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INNOVATIVE TECHNOLOGIES FOR GREENHOUSE GAS EMISSION REDUCTION IN STEEL PRODUCTION

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The main goal of the study was to present the most significant technological innovations aiming at reduction of greenhouse gas emission in steel production. Reduction of greenhouse gas and dust pollution is a very important aspect in the iron and steel industry. New solutions are constantly being searched for to reduce greenhouse gases (GHG). The article presents the most recent innovative technologies which may be applied in the steel industry in order to limit the emission of GHG. The significance of CCS (CO_2 Capture and Storage) and CCU (CO_2 Capture and Utilization) in the steel industry are also discussed.

Key words: steel production, greenhouse gas emission, innovation, carbon capture and storage; carbon capture and utilization

INTRODUCTION

Innovation is acknowledged as a concept central to economic growth and is perceived as a key driver of a company's success [1]. In the innovation and management literature it has been theoretically and empirically examined as a significant source of a company's sustained competitive advantage [2]. From the organizational perspective innovation is essential for creating new opportunities or exploiting the existing ones in order to survive in challenging, dynamic environments [3]. An innovation has been widely recognized and defined as creation and successful exploitation of new ideas which can take place within a single company, a given industry or within the wider environment [4]. Research on innovation at the organizational level has been focused both on a company's technical and administrative systems, thus, an innovation has been considered as a new product, service, production process or technology (technical / technological innovation) or a new program, policy, management practice, organizational structure or administrative solutions (organizational innovation) [5]. Moreover, both technological and organizational innovations may be perceived as radical novelties or incremental changes. The article presents a review of breakthrough technologies applied to reduce greenhouse gas (GHG) emission in steel industry.

SIGNIFICANCE OF INNOVATION IN THE STEEL INDUSTRY

The innovation and management literature emphasizes the critical importance of innovative technologies – embodied both in products and services – in stimulating an organization's growth and increasing its competitiveness [6]. Such completely novel and innovative solutions play a vital role in traditional industries such as the iron and steel industry. To maintain a leading position, innovative, efficient, eco-efficient and cost effective solutions must be implemented in the steel plants to enable them to stay ahead of competitors and to be prepared for economical changes and other influences in the years to come. Innovation is a precondition to achieve sustainability in operational excellence [7]. Introduction of green innovations is an especially important aspect of steel industry modernization. Green innovations are defined as novelties which benefit the environment thus contributing to the environmental sustainability [8]. They refer to a wide range of technologies such as: renewable energy technologies, pollution prevention systems or waste management schemes. According to Cai and Zhou [9] green innovations refer to a company's results and performance but also to its ability to achieve other strategic goals by production process improvements or clean technology initiatives. OECD classification of the green innovation is based on the environmental management characteristics. In such perspective those innovations encompass pollution management, natural resources management, clean technologies and eco-friendly products (in respect of their technical features and environmental impacts). Within increased environmental effects of mass production and improved technology effectiveness, more and more green innovations become beneficial in different contexts.

The study [10] presents examples of green innovations for reduction of negative effects of iron ore sintering process on the environment, while articles [11-13] describe implementation of new, innovative evaluation methods of water footprint, eco-efficiency for various technologies of steel production and model of the decision-making process in steel industry.

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INNOVATIVE STEEL PRODUCTION TECHNOLOGIES FOR GHG REDUCTION

There are several research and development initiative programmes aimed at reducing greenhouse gas emissions in iron and steel industry [14]. ULCOS (Ultra - Low Carbon dioxide Steelmaking) is the most developed European cooperative initiative for GHG reduction in steel production technology. ULCOS consists of all major European Union steel plants, engineering partners, universities and research institutes. The programme is planned to continue at least until 2025. According to the ULCOS programme four breakthrough technologies have been identified to reduce CO_2 emissions by at least 50 %, compared to best practice of 2004 [15]. These technologies are presented in Table 1.

Table 1 **Innovative technologies for green house reduction**

Group	Type
Top Gas Recycling Blast Furnace (BF) with CO_2 Capture and Storage (CCS)	separation of the BF off-gases and recycling of useful components to be used as reducing agent in the BF
	injection of O_2 instead of air into the BF
	CO_2 in off-gases is captured and storage
HIsarna with CCS	technology based on bath-smelting
	uses pre-heated coal instead of coke
	iron ore is melted and the iron oxides in the melted iron ore are reduced to metallic iron
	CO_2 in off-gases is captured and storage
Ulcowin and Ulcolysis	direct reduction of iron ore with reducing gas produced from natural gas
	CO_2 in off-gases is captured and storage
ULCOED with CCS	production of iron through electrolysis

Relative CO_2 emission for innovative technologies was shown in Figure 1.

According to the AISI (American Iron and Steel Institute) CO_2 Breakthrough Program, two innovative technologies have been identified to reduce CO_2 emissions [17]:

1. Molten Oxide Electrolysis (MOE) – Reduction of iron ore through electrolysis.
2. Hydrogen Flash Smelting – Reduction of iron ore in a suspension, with hydrogen as a reducing agent.

