DEVELOPMENT OF ECO-EFFICIENCY EVALUATION WITH MULTICRITERIA ANALYSIS FOR STEEL PRODUCTION

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Abstract

Eco-efficiency analysis development with life cycle approach for steel production will be discussed in the paper. Eco-efficiency analysis is a tool for quantifying the relationship between economic value of technology or product and environmental impacts over the entire life cycle. The main goal of the eco-efficiency analysis is to compare similar processes, technologies or products. Possibility of applying multicriteria analysis for eco-efficiency assessment will be presented. This paper adapts Life Cycle Assessment (LCA) methodology to undertake an analysis of the environmental dimensions of steel production. The algorithm of Multi-Criteria Decision Analysis (MCDA) using for eco-efficiency optimization of steel production will be presented. MCDA allows taking into account the most important criteria of steel production: performance, life cycle of cost, quality of product, environmental aspects, social aspects etc.

Keywords: multicriteria analysis, eco-efficiency, life cycle approach, steel production

1. INTRODUCTION

In Poland in 2012, crude steel was produced at a rate of 8.4 million tons per year, down 4.8% from that of 2011 [1]. In 2012, 4.23 million tons of basic oxygen furnace (BOF) steel and 4.13 millions tons of and electric arc furnaces (EAF) steel were produced. Poland's contribution to the overall EU steel production was 5% at the same level as in 2011. In 2012 the financial performance and conditions of iron and steel plants was affected by three key factors: diminishing internal demand for steel products manufactured in Poland, lower capacity utilization rate and increasing energy and materials prices.

The iron and steel industry is highly energy-intensive and the production of steel is associated with significant greenhouse gas (GHG) emissions. In 2012, CO_2 emissions made up the largest share (98.3%) of the national steel industry's total gas emissions. The emission of the other gases, including NO_2, SO_2, and CO, represented approximately 1.7% of the total, while the average dust emission factor was 0.40 kg/Mg crude steel (average for EAF and BOF operations) [1]. Istrate et al. [2] selected Key Performance Indicators (KPI's) and tried to find a correlation between the maintenance efforts by means of finances and the productivity management in steel making industry. Burchart-Korol [3] presented the first Life Cycle Assessment (LCA) for the entire steel production chain in Poland. The results of that study offered a comprehensive environmental impact evaluation of national steel production which includes BOF and EAF route. The studies showed that the environmental impact assessment results from the existing steel plants in Poland indicate that the production of pig iron has the highest impact on greenhouse gas emissions (GHGs) and fossil fuel depletion in the national integrated steel production route, while the iron ore sintering process, which is the largest contributor to dust and gas emissions in the national iron and steel industry, depletes the most metal. In the national electric arc furnace route electricity consumption has the highest impact on GHGs and fossil fuel depletion. In paper [4] a model of the decision-making process for steel production order realization was presented. Economic and environmental prospects of innovation in steel industry were presented in [5-7]. However still multicriteria analysis application in sustainability aspects assessment and eco-efficiency analyses for iron and steel industry presented in literature are not sufficiently documented.

The main goal of this study is to present possibility of multicriteria analysis for development of eco-efficiency assessment of steel production.

2. METHODS

The eco-efficiency method was defined in 1989 by The World Business Council for Sustainable Development (WBCSD). According to ISO 14045:2012 eco-efficiency is an aspect of sustainability relating the environmental performance of a product system to its product system value. Environmental assessment in eco-efficiency analysis shall be based on LCA according to ISO 14040:2006. More information about LCA quantification of chosen clean coal technology (coal gasification) was done by Burchart-Korol et al. [8]. The eco-efficiency indicator takes into account the environmental impact and economic performance of technology and is measured in order to carry out a comparative analysis. It is a tool of environmental management and indicates the relation of production system value to the related environmental burden. Considering the idea of sustainable development, however, authors want take into account also the social aspect. Therefore, it is worth using here a tool giving more opportunities, that is, multi-criteria decision analysis methods (MCDA). They are applied in order to carry out a comparative analysis under more than one criterion. It is possible to set priorities in assessment criteria, which is an additional benefit of the multi-criteria analysis. An analyst can determine which variants' attributes are more important and which less. Multi-criteria methods are used in many fields. Wherever there is a need to assess and compare the variants according to multiple criteria and select the best of them, multi-criteria methods can be applied. They are methods of decision-making support, which is very important in the management process.

