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CO_2 footprint for distribution oil immersed transformers according to ISO 14067:2018

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Extended Abstract

In the last few decades, climate change and the global warming have emerged as important environmental issues. The cause of global warming is the increase of greenhouse gas emissions (GHG). There are several greenhouse gases responsible for global warming: water vapor, carbon dioxide (CO_2), methane, nitrous oxides, chlorofluorocarbons (CFCs) and others. They are mostly the result of the fossil fuels' combustion in cars, buildings, factories, and power plants. The gas responsible for the most of the global warming is carbon dioxide (CO_2). This increase in the greenhouse gas emissions leads to a greater interest of the consumers, board management and stakeholders in the environmental impact of their activities, products and services.

The verification of the Carbon Footprint of distribution oil immersed transformer, presented in this paper, was recognized as an opportunity for the company to understand its own environmental impact and to identify inefficiencies and opportunities within its business.

Carbon Footprint of a Product (CFP) is a rather new term closely related to the greenhouse gas emissions. The CFP is considered as a total of the greenhouse emissions generated during the life cycle of a product – that is, from raw material acquisition or generation from natural resources to a final disposal. It is described within the standard ISO 14067:2018 Carbon footprint of products – Requirements and guidelines for quantification [1]. This standard belongs to the environmental series ISO 14000 and enables the organization to demonstrate its environmental responsibility.

Life Cycle Assessment (LCA), as well as the Carbon Footprint of products together with environmental impact of the product, are shown in this paper in accordance with standard ISO 14067:2018. The LCA is a method for the quantification of the environmental impacts of individual products. It takes into account a complete life cycle, starting from a raw material production, until the product's final disposal or materials' recycling in accordance with ISO 14040 [2] and ISO 14044 [3]. Greenhouse gases are expressed in mass-based CO_2 equivalents (CO_2e), which is the unit of measurement in the ISO 14067:2018 standard. The functional unit in ISO 14067:2018 can be either a product or a service. In this paper, the functional unit was the product – oil immersed distribution transformer, in four product variations. The LCA scope used in the preparation of this study was "cradle to gate" – it covers the CFP from the acquisition of the raw materials ("cradle") up to dispatch from the factory ("gate").

The objectives of product life cycle considerations in Končar D&ST Inc. are to reduce the use of natural resources and emissions to the environment, as well as to improve social performance at different stages of the product life cycle.

By linking the economic and ecological dimension of the production, different aspects during realization of product in all phases of the life cycle come together. In this way company achieves cleaner products and processes, competitive advantage in the market and improved platform that will meet the needs of the changing business climate.

Lifecycle thinking is based on the principles of reducing environmental impacts at the beginning of product creation, giving a wider picture of material and energy flow and ultimately environmental pollution prevention. These principles are organized in Končar D&ST Inc. internally by planning and introducing cleaner manufacturing processes, environmental protection management and eco-design.

Incorporating ISO 14067:2018 into company business is recognized as an opportunity for transparent communication to interested parties, incorporating CO_2 emissions into annual reports and as a baseline information for a first step towards managing carbon emissions.

***Index Terms*— greenhouse gas emissions, carbon dioxide, Carbon Footprint of a Product, Life Cycle Assessment, ISO 14067:2018 standard.**

I. INTRODUCTION

Climate change arising from anthropogenic activity has been identified as one of the greatest challenges facing the world and will continue to affect business and citizens over future decades.

Climate change has implications for both human and natural systems and could lead to significant impact on resource availability, economic activity and human wellbeing. In response, international, regional, national and local initiatives are being developed and implemented by public and private sectors to mitigate greenhouse gas (GHG) concentrations in the Earth's atmosphere as well as to facilitate adaptation to climate change. [1]

In 2008 the European Union has set three goals to be achieved by 2020 in terms of reducing greenhouse gas emissions (by 20%), share of renewable energy sources (20%) and energy efficiency improvement (20%).

