LIFE CYCLE ASSESSMENT IN OUTBOUND TRANSPORT OF METALLURGICAL PRODUCTS

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Abstract

The aim of the paper is to research a potential of Life Cycle Assessment utilization in the area of outbound transport of metallurgical products. The potential is identified by means of a case study from a metallurgical company producing hot rolled heavy steel plates. Environmental impacts, specifically greenhouse gases emissions (carbon footprint) and at three endpoint indicators (human health, ecosystems, and resources) were researched. Two Life Cycle Impact Assessment methods were used for that purpose: IPCC 2007 GWP 100a and ReCiPe.

Keywords: Green transport, outbound transport, Life Cycle Assessment, metallurgical products

1. INTRODUCTION

Transport is one of the areas having considerable potential within the scope of the implementation of the environmental friendly (green) practices, since it occupies top positions in negative impacts on the environment. The proactive concept, which is focused on reducing the transport CO_2 emissions, other exhaust gases and noise, a congested transport infrastructure, transportation costs, and, last but not least, on complying with the legislative transport restrictions is called Green Transport (GT). GT is a worldwide processed, described and developed topic, but only from a multinational and national perspective, especially for the area of urban or public transport.

As metallurgical industry is characteristic by transport of very large volumes of row materials, semi-finished and final products, there is a big potential of reducing negative environmental impacts. Unfortunately, GT from the viewpoint of metallurgical companies is researched only sporadically and marginally. The transport in metallurgical company with closed metallurgical cycle can be divided into three basic categories:

1. Inbound - a transport of raw materials (especially iron ore and coal) from mines to the metallurgical company.
2. Internal - a transport of semi-finished products (especially pig iron, slags, steel, continuous casting slabs, billets, and blooms) inside the metallurgical company.
3. Outbound - a transport of final metallurgical products (especially hot rolled steel products) from the metallurgical company to customers.

The aim of the paper is to research a potential of Life Cycle Assessment utilization in the area of outbound transport of metallurgical products.

2. LITERATURE REVIEW

2.1. Life Cycle Assessment

Life Cycle Assessment (LCA) isn't a completely new concept, the topic is researched for more than 40 years [1]. A framework for LCA, as it is known today, was created especially by two organizations: the Society for

Environmental Toxicology and Chemistry (SETAC) in August 1990 [1] and the International Organization for Standardization (ISO) in June 1997 [2].

The SETAC report summarizes the current status of the field and outlines the technical basis for life cycle studies. LCA definition according to SETAC seas that LCA is a process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and materials used and wastes released to the environment; to assess the impact of those energy and materials used and released to the environment; and to identify and evaluate opportunities to affect environmental improvements. The assessment includes the entire life cycle of the product, process or activity, encompassing, extracting and processing raw materials; manufacturing, transportation and distribution; use, re-use, maintenance; recycling, and final disposal [3]. This definition is adopted by wide spectrum of other authors (see e.g. [4], [5], [6], [7]).

ISO standards in LCA provide the following definition and guidelines [8], [9]: LCA addresses the environmental aspects and potential environmental impacts (e.g. use of resources and environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (i.e. cradle-to-grave). There are four phases in an LCA study:

1. The goal and scope definition phase - the scope, including system boundary and level of detail, of an LCA depends on the subject and the intended use of the study. The depth and the breadth of LCA can differ considerably depending on the goal of a particular LCA.
2. The life cycle inventory analysis phase (LCI phase) - it is an inventory of input/output data with regard to the system being studied. It involves the collection of the data necessary to meet the goals of the defined study.
3. The life cycle impact assessment phase (LCIA phase) - the purpose of LCIA is to provide additional information to help assess a product system’s LCI results so as to better understand their environmental significance.
4. The interpretation phase - in this phase the results of an LCI or an LCIA, or both, are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.

The general categories of environmental impacts needing consideration include resource use, human health, and ecological consequences.

LCA then can be seen as a methodology used for selection, design and optimization of processes. The assessment includes the analysis of product’s entire life cycle, encompassing extraction and processing raw material, manufacturing, distribution, use, recycling and final disposal. Thus, the economic and environmental evaluation through LCA is performed on the process alternatives to identify the best option that could further be subjected to process optimization [10].