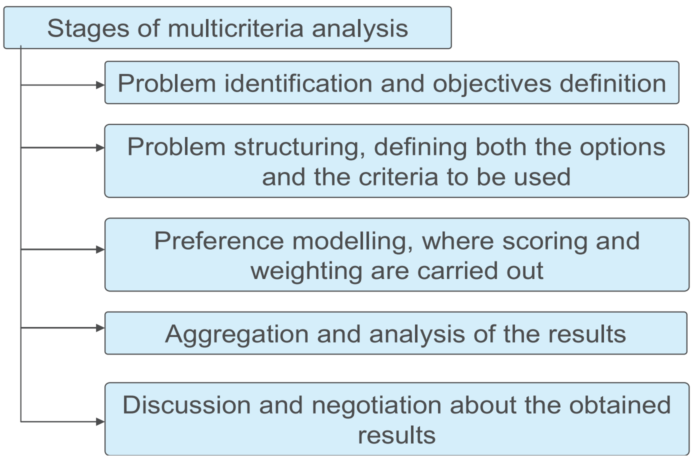

Fig. 1 Stages of multi-criteria analysis [18]

There are many works in literature where multi-criteria analyses are made in sustainable development assessment [9-11]. The Analytic Hierarchy Process (AHP) was used to develop a system for measuring resilience in steel supply chain [12]. In this case the criteria are related to economic, environmental and social aspects. In the United Kingdom an official manual was prepared, commissioned by the Department for the Environment, Transport and the Regions, containing government guidance on the application of multi-criteria analysis techniques for the assessment of options for policy and other decisions, including those having impact on the environment [13]. This indicates that it is a very important tool to support decisions, including political. In the literature can also find publications about application of multi-criteria analyses in steel industry. Geldermann et al. [14] presented the application of the fuzzy Promethee method for assessing technologies of steel production, whereas in [15] is shown how to determine the composite sustainability performance index for steel industry using the AHP method. In addition, multi-criteria methods were used for the steel industry in a logistical aspect [16, 17]. The aim of this article is to present a general scheme of how to evaluate steel production technologies in the context of sustainable development using the multi-criteria decision method. Multi-criteria methods make it possible to consider any number of criteria [18]. Therefore, in addition to the environmental, economic and social aspect, the analysis can be extended to the issue of product quality. Recchia et al. [19] proposed an algorithm of multi-criteria analysis (see **Fig. 1**).

3. RESULTS AND DISCUSION

Eco-efficiency analysis development with multicriteria decision method approach for steel production will be discussed in the paper. This paper adapts Life Cycle Assessment (LCA) methodology to undertake an analysis of the environmental dimensions of steel production. The algorithm of Multi-Criteria Decision Analysis (MCDA) using for eco-efficiency optimization of steel production was presented (see **Fig. 2**).