Concern over climate change has stimulated interest in estimating the total amount of greenhouse gasses (GHG) produced during the different stages in the ―life cycle of goods and services — i.e. their production, processing, transportation, sale, use and disposal. [4]

The result of GHG calculations in different stages is referred as a carbon footprint of product (CFP). In this calculation carbon footprint is the total amount of GHGs produced for a given activity, while product is any good or service that is marketed. In this context, the CFP of a product differs from the CFPs performed at the level of projects, corporations, supply chains, municipalities, nations or individuals.

Collecting the most accurate information requires a good understanding of emissions in all parts of the life cycle, usually either from raw material to factory gate (cradle to gate) or until the end of life span (cradle to grave).

Many businesses are now calculating carbon footprint of their products and services - some to meet supply chain needs to disclose carbon emissions, e.g. in sales tenders and others to actively reduce carbon footprint of production. Products and services we purchase and consume today demand a large amount of energy throughout their entire life cycle, from its production / creation to the time of their disposal at the end of the life cycle. This energy comes mainly from fossil fuels such as petroleum, coal and natural gas, all of which release carbon dioxide (CO_2) into the atmosphere, which is the cause of global warming.

Given that end users are also included in the last step - disposal and recycling, the CFP is a useful tool that involves both the manufacturer and the end user in activities to reduce GHG emissions.

As CO_2 and other greenhouse gases contribute to climate change, selecting low carbon products instead of those that have a major negative impact on the environment is one way in which a customer can make a difference.

Due to increasing demands from customer side for calculating the carbon footprint of a single transformer, a need for calculating the carbon footprint of Končar D&ST products has occurred.

The objective of this study is Life Cycle Assessment (LCA), as well as the Carbon Footprint of products together with environmental impact of the product – oil immersed distribution transformer. For the purpose of this study, standard ISO 14067:2018, as well as other standards from ISO 14000 family (ISO 14040 and ISO 14044 [2] [3]), were used as a tool to calculate the carbon footprint of Končar D&ST's product.

I.I. CFP BACKGROUND

According to the Kyoto Protocol (which was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005), during the first commitment period, 37 industrialized countries and the European Community committed to reduce GHG emissions to an average of five percent against 1990 levels. During the second commitment period, Parties committed to reduce GHG emissions by at least 18 percent below 1990 levels in the eight-year period from 2013 to 2020; however, the composition of Parties in the second commitment period is different from the first. [5]

As a measure of achieving these goals, the idea of developing a carbon footprint calculation mechanism that would visualize CO_2 emissions has appeared. The life cycle of the product depends on many factors such as raw material extraction, material processing, parts manufacturing, assembly, transport, product use and maintenance and end of life (disposal and recycling). (Fig. 1) [5]

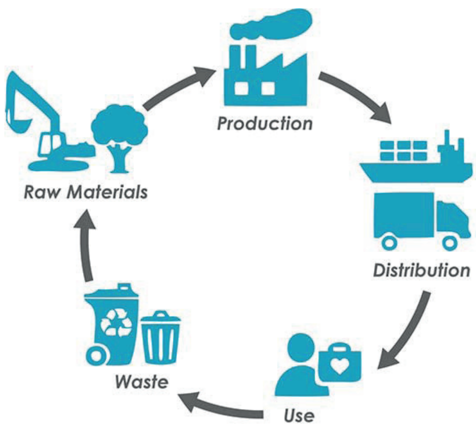

Figure 1. A life cycle of a product [5]

The carbon footprint of a product is usually calculated as the sum of the total greenhouse gas (GHG) emissions emitted at each stage of a product's life cycle by calculating its emissions, and then converting that figure to an equivalent amount of CO_2 emissions (CO_2e).

