ECO-EFFECTIVENESS POTENTIAL AND CIRCULAR ECONOMY APPROACH FOR SUPPORTING THE RESOURCES MANAGEMENT IN STEEL PRODUCTION

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Abstract

Natural resources management is one of the environmental policy priorities in steel industry. In the paper, attention was given to the potential of eco-effectiveness and circular economy concept for supporting decision-making related to the management of natural resources in steel production. In this paper was explored the eco-efficiency and eco-effectiveness for supporting production management. It was presented the importance and the role of circular economy and life cycle approach for systematizing the problems of natural resource depletion in steel industry. Circular economy and cradle-to-cradle approach are fundamental elements for establishing more sustainable steel.

Keywords: Circular economy, eco-effectiveness, eco-efficiency, life cycle approach, steel industry

1. INTRODUCTION

The steel industry is an integral part of the circular economy. Steel is sustainable product in circular economy through fundamental advantages, which are reusable and 100 % recyclable. Circular economy encourages zero waste, the reuse and recycling of materials and a reduction of materials used through life cycle perspective. World Steel Association has supports the life cycle approach for steel products and has developed application of Life Cycle Assessment (LCA) for steel to enable designers to make decision which material is more sustainable [1]. LCA is technique which help to evaluate environmental aspects in life cycle of products including manufacture, use, recycling and end-of-life phase. So far management of resources and ecoinnovations for steel supply chains were presented in the papers [2-5]. The environmental footprint including carbon, water and land footprint of steel products should be evaluated through a life cycle perspective. Life cycle approach takes into account each of stage in life cycle of steel products (production, the use and end-of life). According to European Steel Association [6] a life-cycle perspective shows that the use of steel in innovative applications saves more CO_2 emission than is emitted in the production phase.

The main goal of the paper is presented potential of eco-efficiency and eco-effectiveness and circular economy approach for supporting production management in steel industry. It was presented the role of life cycle approach for identification the problems of natural resource depletion in steel industry.

2. THE SIGNIFICANCE OF ECO-EFFICIENCY AND ECO-EFFECTIVENESS

Eco-efficiency originates from efficiency, which means doing things in the right way and compares output and input. Efficiency is related to the internal tasks and activities of a enterprises or supply chain [7]. The eco-efficiency concept was defined by The World Business Council for Sustainable Development (WBCSD) as being achieved by the delivery of competitively priced products that satisfy human needs and bring quality of life, while progressively reducing environmental impacts and resource intensity throughout the life cycle [8, 9]. Eco-efficiency means doing more with less, which mean more value to a product with using fewer natural resources and releasing less pollution. Seven elements of eco-efficiency was identified by the WBCSD (see **Figure 1**).

