FOSSIL FUELS CONSUMPTION EVALUATION IN BLAST FURNACE TECHNOLOGY BASED ON DIFFERENT LIFE CYCLE IMPACT ASSESSMENT METHODS

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Abstract

Non-renewable resources management is one of the key issues of sustainable development. Therefore it is important to implement methods for assessing of the materials and fuels use in industrial processes. In this paper evaluation of fossil fuels consumption in blast furnace technology based on different life cycle impact assessment methods was presented. In order to evaluate the consumption of resources was used four life cycle impacts assessment methods: Ecoindicator 99, Cumulative Energy Demand, Cumulative Exergy Demand and ReCiPe. Different scenarios of using waste plastics as alternative fuels to reduce consumption of fossil fuels was presented. Life Cycle Assessment (LCA) analysis was carried out in accordance with standard EN ISO 14040:2006, by four phase: goal and scope definition of LCA, inventory analysis LCI (Life Cycle Inventory), impact assessment LCIA (Life Cycle Impact Assessment) and interpretation. In order to perform LCA analysis was used SimaPro 7.3 software.

Keywords: Life Cycle Assessment (LCA), Life Cycle Impact Assessment (LCIA), environmental assessment, fossil fuels, pig iron production

1. INTRODUCTION

The iron and steel industry is very energy-intensive industry, especially iron-making. The largest source of greenhouse gas emissions in the blast furnace technology is due to the high coke consumption. Based on previous work in this field was set two emission reduction lines: the replacement of coke by substitute fuels and the use of alternative technologies to the blast furnace process [1,2]. In [2] was presented assessment results of environmental impacts in conventional blast furnace iron-making system based on LCA (Life Cycle Assessment), and found that fossil fuels are the main sources of greenhouse gas emissions for steel plant, especially for iron-making. Therefore, in this study were evaluated fossil fuels consumption in blast furnace technology based on different life cycle impact assessment methods. This paper presents LCA application in blast furnace technology and the results of LCA study comparing used coke (common fuel) and waste plastics (alternative fuel). Tests were performed at the Central Mining Institute. In order to perform LCA analysis for blast furnace technology were used SimaPro 7.3 software and were applied four of the life cycle impact assessment methods - Ecoindicator 99, Cumulative Energy Demand, Cumulative Exergy Demand and ReCiPe – to evaluate fossil fuels consumption of five scenarios depending on used waste plastics.

2. METHODS

Environmental impact assessment of alternative fuels - waste plastics used in the blast furnace technology based on the technique of LCA were conducted for five scenarios. In accordance with ISO 14040:2006, set the objective, scope, system boundaries and limitations of LCA and the analysis of inputs and outputs of LCI. The system boundary was defined as “cradle to gate” production of pig iron including all inputs, raw material, energy, emissions and waste. Life Cycle Inventory (LCI) data for the blast furnace technology were adopted from the publication [3]. For comparative purposes, all data were determined in relation to the same functional unit, a ton of liquid steel. In this paper, the analysis focuses on consumption of fossil fuels, without regard to other categories of impact (such as human health, ecosystem quality, global warming, etc.). The amount of the coke and waste plastic used in analyzed scenarios is shown in Table 1. For fossil fuels consumption evaluation in blast furnace iron-making system four life cycle impact assessment methods were used (Table 2).

Table 1 The amount of the coke and waste plastic in analyzed scenarios [3]

Scenarios	Symbol	Waste plastic	Coke kg/ Mg l.s.	Waste plastic kg/ Mg l.s.
Scenario 1	W0	without waste plastics	384,9	0
Scenario 2	W1	polyethylene (PE)	326,2	50,0
Scenario 3	W2	polypropylene (PP)	334,2	50,0
Scenario 4	W3	polystyrene (PS)	320,9	50,0
Scenario 5	W4	polyethylene terephthalate (PET)	356,5	50,0

where: l.s. – liquid steel

Table 2 Chosen life cycle impact assessment methods for fossil fuels consumption evaluation

Method	Abbreviation	Impact category	Unit
Eco-indicator 99 (H/A) V2.08 / Europe EI 99 H/A	EI 99	Fossil fuels	MJ surplus
Cumulative Exergy Demand V1.02	CExD	Non renewable, fossil	MJ
Cumulative Energy Demand V1.08	CED	Non renewable, fossil	MJ
ReCiPe Endpoint (H) V1.05 / Europe ReCiPe H/A	ReCiPe	Fossil depletion	$

The basic structure of impact assessment methods in SimaPro is characterization, damage assessment, normalization and weighting. The last three steps are optional according to the ISO standards. This means they are not always available in all methods. Two methods used in this studies – EI 99 and ReCiPe - allow weighting across impact categories. This means the impact (or damage) category indicator results are multiplied by weighting factors, and are added to create a total or single score [4].