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I.II. GREENHOUSE GAS EMISSION STANDARD

There are different standards regarding the monitoring of greenhouse gas emissions, which are designed to provide a framework for businesses, governments, and other entities to measure and report their greenhouse gas emissions in ways that support their missions and goals. Three of them are described in the following paragraphs.

a) Greenhouse Gas Protocol

This protocol provides standards, guidance, tools and training for business and government to measure and manage climate-warming emissions. GHG Protocol establishes comprehensive global standardized frameworks to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, value chains and mitigation actions. The Greenhouse Gas Protocol provides the foundation for sustainable climate strategies and more efficient, resilient and profitable organizations. The GHG Protocol Product Standard is one of a suite of accounting tools developed by the GHG Protocol to encourage users to understand, quantify, and manage greenhouse gas emissions. [7]

b) Publicly Available Specification (PAS) 2050

Specification for the assessment of the life cycle greenhouse gas emissions of goods and services was developed by the British Standards Institution in 2008. PAS 2050 is the first consensus-based and internationally applicable standard on product carbon footprinting that has been used as the basis for the development of other standards internationally. Builds on existing international LCA standard (ISO 14044), covers all GHGs specified by the IPCC (Integrated Pollution Prevention and Control), covers whole life cycle of product (raw materials to end of life or 'cradle to grave'), designed to be used on any product, by any company, in any geographic location. [8]

c) ISO 14067

The Carbon Footprint of a Product is the total of the greenhouse emissions generated during the life cycle assessment of a product. The GHG are considered all gaseous substances for which the IPCC has defined a global warming potential coefficient. They are expressed in mass-based CO_2 equivalents (CO_2e), which is the unit of measurement in ISO 14067.

A carbon footprint and life cycle assessment (LCA) is used to systematically record and analyze the impact on the environment throughout the entire life cycle of a product or service. This involves an end-to-end analysis of the product or service. The analysis considers all raw materials, transports, production processes, usage and disposal of the product. A carbon footprint at product level is a special application of the LCA methodology that specifically focuses on greenhouse gas emissions. [1]

I.III. LIFE CYCLE ASSESMENT

A Product Carbon Footprint is based on a life cycle assessment (LCA), but focuses on a single issue which is global warming. An LCA shows where the environmental impact in the overall chain takes place which can serve as an opportunity to improve a certain process or product parts. Eventually, this can lead towards savings in, for example raw materials, energy use and total costs, and to a more sustainable product which can be used as promotion point when selling the product.

According to ISO 14040 an LCA study consists of four main phases [2]:

Step 1: Defining the goal and scope of the study.

Step 2: Making a model of the product life cycle with all the environmental inputs and outputs. This data collection effort is usually referred to as life cycle inventory (LCI).

Step 3: Understanding the environmental relevance of all the inputs and outputs. This is referred to as life cycle impact assessment (LCIA).

Step 4: The interpretation of the study.

The principles of the LCA standard were followed when carrying out the case studies presented in this report. The four phases of LCA are presented in Figure 2.

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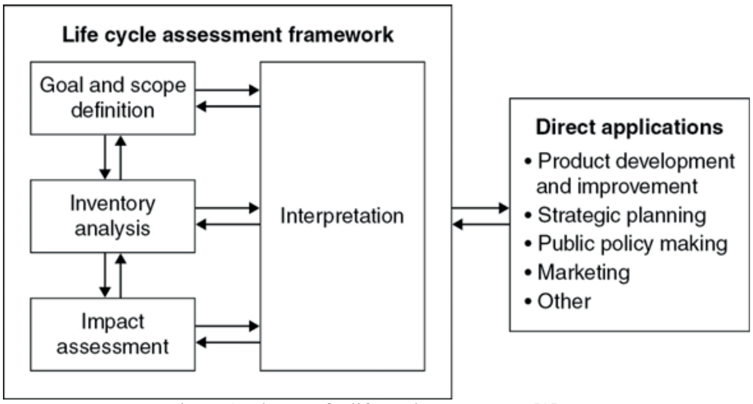