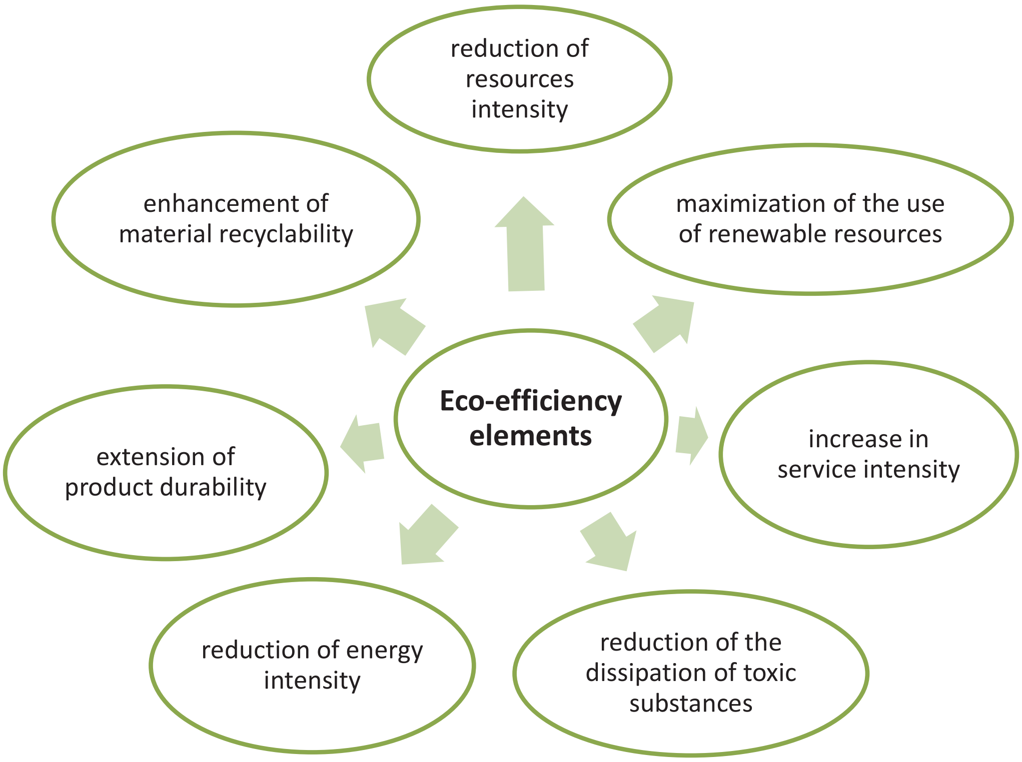

Figure 1 Main elements of eco-efficiency [8]

According to ISO 14045:2012 [10] eco-efficiency is an aspect of sustainable development relating the environmental performance of a product system to its system value. Eco-efficiency indicator is measured relating environmental performance of a product system to its product system value. An eco-efficiency is a relative concept and a product system is only more-or-less eco-efficient in relation to another product system [9,11]. Environmental assessment in eco-efficiency assessment have to be based on Life Cycle Assessment (LCA) according to ISO 14040:2006 [12] and ISO 14044:2006 [13]. LCA is an environmental assessment method for evaluation of impacts that a product, process or technology has on the environment over the entire period of its life - from the extraction of the raw material through the manufacturing, packaging and marketing processes, the use, re-use and maintenance of the product or technology, to its eventual recycling or disposal as waste at the end of its useful life [14]. It was found that eco-efficiency is important concept for assessment of environmental and economic indicators but eco-efficiency can’t stop the increasing release of pollutants and this concept is not sufficient for the attainment of sustainability [15] and eco-efficiency is not being a strategy for success over the long term [16]. Wang et al. [15] proposed a new framework of sustainable industrial system, where the eco-effectiveness plays important role.

Eco-effectiveness originates from effectiveness, which means doing the right things and compares an accomplished work to planned targets. Effectiveness is externally related to company [7]. Eco-effectiveness was established in order to complete shortcomings of eco-efficiency. Eco-effectiveness with cradle-to-cradle design shows an alternative concept to the eco-efficiency [17]. The concept was first defined in the book “Cradle to Cradle - Remaking the way we make things” by McDonough and Braungart [17]. The Cradle to cradle concept and the underlying criteria are based on three fundamental principles: waste equals food, use current solar income and celebrate diversity. Eco-effectiveness is oriented to the redesign of the whole production system, by encouraging ecologically appropriate design of products, by closing material flows, recovering resources and using materials that result in minimal environmental impact [17].

Both eco-effectiveness and eco-efficiency are important concepts in the development of life cycle approach of steel. These concepts should complement each other. The use of eco-efficiency enables to compute economic efficiency and environmental efficiency of steel products and allows to develop a benchmarking of various alternative of steel products, while the use of eco-effectiveness allows to specify the beneficial environmental footprint from cradle to cradle.

3. CIRCULAR ECONOMY APPROACH IN STEELMAKING

The conventional linear economy model is based on the premise of take, make, use and waste disposed. In a circular economy model is make, improve and renew. The circular economy is described by four principles: use less, do more, manage resources and work together (see **Figure 2**) [18]. The Ellen MacArthur Foundation commissioned a report called "Towards the Circular Economy". It was the first report, which consider the economic, business and organization opportunity for the transition from linear economy model to a circular economy concept [19].