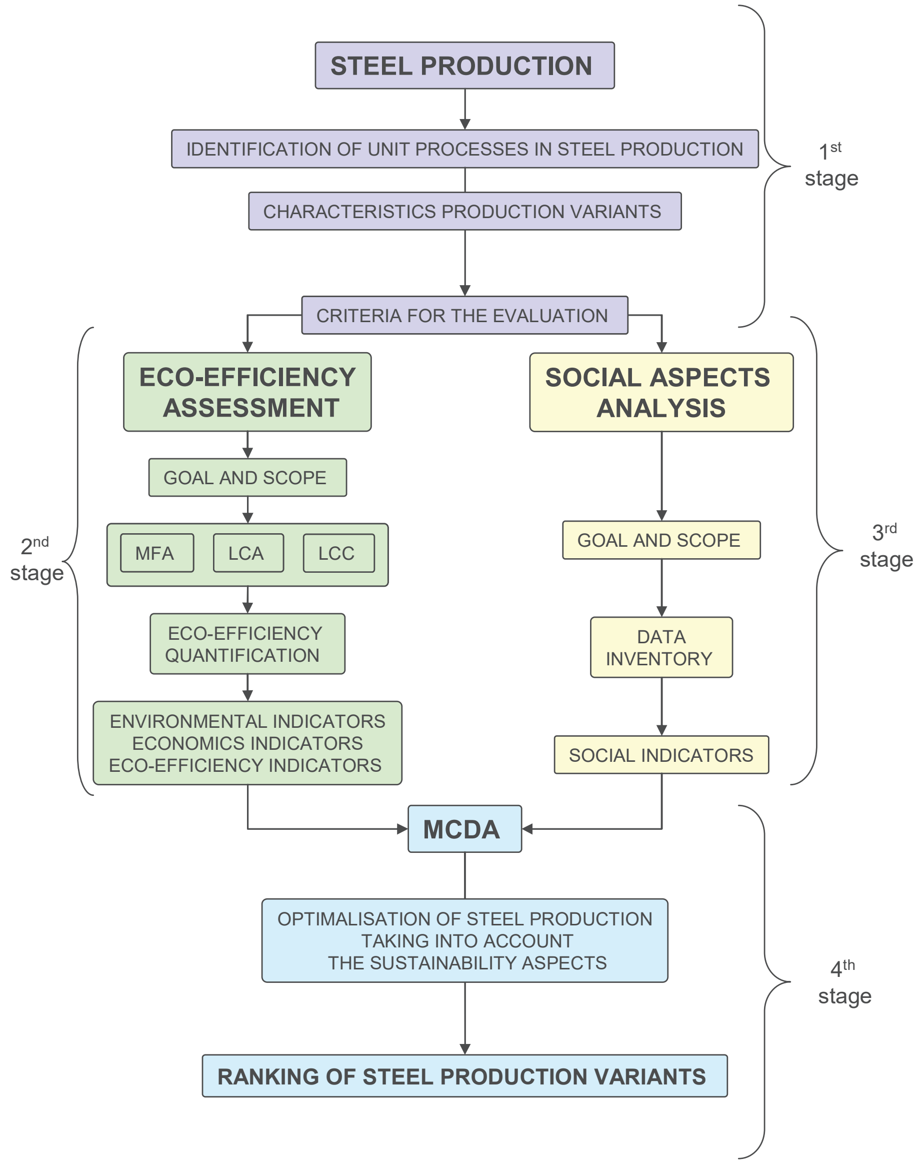

Fig. 2 The methodology framework of MCDA application in steel production for development of eco-efficiency evaluation, proposed by authors

The scope of the first stage is identification and characteristics of steel production technology and selection of variants and determination of **criteria** for the evaluation variants in steel production: technology variable parameters (materials, energy and water use, capital expenditures and costs, technology and social aspects - performance, productivity), as well as indicators of environmental assessment, economic analysis and social evaluation.

The second stage consists of e**co-efficiency analysis** for steel production for each variant of steel production. This stage includes defining the system boundary, the functional unit, the allocations to external systems, the economics evaluation methods, the environmental assessment method and types of impacts and Material Flow Analysis (MFA) of steel production. The results of Life Cycle Inventory (LCI) research may be used directly as input to an eco-efficiency assessment. (MFA) is a method to establish an inventory for an LCA. MFA for integrated steel plant route was carried out in Umberto for Eco-efficiency, included in Fig.3. One of the steps of LCA is selection of impact assessment methods (Life Cycle Impact Assessment - LCIA) and impacts categories important for steel production: energy demand, carbon footprint, water footprint, fossil depletion etc. The product system value assessment is based on Life Cycle Costing (LCC). Based on environmental and economic analysis it is possible to identify the determinants of eco-efficiency assessment for steel production.

