that is collected during the inventory analysis is related to the steps from "manufacture of main parts and product" to the step "recycling of materials". Manufacturing, waste, waste water and energy information have been collected from first level suppliers. Material information of the whole product has been collected from ABB PLM system (Product Life Cycle Management System). Information of the use phase consists from the data and test results from ABB. Recycling information are from the electronic waste handler. The LCA study is made based on this information.

4.3 Phases of LCA

Phases in this LCA differ slightly from the phases introduced in chapter "Life cycle phases of LCA". In that chapter 3 there were introduced five different phases which are manufacturing phases, distribution phases, installation phases,

use phases and end of life phases. In LCA made in ABB was only three different phases, which are manufacturing phase, use phase and end of life phase which are presented in Figure 5.

The main reason to exclude the distribution and installation phases from the LCA study was that there is no distribution phase in ABB's production process this step is included use phase. For environmental view the installation phase is irrelevant for the results. These are the basics assumptions that can be made in the goal and scope of the study. These kinds of decisions depend on the product and production process and as well on the results that the study is aiming.

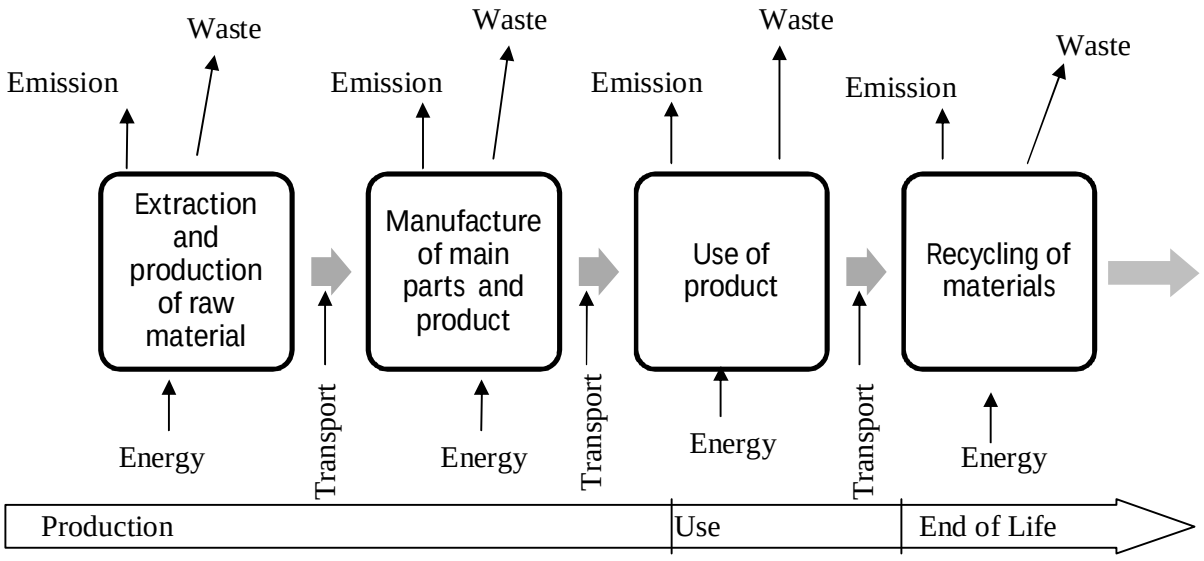

Figure 5. Steps and phases used in LCA made in ABB. /1/

5 OPERATIONAL DESCRIPTION OF 615 SERIES LCA PROCESS

5.1 Operational description of different stages

5.1.1 Creating the PCR

Before the LCA study of 615 series was started the PCR was created and the earlier LCAs were gone through. The new PCR which now meets the requirements of ISO 14040 and ISO 14044 standards is an updated version of old PSR.

Some parts of the PSR were outdated and some information is still valid. For example in the PCR there are steps for the use and transportation scenarios and some LCA phases like distribution and installation which were missing from the PSR. Also the structure of the PCR document is slightly different from PSR.

The earlier LCA studies were a good starting point for the new LCA process. The guideline has something to base on and the final results can be compared to the earlier results.