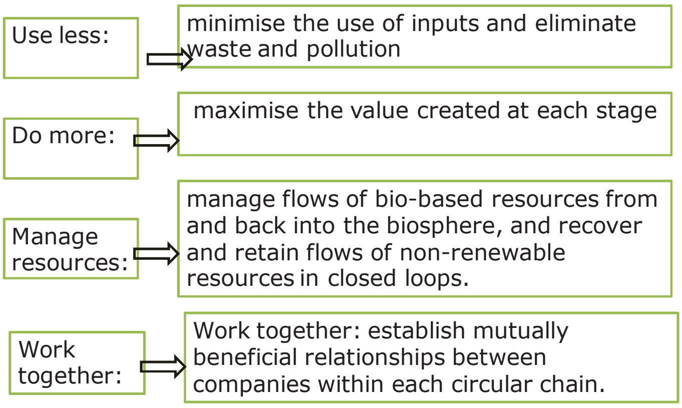

Figure 2 The principles of circular economy [18].

According to European Environment Agency Report [20] creating a circular economy requires fundamental changes throughout the value chain, from product design and production processes to new business models and consumption patterns. Recycling will turn waste into a useful resource and extending lifetimes of product will help preserve resources. The Circular Economy Package [21] includes ambitious program of action, with measures covering the whole cycle from production and consumption to waste management and the market for secondary raw materials. Important key of circular economy is closing the product life cycle loop through higher reuse and recycling.

Waste management is an integral part of circular economy. Waste which can't be avoided, can become a valuable resource, this waste should turn into resources. Up till now waste has been seen as a source of pollution, but now circular economy concept requires a new approach for waste management. Well managed waste can be a valuable source of materials, especially when many raw materials are becoming scarce. The best option is to stop creating waste. When that is not possible, other choices are reusing, repairing and recycling change the waste into the useful materials or products, which will maximize resource efficiency.

The environmental benefits of adopting a circular economy approach in steel production are considerable. The largest benefits are reduction of consumption raw materials, natural resources and minimising the wastes. Steel is the most recycled material with no degradation in performance. According to circular economy approach was developed a hierarchy 4 Rs - reduce, reuse, remanufacture and recycle (see **Figure 3**). Reduce means decreasing the amount of raw materials, energy and other natural resources used to create steel and reducing the weight of steel used in products. Reuse is using an object or material again, either for its original purpose or for a similar purpose, without significantly altering the physical form of the object or material.

Remanufacture is the process of restoring durable used steel products to as-new condition. Melting steel products at the end of their useful life to create new steels. Recycling alters the physical form of the steel object so that a new application can be created from the recycled material [22].

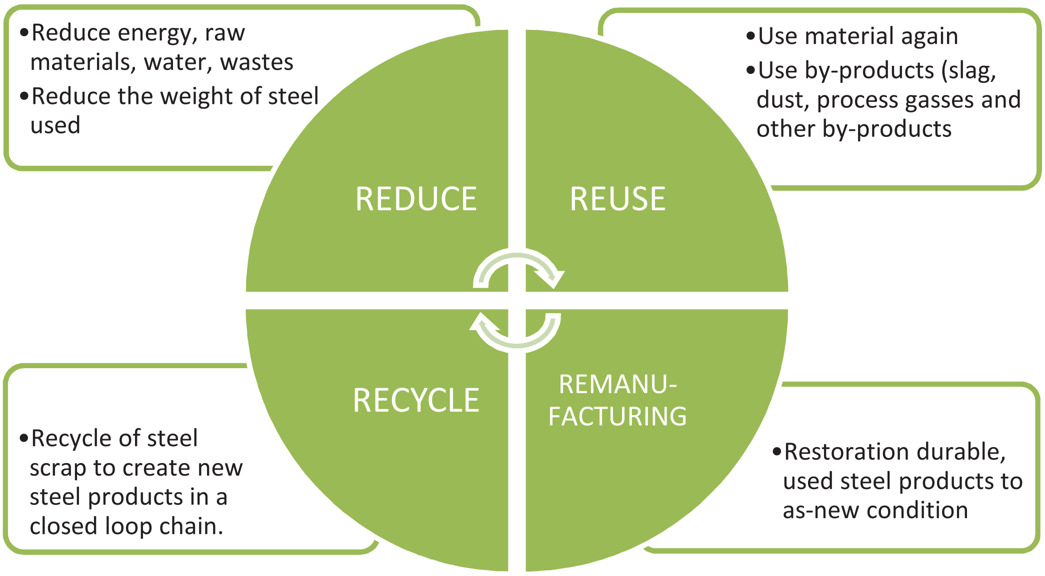

Figure 3 Circular economy approach in steelmaking (according to [22])