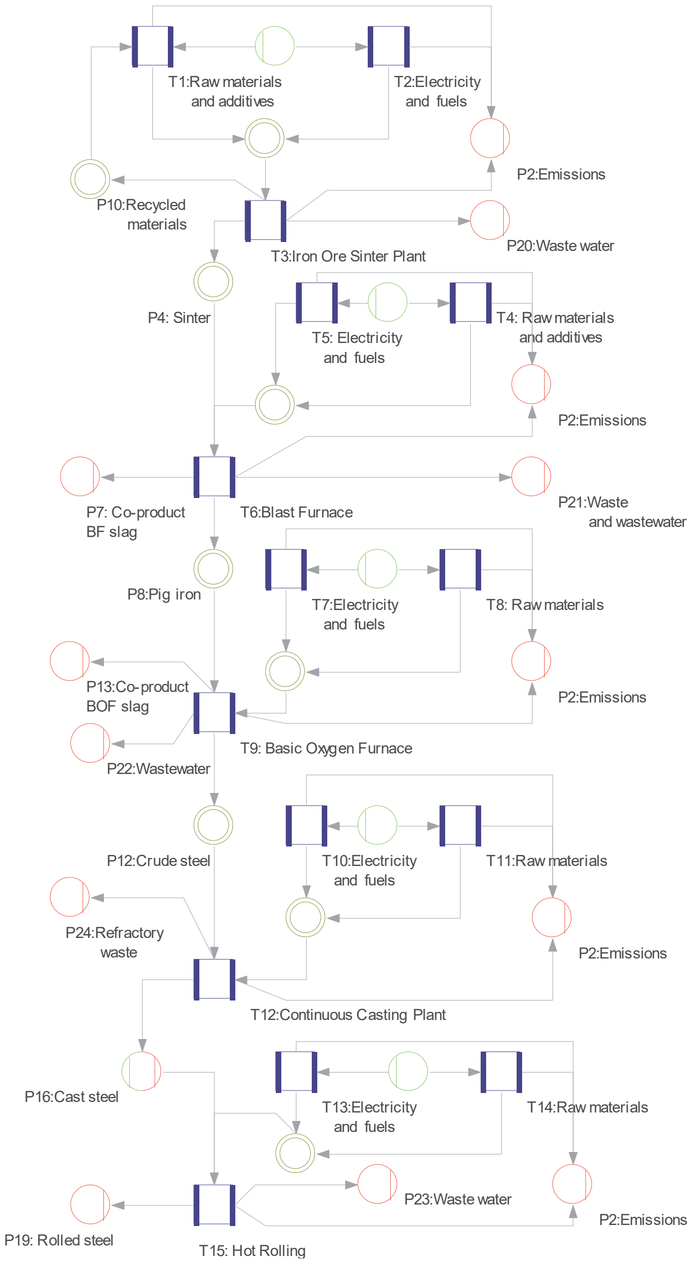

Fig. 3 MFA of integrated steel production route in Poland based on Umberto for Eco-efficiency 5.6

The scope of the third stage is **social assessment** of steel products based on Social Life Cycle Assessment (SLCA). The results are social indicators in life cycle of steel production.

The last stage concerns development of eco-efficiency evaluation with multicriteria analysis MCDA and **optimization** of steel production taking into account the sustainability aspects. MCDA allows taking into account the most important criteria of steel production: performance, life cycle of cost, quality of product, environmental aspects, social aspects etc. This stage consists of the following elements: the choice of MCDA methods, integrated assessment of environmental, social and economic aspects (aspects of sustainable development) for steel production. The results of the stage are sustainability indicators based on MCDA methods and ranking of steel production variants using the MCDA methods taking into account the decision-maker assumptions.

Presented MFA of the national steel production routes on **Fig. 3** describes the systematic assessment of the flows and stocks of materials, electricity and fuels within a steel production. The concept of MFA is based on the calculation of balances along a steel production technology, including each stage of steel production and all input and output data. This analysis provides information on the material and energy used and their amount, which can lead to cost accounting and economic value assessment. Results obtained through MFA form the basis for LCA and for eco-efficiency development of steel production.

CONCLUSION

Eco-efficiency analyses of steel production technologies presented in literature are not sufficiently documented. In particular, there is a lack of credible information about environmental impact in life cycle approach of these technologies. Also the information on the economic and social aspects of steel production is not sufficient. The results of previous studies indicate that further research is justified as it would allow the evaluation of all aspects of sustainability. Authors proposed a new methodology framework of optimization of steel production based on the integration of all elements of sustainability for eco-efficiency development. In this paper new concept related with eco-design based on MCDA methods was proposed.

The proposed methodology framework in this study for eco-efficiency development and sustainable aspects evaluation of steel production with MCDA methods can be applied at the design stage of technology to develop the most optimal steel production technology in terms of all aspects of sustainability.

The results obtained from this study can help decision makers in the steel production field understand the importance of integrated of sustainability aspects and direction of optimalisation of steel production.

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