5.1.2 Goal and scope of 615 series LCA

The goal of the study is to find out the environmental impact of 615 series protection relays. Minimum and maximum impact will be presented by using two different variants of REF615. Decision of these two variant is based on minimum and maximum hardware constructions and the fact that all the other variants of 615 series are somewhere in between these two. In this study two parallel main suppliers with different distances and transporting methods are also compared to each other.

This LCA study is based on ISO14044 standard (International Standardisation Organisation). The LCA tool used in this study is GaBi software with a

commercial component database. Functional unit in the LCA study is defined as a product variant.

Environmental Product Declaration (EPD) will be made based on LCA calculation results. EPD and the results of this study will be utilized e.g. in marketing communication.

5.1.3 Gathering the information (inventory analysis)

Materials and masses of mechanical parts were obtained directly from the ABB PLM system. Printed circuit boards and electrical components information come from GaBi database excluding some components information of which has been inquired from suppliers. For the first level suppliers there have been made an inquiry about their production process, energy consumption, waste, waste water and water consumption per produced product.

According to the ISO 14040-14044 standards 5% of the total weight of the IED can be excluded from the study. 10% of the total information of the study can be replaced by generic information from the database. /6/

The assessments about the IED's life-time, typical end user and transporting methods are given by ABB. Energy consumption of the IED is based on measurements and test results made in ABB.

5.1.4 Result evaluation and impact assessment

The following results in table 2. are based on inventory analysis made in the ABB for the 615 series. The presented results are not the final ones since the recycling phase information was missing at the point of the time the thesis was finalized. The change of the final results will be minor. The results are average results from the bigger and the smaller variants.

Table 2.LCA results for 615 series

A 615 series variant				
Environmental Impact	**Manufacture**	**Use**	**Total**	**Equivalent unit**
Acidification	0.87	3.05	3.92	SO_2 kg
Eutrophication	0.05	0.16	0.22	Phosphate kg
Global Warming	120.39	715.58	835.97	CO_2 kg
Ozone Layer Depletion	0.00	0.00	0,00	R11 kg
Photochemical Ozone Demand	0.05	0.18	0.24	Ethene kg

Differences between these two variants can be seen from the results. Bigger variant has bigger impacts in all impact categories the figures 6.-10. Differences in manufacturing phase come directly from the amount of PWBs inside the IED. In use phase the differences between the variants come from energy consumption of the IEDs. The bigger one uses more energy than the smaller one.

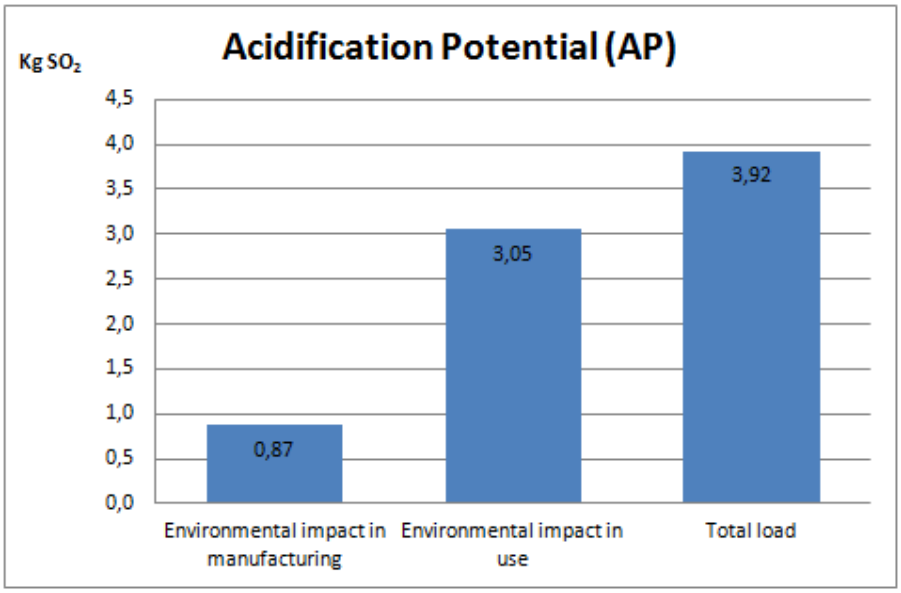

Figure 6. Acidification Potential in the manufacturing and use phase.