Waste management in the European steel industry including re-use and recycling is used for many years [6]. Selected examples of co-products produced in the integrated steelmaking route, which can replace primary materials/products, thus avoiding the environmental burden, is presented in **Table 1**.

Table 1 Steel co-products and avoided primary materials/products which may be replaced by co-products from steel production

Co-products in the integrated steelmaking route	Avoided primary materials or avoided primary products
Blast furnace slag Basic oxygen furnace slag	Cement production Gravel production Lime production
Coke oven gas Blast furnace gas Basic oxygen furnace gas	Electricity and heat production from coal, fuel oil or natural gas
Steam	Steam generation
Iron scrap	Iron production
Scales	Iron ore extraction

Since many years steel sector has been using the process gas from melting iron ore in blast furnaces to produce energy used in other production steps. The gases deliver the heat required for coke plants and the ovens in the rolling mills. Each year an average 45 million t of ferrous slags are generated from steelmaking in Europe. Far from being waste, slags are sought-after materials in numerous applications and they are always a sustainable alternative to natural resources. More than 80 % of ferrous slags are used for building roads, bridges or waterways. Slags with defined silicate content have been serving as fertilizers in agriculture for decades. Other significant application for ferrous slags is cement production [6]. The use of steel co-products instead of primary products reduces greenhouse gasses emissions from manufacturing process. Therefore is looking for a new production methods, which eliminate emissions from the cement production system. Recycled materials and waste can be suitable for blending with Ordinary Portland Cement (OPC) as substitute, and can replacement binders. Blast furnace slag is example of cement replacement material [23]. According to the paper [24] for every 1 kg of steel scrap that is recycled at the end of the products life, a saving of 1.5 kg CO_2-e emissions, 13.4 MJ primary energy and 1.4 kg iron ore can be achieved. This equates to 73 %, 64 % and 90 %, respectively, when compared to 100 % primary production. The Declaration by the Metals Industry on Recycling Principles [25] defines the distinction between the recycled content approach and the end-of-life approach and why the latter is supported by the metals industry. The end-of-life approach in steel life cycle encourages the recycling of steel products at the end of their life and therefore reduces wastes and saves the natural resources use in creating new steel products that is why they constitute the main cores of a circular economy [24, 25].

4. CONCLUSION

It was found that the most important challenges for the development of the steel industry in circular economy model are: increasing energy efficiency in steel production, increasing material efficiency, more intelligent application of steel, increasing the share of renewable sources, reducing the consumption of raw materials, energy and emissions and increasing utilization of wastes. Life cycle approach with eco-design with reduce, reuse, remanufacture and recycle raw materials, co-products and steel products should play a significant role in steel production.

Application of LCA, eco-efficiency and eco-effectiveness concepts were proposed for steel products assessment from a life cycle perspective. The use of co-products (in linear economy model understood as by-products) brings environmental benefits, which include mainly reduction of the environmental footprint due to avoidance of primary materials use. Environmental burdens of co-products are lower than the environmental burdens for primary materials, which they substitute. Life cycle perspective with circular economy model allow avoiding unintended consequences associated with moving the environmental burdens from one phase of life cycle to another.

To face the challenges of circular economy approach, steel sector requires continuous changes and improvement management methods, which need to create more value with using fewer inputs, reduce costs and minimise environmental impacts and do more added value with less input. In the fulfillment of these objectives might help presented methods, including eco-efficiency and eco-effectiveness, which can support the natural resources management in steel industry.