Eco-indicator 99 (EI 99) is a damage oriented method for life cycle impact assessment. This method allows obtain results into three damage categories: Human Heath, Ecosystem Quality and Resources. Damages to Resources, minerals and fossil fuels, are expressed as surplus energy for the future mining of resources. For fossil fuels surplus energy is based on the future use of oil shale and tar sands [5]. Fossil fuels consumption is evaluated as surplus energy per extracted MJ, kg or m^3 fossil fuel, as a result of lower quality resources.

Cumulative Energy Demand (CED) is expanded for energy resources available in the SimaPro database. CED of a product represents the direct and indirect energy use throughout the life cycle, including the energy consumed during the extraction, manufacturing, and disposal of the raw and auxiliary materials [6]. “Non renewable, fossil” is one of five resource categories: two non renewable - fossil, nuclear and three renewable - biomass, water and “wind, solar, geotherm” given for the energy resources as characterization factors [7].

Cumulative Exergy Demand (CExD) is introduced to depict total exergy removal from nature to provide a product, summing up the exergy of all resources required. CExD assesses the quality of energy demand and includes the exergy of energy carriers as well as of non-energetic materials. The impact category indicator “non renewable, fossil” is one of ten resource categories: five non renewable - fossil, nuclear, primary, metals, minerals and five renewable - solar, potential, biomass, water and kinetic [7,8].

The primary objective of the *ReCiPe* method, is to transform the long list of Life Cycle Inventory results, into a limited number of indicator scores. These indicator scores express the relative severity on an environmental impact category. In ReCiPe we determine indicators at two levels: eighteen midpoint indicators and three endpoint indicators [9]. This method is considered as a follow up of the CML 2002 and the EI99 methods. The indicator scores are determined in a similar way as in the EI99 method. The impact category “fossil fuel depletion” (unit – surplus cost, $) is one of eighteen midpoint categories [10].

3. RESULTS AND DISCUSSION

The results of an evaluation of fossil fuels consumption caused by blast furnace based on the technique of LCA were presented. Environmental impact assessment of waste plastics (alternative fuels) in blast furnace depending on used of the life cycle impact assessment method was shown in Table 3.

Table 3 Environmental impact assessment in category associated with fossil fuels consumption, per one ton of liquid steel (own calculations in the SimaPro)

Methods	Impact category	Unit	W0	W1	W2	W3	W4
EI 99	Fossil fuels	MJ surplus	682	77	100	-5	154
CExD	Non renewable, fossil	MJ	32521	21732	22813	20660	25355
CED	Non renewable, fossil	MJ	31655	21042	22070	20069	24769
ReCiPe	Fossil depletion	$	12114	8053	8446	7683	9481

According to the Ecoindicator 99 factor for fossil fuels consumption for scenarios with waste plastic are very low compared to the scenario without waste plastic only with coke (W0) and decrease on average by 85% was observed. For other life cycle impact assessment methods factors related to fossil fuel consumption in the W1-W4 decrease on average by 30% was observed.

Life cycle assessment based on all LCIA methods shows that scenario 4 (W3) causes the lowest impact on fossil fuels consumption. It is means that using of polystyrene (PS) in blast furnace causes the greatest environmental benefit.

Figures 1-4 present five main elements of the input of blast furnace technology, which have the largest impact on fossil fuels consumption (in accordance with the four chosen LCIA methods). It was found that the largest impact has coke, which is primarily used in the production of pig iron in a blast furnace, while the use of waste plastic caused avoiding of part of coke in the process.

In next step of these studies was conducted a comparative environmental analysis with two methods - EI 99 and Recipe after the weighing step, which is presented in Table 4.

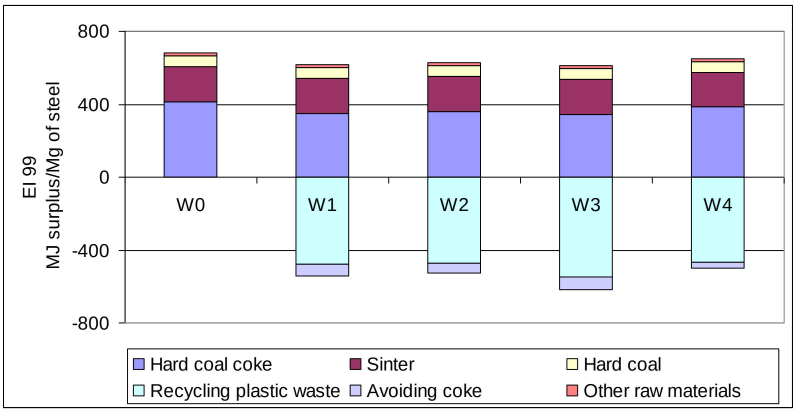

Fig. 1 Influence of main input factors in blast furnace technology on fossil fuels consumption, per one ton of liquid steel based on EI 99 method (own calculations in the SimaPro)