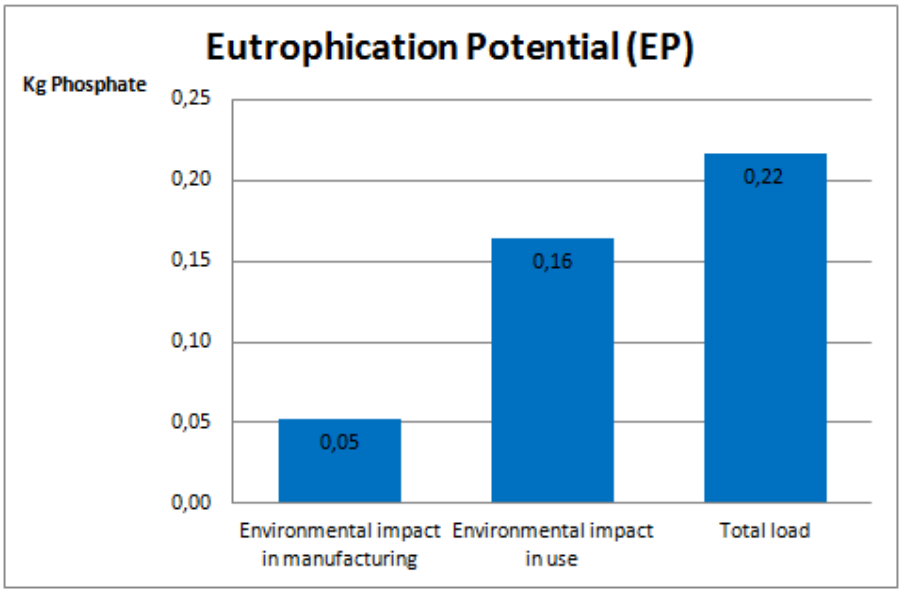

Figure 7. . Eutrophication Potential in the manufacturing and use phase.

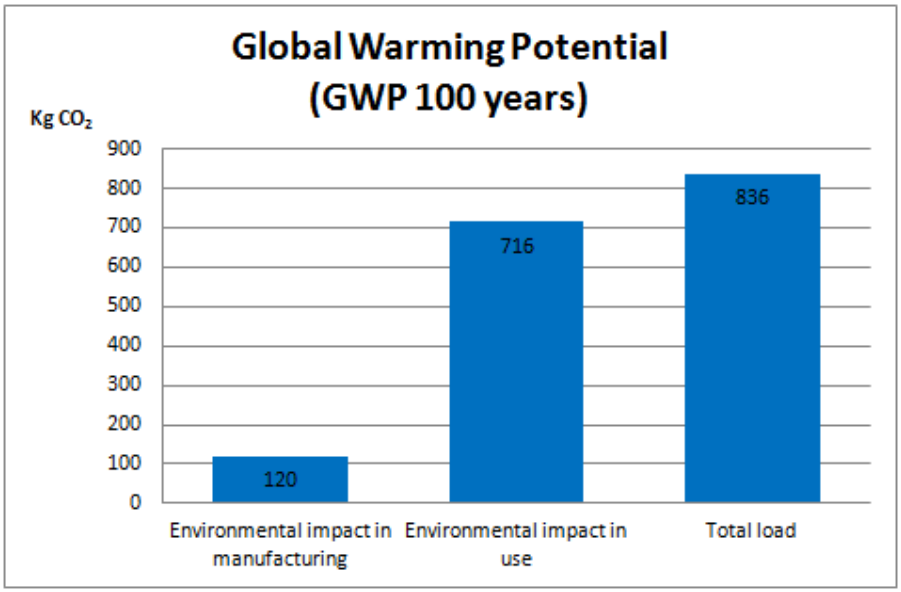

Figure 8. Global Warming Potential in the manufacturing and use phase.