ACKNOWLEDGEMENTS

The research was carried out within the framework of the statutory work of the Central Mining Institute in Katowice (Poland) entitled: The environmental impact assessment of steel production technology based on the natural resource depletion analysis, No. 11311036-324

REFERENCES

[1] The World Steel Association, www.worldsteel.org (04.04.2016).

[2] LENORT, R., WICHER, P. Concept of a System for Resilience Measurement in Industrial Supply Chain. In *METAL 2013: 22nd International Conference Metallurgy and Materials*. Ostrava: TANGER, 2012, pp. 1982-1988.

[3] PUSTĚJOVSKÁ, P., JURSOVÁ, S. Measure to Reduce CO_2 Emissions in Metallurgy. In *METAL 2011: 20th International Conference on Metallurgy and Materials*. Ostrava: TANGER, 2011.

[4] GRACZYK, M., BURCHART-KOROL, D., WITKOWSKI, K. Reverse Logistics Processes in Steel Supply Chains. In *METAL 2012: 21st International Conference Metallurgy and Materials*. Ostrava: TANGER, 2012.

[5] SANIUK, S., SANIUK, A. Prototyping of Production Networks in Regional Metallurgical Cluster. In *METAL 2012: 21st International Conference Metallurgy and Materials*. Ostrava: TANGER, 2012.

[6] http://www.eurofer.org (11.04.2016).

[7] DRUCKER, P.F. *The Effective Executive.* New York: Harper.Business, 1993.

[8] http://www.wbcsd.org (11.04.2016).

[9] KOROL, J., BURCHART-KOROL, D., PICHLAK, M. Expansion of environmental impact assessment for eco-efficiency evaluation of biocomposites for industrial application. *Journal of Cleaner Production*, 2016, no. 113, pp. 144-152.

[10] EN ISO 14045:2012 Environmental management - Eco-efficiency assessment of product systems -Principles, requirements and guidelines.

[11] BURCHART-KOROL, D., KOROL, J., FUGIEL, A. Development of Eco-Efficiency Evaluation with Multicriteria Analysis for Steel Production. In *METAL 2014: 23rd International Conference on Metallurgy and Materials*. Ostrava: TANGER, 2014.

[12] ISO 14040:2006. Environmental management - life cycle assessment - principles and framework.

[13] ISO 14044: 2006 - Environmental management - Life cycle assessment - Requirements and guidelines.

[14] CZAPLICKA-KOLARZ, K., BURCHART-KOROL, D., KOROL, J., Environmental assessment of biocomposites based on LCA, *Polimery*, 2013, vol. 58, no. 6, pp. 476-481.

[15] WANG, G., CÔTÉ, R. Integrating eco-efficiency and eco-effectiveness into the design of sustainable industrial systems in China, *The International Journal of Sustainable Development and World Ecology,* 2011, no. 18, pp. 65-77.

[16] MCDONOUGH, W., BRAUNGART, M. *From cradle to cradle*. New York: North Point Press, 2002.

[17] MCDONOUGH, W.; BRAUNGART, M. *Cradle to Cradle - Remaking the way we make things*. New York: North Point Press, 2002.

[18] https://www.rabobank.com (19.04.2016).

[19] https://www.ellenmacarthurfoundation.org/ (19.04.2016).

[20] European Environment Agency Report: "Circular economy in Europe - Developing the knowledge base" in: http://www.eea.europa.eu (12.04.2016).

[21] European Commission's 2015 Circular Economy Package in: http://ec.europa.eu.

[22] STEEL - THE PERMANENT MATERIAL IN THE CIRCULAR ECONOMY in https://www.worldsteel.org.

[23] IMBABI, M., CARRIGAN, C., MCKENNA, S. Trends and developments in green cement and concrete technology, *International Journal of Sustainable Built Environment,* 2012, vol. 1, pp.194-216.

[24] BROADBENT, C. Steel's recyclability: demonstrating the benefits of recycling steel to achieve a circular economy, *The International Journal of Life Cycle Assessment,* 2016, DOI 10.1007/s11367-016-1081-1.

[25] ATHERTON, J. Declaration by the metals industry on recycling principles. *The International Journal of Life Cycle Assessment*, 2007, no. 12, pp. 59-60.