3. EXPERIMENTAL PART

A model situation based on the particular outbound transport of a metallurgical company producing hot rolled heavy plates was created to meet the aim of the paper. Environmental impacts of the metallurgical products transport were evaluated based on LCA according to ISO 14040:2006. The outbound transport is carried out by diesel lorry and rail. The share of road transport is 40 %. An average distance to customers is 400 km. The supposed transported volume is 32 000 t per month. Thus 12 800 t per month is transported using road transport, i.e. 5 120 000 tkm per month, and 19 200 t per month using rail transport, i.e. 7 680 000 tkm per month. The functional unit (FU) is 12 800 000 tkm per month.

Provided that an average traveled mass using road transport is 20 t per lorry, the average number of travelled lorries is 640 per month. Assuming that an average traveled mass using rail transport is 1 200 t per train set, the average number of travelled train sets is 16 per month.

3.1. LCIA methods

The LCA of the outbound transport was carried out using the LCA software SimaPro v.8 (Pre Consultants B.V) and the Ecoinvent database 3.1 within the program. The study performed an environmental evaluation according to two LCIA methods:

- IPCC 2007 GWP 100a (Intergovernmental Panel on Climate Change 2007, global warming potential, 100 years).
- ReCiPe (Midpoint and Endpoint).

IPCC 2007 GWP 100a method was chosen, because one of the most important negative aspects of the transport are greenhouse gases (GHGs) emissions (carbon footprint). The IPCC method allows assessing the impact of GHGs on the greenhouse effect as a function of the CO_2 (CO_2 eq) released during the assumed time horizon of 100 years [11]. ReCiPe method was chosen to model next very important aspect of the transport, which is negative impact on human health, ecosystem, and resource consumption.

ReCiPe is the most complex method, which shows the analyses of the environmental impact in various impact categories and damage categories. The primary objective of the ReCiPe Midpoint method is to transform the long list of life cycle inventory results into a limited number of indicator scores. These indicator scores express the environmental impact categories. In the ReCiPe Endpoint, the indicators are determined at three damage categories [12]:

- Damage to Human Health is measured in units of Disability-Adjusted Life Years (DALY), which express the number of years lived disabled and the number of years of life lost. Climate change, ozone depletion, photochemical smog production, humans' toxicity, ionizing radiation and the particulate matter formation have been taken into account in this damage category.
- Damage to Ecosystem Quality is reflected by the diversity of species within, and the damage to an ecosystem may be expressed in terms of the number of species that disappear in a given area as a result of contamination. This category includes acidification, eco-toxicity, eutrophication, and land occupation.
- Damage to Resources category, connected with the use of fossil fuels and minerals, is based on the assumption that non-renewable resources should be available for future population.

Results are expressed in ecopoints (Pt). One ecopoint represents one thousandth fraction of yearly damage to the environment caused by one European.

3.2. LCIA results

Data regarding the transport and the life cycle inventory was taken from Ecoinvent database 3.1. Life cycle inventory of road transport (with lorry 16-32 t, EURO 5) refers to the entire transport life cycle and includes stages as follows:

- Operation of lorries.
- Production, maintenance and disposal of lorries.
- Construction and maintenance and disposal of road.

Life cycle inventory of rail transport includes:

- Operation of rail sets.
- Production, maintenance and disposal of rail sets.
- Construction and maintenance and disposal of railway tracks.

Total GHGs emissions (carbon footprint) of the outbound transport using the IPCC GWP 100a method are 1 145.17 CO_2 eq t per FU. The most important sources of climate change for evaluated transport are shown in **Figure 1**. More GHGs emissions are produced by road transport (73.1%). The highest GHGs emissions are related to the operation stage.