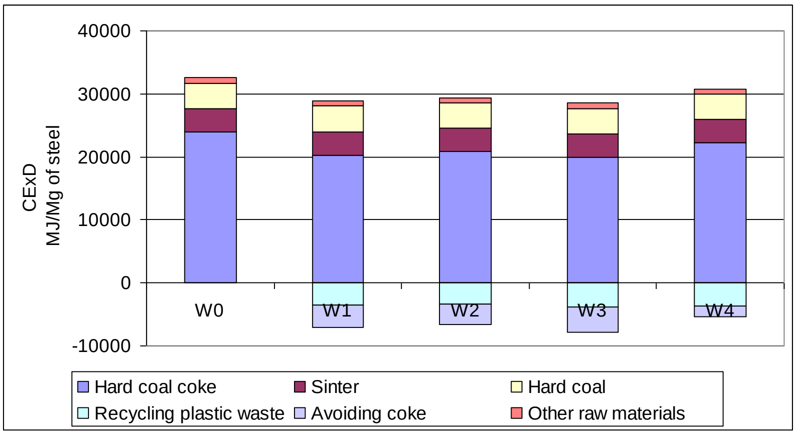

Fig. 2 Influence of main input factors in blast furnace technology on fossil fuels consumption, per one ton of liquid steel based on CExD method (own calculations in the SimaPro).

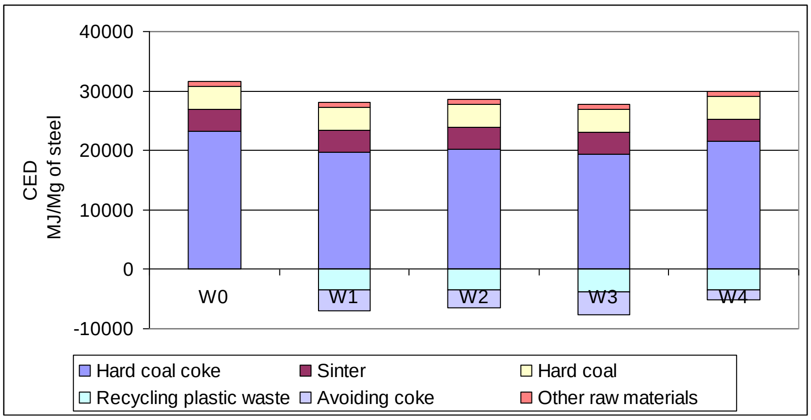

Fig. 3 Influence of main input factors in blast furnace technology on fossil fuels consumption, per one ton of liquid steel based on CED method (own calculations in the SimaPro)

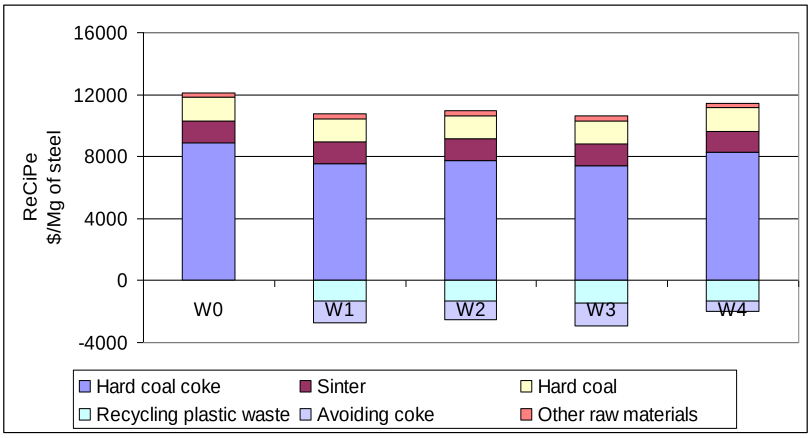

Fig. 4 Influence of main input factors in blast furnace technology on fossil fuels consumption, per one ton of liquid steel based on ReCiPe method (own calculations in the SimaPro)

Table 4 Environmental impact assessment after weighting.

Method	Impact category	Unit	W0	W1	W2	W3	W4
EI 99 H/A	Total	Pt	265,87	216,38	221,89	214,32	233,02
	Fossil fuels	Pt	18,07	2,05	2,64	-0,14	4,08
	Fossil fuels	%	6,79	0,95	1,19	-0,06	1,75
ReCiPe	Total	Pt	256,46	186,72	194,32	178,27	211,93
	Fossil depletion	Pt	90,39	60,09	63,02	57,33	70,75
	Fossil depletion	%	35,25	32,18	32,43	32,16	33,38

LCA can be used in blast furnace technology as a means to comprehensively evaluate processes, material and fuel choices and their effects on life cycle GHG emissions. One of the option for broadening the Life Cycle Assessment approaches could be to integrate this methods with economic methods into eco-efficiency. It is important to integrated economic assessment and results of LCA into product design at an early stage to improve eco-efficiency of the product or technology [11]. Life Cycle Assessment can be used for environmental impact assessment it (LCA), Activity Based Costing (ABC) can be used for cost estimation [1,12]. On the basis of the obtained indicators could be used to design the decision support system [13].