Figure 2. Phases of a life cycle assessment [2]

II. EXPERIMENTAL

The overall goal of conducting a CFP study is to calculate the potential contribution of a product to global warming potential expressed as CO_2e by quantifying all significant GHG emissions and removals over the product's life cycle or selected processes, in line with cut-off criteria. [1]

The CFP study can be conducted according to several types of LCA methodology, for instance:

- Cradle-to-grave – full life cycle assessment from resource extraction ('cradle') to use phase and disposal phase ('grave');
- Cradle-to-gate is an assessment of a partial product life cycle from resource extraction (cradle) to the factory gate (i.e., before it is transported to the consumer);
- Cradle-to-cradle (or closed loop production) – a specific kind of cradle-to-grave assessment, where the end-of-life disposal step for the product is a recycling process.

In this CFP study report cradle-to-gate methodology was used. This means the product was studied from extraction of raw materials to its production. The goal of this project was to produce validated environmental data for oil immersed transformers, in order to get insight in their environmental performance. International Electrotechnical Vocabulary defines a transformer as a static piece of apparatus with two or more windings which, by electromagnetic induction, transforms a system of alternating voltage and current into another system of voltage and current, usually of different values and at the same frequency for the purpose of transmitting electrical power. [9] Distribution Transformers are used in distribution networks in order to transmit energy from the medium voltage (MV) network to the low voltage (LV) network of the consumers. [10]

An oil immersed distribution transformer is composed of the following main components: transformer core made from special grade magnetic steel; low voltage winding made from aluminum coil; high voltage winding made from aluminum wire; tank and cover made from low carbon steel; transformer oil (mineral oil or synthetic ester); insulation components made from paper and pressboard; some store-bought components, such as tap changer, bushings etc. Most of the raw materials (magnetic steel, aluminum coil and wire, transformer oil) are produced in a way specific for a transformer industry and will not be explained here.

In the production of Končar D&ST, raw materials are machined and assembled, together with store-bought components, in a complete product: the magnetic steel is slit, cut and stacked into transformer core; aluminum coil and aluminum wire, together with diamond-dotted insulation paper are transformed into low voltage windings and high voltage winding, respectively. Windings are assembled onto the core, connected with cover and then tanked. So prepared semi-product is dried in a low-frequency heating (LFH) plant, vacuumed and filled with transformer oil.

Figure 3 displays a schematic overview of the production process, including system boundaries. All relevant and known processes and materials have been included.

Standard ISO 14067 asks for unit declaration together with cradle-to-gate boundaries which in this case is the same for all types of transformers included in the study.

Declared unit: the cradle-to-gate CO_2 eq. emissions of oil immersed transformer.

Study was performed for specific products from one plant and one manufacturer and data was collected for the year 2018.

The carbon footprint study includes cradle-to-gate CO_2e emission data for the following transformers, produced at Končar D&ST Inc. in Zagreb, Croatia [11], shown in Figures 4-6:

- Object 1 (400 kVA);
- Object 2 (400 kVA);
- Object 3 (400 kVA);
- Object 4 (630 kVA).