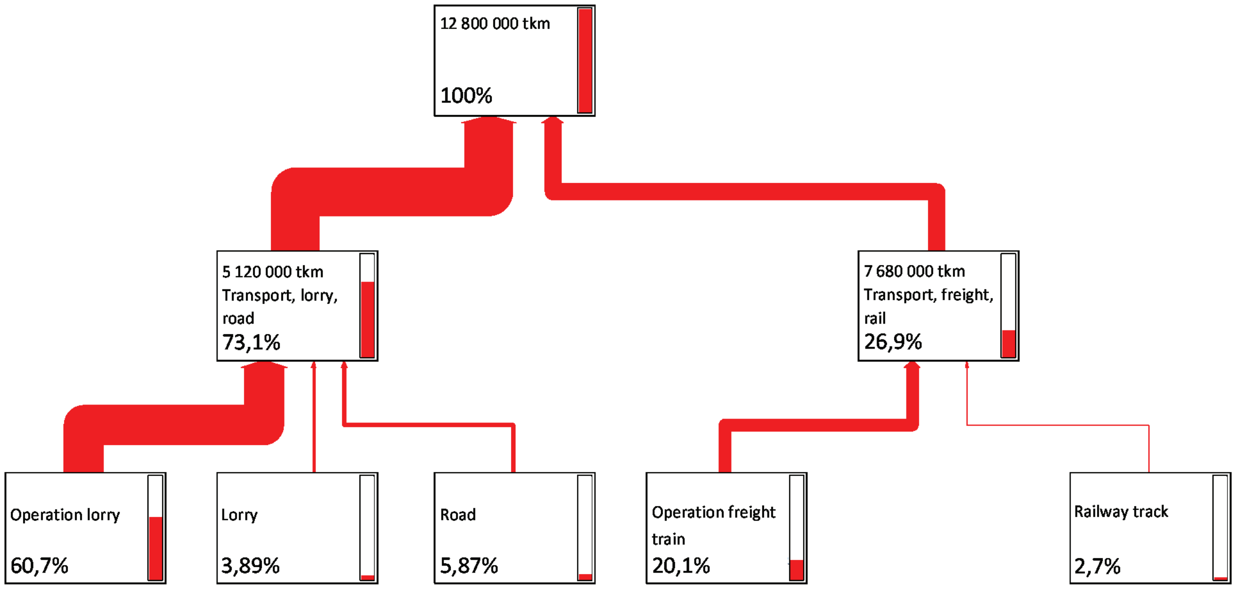

Figure 1 The share of the GHGs emissions

The results of LCIA of the outbound transport based on ReCiPe Midpoint method are shown in **Table 1**. The impact of the damage categories according to ReCiPe Endpoint method is presented in **Table 2**. Higher impact of the outbound transport is in Human Health and Resources categories.

Table 1 Results of LCIA analysis using the ReCiPe Midpoint method per FU

Impact category	Unit	Result
Ozone depletion	kg CFC-11 eq	0.15
Terrestrial acidification	kg SO_2 eq	4 123.73
Freshwater eutrophication	kg P eq	270.07
Marine eutrophication	kg N eq	232.30
Human toxicity	kg 1.4-DB eq	244 699.25
Photochemical oxidant formation	kg NMVOC	5 624.82
Particulate matter formation	kg PM10 eq	1 817.50
Terrestrial ecotoxicity	kg 1.4-DB eq	102.47
Freshwater ecotoxicity	kg 1.4-DB eq	6 010.69
Marine ecotoxicity	kg 1.4-DB eq	6 511.17
Ionising radiation	kBq U235 eq	239 916.68
Agricultural land occupation	m^2a	8 608.95
Urban land occupation	m^2a	19 385.16
Natural land transformation	m^2	382.95
Water depletion	m^3	14 550.24
Metal depletion	kg Fe eq	80 184.88
Fossil depletion	kg oil eq	381 867.33

Table 2 Damage categories caused with the outbound transport per FU

Damage category	**Unit***	**Result**
Human Health	kPt / FU	44.58
Ecosystems	kPt / FU	22.71
Resources	kPt / FU	44.63
Total	kPt / FU	111.92

* kPt - thousands of eco-points

4. CONCLUSION

The article shows that LCA can be a suitable methodology for assessment of environmental impact of a metallurgical company transport from the global viewpoint. Presented results demonstrates a wide gamut of impact categories, which can be obtained using the LCA in transport of metallurgical raw materials, semi-finished and final products. As a practical problem can be seen the fact that the aggregated damage categories measured in an eco-points aren't intelligible for the managerial practice.

Future research work will be focused on a model design, which allows to evaluate transport of metallurgical product also from the economic point of view. The model will be based on a multicriteria decision making method [13]. It allows to select the most appropriate share of the road and rail transport on the basis of economic and ecological evaluation.

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