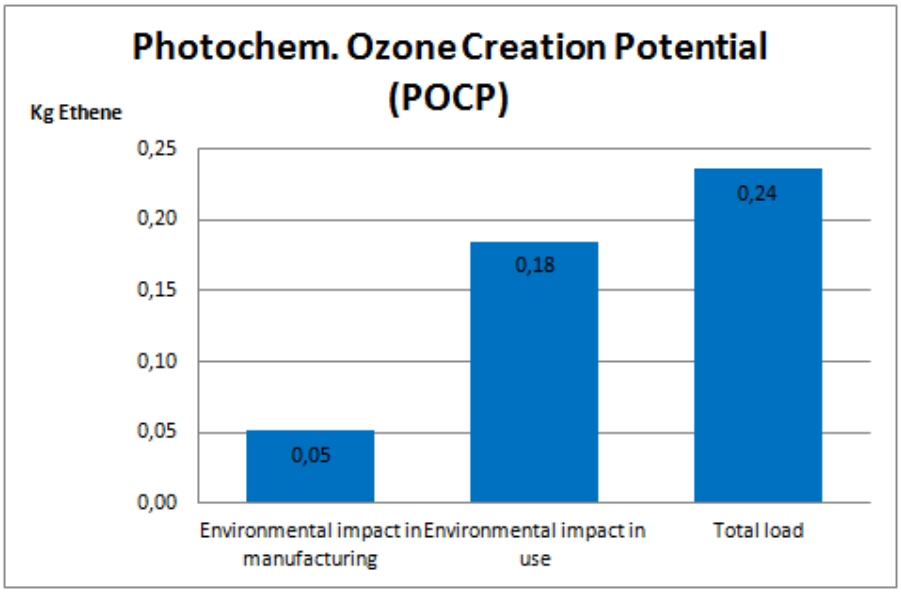

Figure 9. Photochemical Ozone Creation Potential in the manufacturing and use phase.

Impact assessment

Acidification impact of the IED can be compared to one-family house's SO_2 emission when the house has been warmed up by wood. Based on 2009 statistics SO_2 emissions to 150 m^2 house was about 1.72 kg per year. So the acidification impact of IED on its life time is same than the acidification impact of the 150 m^2 house in less than two and a half years. /15/

Eutrophication potential of the IED can be compared to total load of phosphate caused by human in a one day. The total load of phosphate for human in a day is 2.2 g and the total load for bigger IED variant is 220 g on its life time. So a human causes same amount of phosphate emissions in 100 days than the IED causes in its life time. /14/

Global Warming Potential calculated by CO_2-equvivalent for the IED can be compared to average CO_2 for new car in year 2010. The average of CO_2 emissions for new car was 145 g/km and the total GWP for IED was 836 kg on its life time. CO_2 emissions for the IED on its life time equals to driving a new car for less than 6000 km. /12/

Photochemical Ozone Creation Potential caused by bigger variant can be compared to ethane emissions caused from one-family house. In house 9.8 m^3 wood is used in one year to heating and that cause 5.5 kg of ethane on one year. One IED causes 0.24 kg of ethane on its life time and that is same amount than heating of the one-family house causes in less than three weeks. /13/

5.2 Critical review of LCA and possibilities to utilize the results

The goal and scope has been followed during this LCA study. Cut-off rule of 5% has been followed. Information from first level suppliers has been updated by inquiry which has been made directly to suppliers.

General data have been used for example in used energy during IED's life time which was European energy mix from GaBi database. Some of the missing

information is ignored like some components that couldn’t be matched to the database. All the generalizations and missing information are documented and justified.

Results of the LCA study will be used to create an EPD. The result will also be used for marketing purposes.

6 CONCLUSIONS AND ASSESSMENT OF THE LCA PROCESS

The whole LCA process includes many different steps and things that have to be taken into account. Creating the PCR is very critical step to the whole LCA process. Wrong assumption in PCR or in goal and scope of the study will affect to the final results.

During the LCA study it is important to dare to make decisions to get finalized the study. In every study there are data that is not available and things that do not have one right answer. These are the situations where the decision must be done.

There are also flaws in LCA study because all decisions affects the study and complyer of the study can affects to the final results. It is important to create the goal and scope properly and follow it through the study.

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