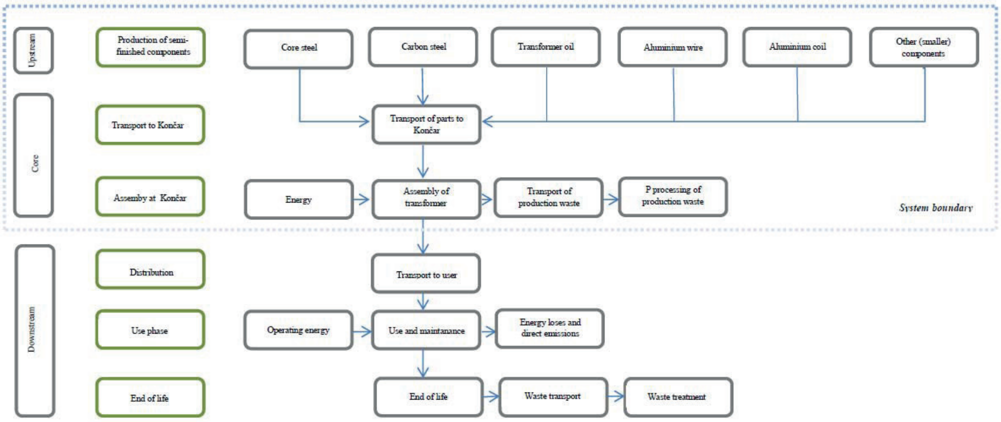

Figure 3. Schematic overview of the Končar D&ST's production

Figure 4. Visualization of Object 1, Object 2, Object 3

Figure 5. Visualization of Object 1, Object 2, Object 3

Figure 6. Visualization of Object 4

II.I. INVENTORY ANALYSIS

Life cycle inventory analysis is a phase of a life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle. [1]

Inventory was discussed for the four types of transformers in a way that all components from the bill of materials per each transformer, weighing more than 1 kg, were taken into account. All transformer components were analyzed according to the name of the component, data type, reference process, weight and the main part to which the component belongs.

Main components covered with this study were: aluminum coil, aluminum wire, carbon steel, core steel and transformer oil. LCA software used in this CFP study report was SimaPro 9.0.

Selection of processes that covers 80% of the total CO_2e emissions was made and primary data was collected for these processes.

Electricity consumption at Končar D&ST includes the following processes:

- Lines for cutting transformer sheets (slitting and cutting);
- Preparation of the insulation parts;
- Preparation of the windings;
- Production and assembly;
- Drying of active parts (core and windings);
- Manipulation with electric forklifts;

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As well as:

- Testing station;
- Lighting;
- Ventilation;
- Compressed air;
- Offices.

The origin of the electricity used by Končar D&ST in 2018 was retrieved from the website of HEP, Končar D&ST's power supplier:

- 42% hydroelectric power plants;
- 17% thermal power plants;
- 17% renewable energy sources;
- 14% nuclear power plants;
- 10% unknown.

Data on production waste at Končar D&ST is indicted per material and type of transformer. Types of wastes that are generated in Končar D&ST which were analyzed in this study are core sheets steel, aluminum and waste transformer oil. [11]

III. RESULTS AND DISCUSSION

In this phase of a CFP study, the potential climate change impact of each GHG emitted and removed by the product system was calculated by multiplying the mass of GHG released or removed by the 100-year GWP (Global warming potential) given by the IPCC in units of kg CO_2e per kg emission. [1]

Steel for the core, aluminum wire and cold-rolled steel make up the top three of materials with the largest contribution to the total CO_2e emissions.

Table I. shows total emissions expressed in kilograms of CO_2 equivalents. [11]

TABLE I. Total by carbon source in kg CO_2 eq.

Transformer	Total kg CO_2eq.
OBJECT 1	4673
OBJECT 2	4915
OBJECT 3	5003
OBJECT 4	6736

The carbon footprint of the transformers covered by the study ranges from 4676 kg CO_2 eq. for the Object 1 to 6736 kg CO_2 eq. for Object 4. This difference can be explained by the total amount of materials used in the different types of transformers (different weight of core, tank etc.). Due to small differences in design and functionality, the Object 1 has a slightly lower carbon footprint. Also, there is a slight difference in carbon footprint between the Object 1 and the other two 400 kVA transformers, which was mostly caused by materials used in the windings.

The larger carbon footprint of the Object 4 (630 kVA) compared to the other three transformers can be explained by its total mass. Compared to the 400 kVA transformers, the Object 4 is considerably heavier because more material is used for production. When calculating the emissions in kg CO_2 eq. per kg material used for the different transformers, results for the Object 2, Object 3 and Object 1 are that approx. 3,8 kg CO_2e per kg of used material. Whereas the Object 4 has a carbon footprint of 4,0 kg CO_2e per kg of used material. [11]

Data for each unit process within the systems boundary can be classified under major groups [2]:

- Energy inputs, raw material inputs, ancillary inputs, other physical inputs;
- Products, co-products and waste;
- Emissions to air, discharges to water and soil;
- Other environmental aspects.