5. CONCLUSION

Fossil fuels are the main sources of greenhouse gas emission for iron-making, therefore in these studies evaluation of fossil fuels consumption in blast furnace technology based on four different life cycle impact assessment methods was performed.

The aim of the study were to compare five scenario depending on waste plastic amount and to highlight the differences between the methods used for the life cycle impact assessment. For resources impact category, only fossil fuels consumption was taken into account. The impact category “fossil fuel” is one of the most important impact categories when studying blast furnace technology

Different scenarios of using waste plastics as alternative fuels to reduce consumption of fossil fuels showed the possibility of avoiding the coke, which is the main fuel in the iron production process is coke and causes the largest impact of greenhouse gas emissions.

LITERATURE

[1] BURCHART-KOROL D: Significance of Environmental LCA Method in the Iron and Steel Industry, *Metalurgija* 50 (2011) 3, pp. 205-208

[2] BURCHART-KOROL D., Evaluation of Environmental Impacts in Iron-Making based on Life Cycle Assessment, *METAL 2011: 20th Anniversary International Conference on Metallurgy and Materials*. Ostrava: TANGER, 2011, pp. 1246-1252.

[3] SEKINE Y., FUKUDA K., KATO K., ADACHI Y., MATSUNO Y.: CO_2 Reduction Potentials by Utilizing Waste Plastics in Steel Works, *International Journal of Life Cycle Assessment*, nr 14, 2009, p.122

[4] GOEDKOOP M, OELE M., SCHRYVER A., VIEIRA M.: SimaPro Database Manual Methods library, PRé Consultants, the Netherlands, May 2008

[5] GOEDKOOP M., SPRIENSMA R.: The Eco-indicator 99 A Damage Oriented Method for Life Cycle Impact Assessment, *Methodology Report* PRé Consultants B.V. 2000

[6] DEUTSCHER V.: VDI-richtlinie 4600: Cumulative Energy Demand, Terms, Definitions, Methods of Calculation; Verein Deutscher Ingenieure: Düseldorf, 1997.

[7] FRISCHKNECHT R., JUNGBLUTH N., ALTHAUS H.J., DOKA G., DONES R., HISCHIER R., HELLWEG S., HUMBERT S.,MARGNI M., NEMECEK T., SPIELMANN M.: Implementation of Life Cycle Impact Assessment Methods: Data v2.0. ecoinvent report No. 3, Swiss centre for Life Cycle Inventories, Dübendorf, Switzerland 2007.

[8] BÖSCH M.E., HELLWEG S., HUIJBREGTS M.A.J., FRISCHKNECHT R.: Applying Cumulative Energy Demand (CExD) Indicators to the Ecoinvent Database. In: *International Journal of Life Cycle Assessment* 12 (3) (2007) pp. 181–190.

[9] GOEDKOOP M., HEIJUNGS R., HUIJBREGTS M., SCHRYVER A., STRUIJS J., ZELM R.: ReCiPe 2008: A Life Cycle Impact Assessment Method which Comprises Harmonised Category Indicators at the Midpoint and the Endpoint Level: First edition, Report I: Characterisation, Ministry of Housing, Spatial Planning and Environment (VROM), The Netherlands, 2009.

[10] The ReCiPe methodology, http://www.lcia-recipe.net/, March 2011.

[11] GOLAK S., BURCHART-KOROL D., CZAPLICKA-KOLARZ K., WIECZOREK T.: Application of Neural Network for the Prediction of Eco-efficiency. Lecture Notes in Computer Science, D. Liu et al. (Eds.): ISNN 2011, Part III, LNCS 6677, pp. 380–387, 2011 (Springer-Verlag Berlin Heidelberg 2011).

[12] SANIUK A., SANIUK S., WITKOWSKI K., Using Activity Based Costing in the Metalworking Processes, In: *METAL 2011 Conference proceedings*, TANGER 2011, Ostrava, Czech Republic, EU, ISBN 978-80-87294-22-2.

[13] SAMOLEJOVÁ, A.; FELIKS, J.; LENORT, R.; BESTA, P. A Hybrid Decision Support System for Iron Ore Supply. *Metalurgija*, vol. 51, no. 1, 2012, pp. 91-93. ISSN 0543-5846.