The quality of CFP data relies strongly on the quality of input data. According to standard ISO 14067 it is preferable to use data derived from company's own processes (i.e. primary data). In addition to that, raw materials from suppliers were analyzed considering they can strongly influence the CFP. In this CFP study report, authors strived to use primary data from suppliers of the main parts. Besides that, they relied on industry average data where no supplier-specific information was available.

Končar D&ST provided all data based on the bills of materials and technical drawings of the various transformers which displayed composition and the amounts of used materials. [11]

IV. CONCLUSION

Measures to reduce the carbon footprint of the products covered by the study can be implemented in several ways. Končar D&ST is considering three possible options.

One way is to influence the production process in Končar D&ST through various measures (product design or development, alternative materials). Since 2% of the total CO_2 impact calculated in this study is the contribution of the processes at the Končar D&ST production site, this would be almost half of the contribution to the total 5% reduction which was Končar D&ST's CFP reduction goal.

Another way of CFP reduction is through material purchasing, since other 98% of the total CFP is a contribution that comes from suppliers of the materials. These improvement measures can be done in one of the following ways:

- Communicate with the suppliers with high CO_2 contribution about the energy sources that they use in their process – e.g. energy generated in a conventional way could be replaced by some form of renewable energy;
- Request from suppliers to use a certain type of fuel when transporting goods to Končar D&ST (e.g. EURO 5, EURO 6);
- Suggest to tank suppliers to buy raw materials produced in arc furnaces (which use a large content of raw materials from secondary sources – recycled) and not in conversion furnaces (large content of raw materials from primary sources), and therefore adopt a procurement plan that benefits a supplier who uses a large content of raw materials from secondary sources;
- In the future, buy material in a greater percentage than before from a major supplier who has a smaller total carbon footprint.

Third goal option to reduce CO_2 footprint is tree planting since trees and green plants take in carbon dioxide for photosynthesis and in this way should reduce CO_2. Tree planting these days is becoming an increasingly popular tool to combat climate change. New analyses show that there is enough space in the world's existing parks, forests and abandoned land to plant 1,2 trillion additional trees, which would have the CO_2 storage capacity to cancel out a decade of carbon dioxide emissions.

V. REFERENCES

[1] ISO 14067 Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification, First edition, 2018.
[2] ISO 14040 Environmental management – Life Cycle Assessment – Principles and framework, Second edition, 2006.
[3] ISO 14044 Environmental management – Life Cycle Assessment – Requirements and guidelines, First edition, 2006.
[4] Counting carbon in the marketplace: Part I – Overview paper, Simon Bolwig, DTU Climate Centre Risø, Technical University of Denmark and Peter Gibbon, Senior Researcher, Head of research unit on Trade and development, Danish Institute for International Studies; „Global forum on trade and climate change“, Paris, 9 and 10 June 2009
[5] United Nations Framework Convention on Climate Change: Kyoto Protocol Reference Manual on accounting of emissions and assigned amount, 2008.
[6] https://thelcacentre.com/wat-is-lca/; accessed in September 2019.
[7] https://ghgprotocol.org/about-us; accessed in September 2019.
[8] PAS 2050 – Specification for the assessment of the life cycle greenhouse gas emissions of goods and services
[9] International Electrotechnical Vocabulary, Chapter 421: Power transformers and reactors
[10] Pavlos S. Georgilakis: Spotlight on Modern Transformer Design, Springer, 2009.
[11] Partial carbon footprint for oil immersed transformers; Končar D&ST, SGS Search Consultancy; 2019.