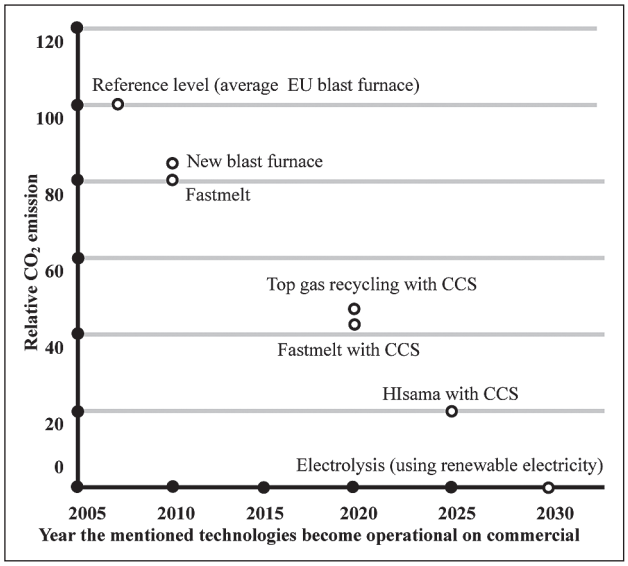

Figure 1 Innovative technologies and their relative emission of CO_2 [16]

The Japan Iron and Steel Federation is running a research programme called CO_2 Ultimate Reduction in Steelmaking Process by Innovative Technology for Cool Earth 50 (COURSE 50). The main goal of the programme is to develop innovative steel production technologies which can reduce CO_2 emissions by 30 %. CCS and reduction of iron ore with hydrogen are the two new technologies identified in this programme [18]. According to the POSCO CO_2 Breakthrough Framework programme in Korea, innovative technologies for reduced CO_2 emissions from steel plants are CCS using excess heat and ammonia, CO_2 fixation using marine bio-slag, hydrogen production from by-product gases from the steelmaking process, and heat recovery from sintered ore [19]. The research programmes mentioned above involve several factors and large investments. It is noticeable that a majority of the programmes mentioned rely on the development of the CCS technology. According to Pardo and Moya [20], apart from the most promising technologies which are currently under development, industrial innovative technologies are demonstrated on industrial scale but they are hardly established in Europe. Due to the large size of these projects and the associated high investment costs, the selection of these innovative technologies is based on their potential for energy saving and CO_2 emission reduction in Europe. This group includes Corex/Finex ironmaking, MIDREX, EnergIron/HYL, DSP (Direct Sheet Plant) and CCS. Although the European industry admits that Finex/Corex technologies could be used in the future in case of a need to increment the production in the integrated route, there is little credibility the use of these technologies will replace current European steel plants. According to IEA, advanced innovative technologies such as Finex, and HIsarna processes for the potentials of CCS in the iron and steel sector were suggested on the future roadmap.

CCS IMPORTANCE IN REDUCING GHG EMISSIONS

In the steel industry CCS will play an important role in reducing GHG emissions. CCS technology covers three unit processes: capture and compression from combustion, transportation and storage. Assessment of the capture technology in power generation sectors has been much researched. Economic and environmental evaluation of CCS using in innovative energy production system was shown in paper [21]. The use of CCS results in considerable (by 70 – 80 %) reduction of the environmental impact in the "climate change" category.

However, due to the high energy consumption of the processes necessary to prepare the captured gas for transmission, the CO_2 capture process contributes to reducing the overall efficiency of a power plant. In the iron making technology, the major part of carbon dioxide generation is related to the reduction of the iron ore [22]. The CO_2 separation technologies within power plants could be applicable to capture CO_2 from the steel industry. When exploring CO_2 capture options in industrial processes, it is important to take note of impurities such as SO_x, NO_x, particulate matter, partial pressure of CO_2 and volume of flue gas, temperature of inlet flue gas stream. The Captured CO_2 must be transported to a storage site, because suitable storage sites are rarely located near the CO_2 source. In such case there are several options such as shipping, pipeline, road and railway transportation [22].

CCU SIGNIFICANCE IN REDUCING GHG EMISSIONS

CO_2 capture and utilization (CCU) technology in iron and steel industry can consist of the unit processes: CO_2 capture, waste heat recovery from flue gas and molten steelmaking slag and CO_2 utilization [23]. CCU could be critical in the near-term to support longer-term objectives for deployment of CCS in steel industry from the year 2035 onwards. Emission reduction pathways through which CCU technologies can reduce emissions of CO_2 to the atmosphere include: CO_2 to fuels, enhanced commodity production, enhanced hydrocarbon production, CO_2 mineralisation and chemicals production [24]. The growing importance of CCU can be seen in the industry sector, including steel production. With CCU the CO_2 is converted to value added products. While CCS is a waste mitigation technology, CCU will produce a lot of profits.

CONCLUSIONS

The paper highlights the significance of incorporation of innovative steel production technologies to reduce the GHGs emissions. It is expected that the presented innovative steel production technologies will, at best, result in 25 – 35 % reduction in GHGs.

Further research and development programmes should be conducted in order to assess the innovative technologies of steel production. It should be considered from the perspective of environmental analysis and economic aspects with life cycle approach, which allows the eco-efficiency analysis. The eco-efficiency assessment method allows the evaluation of the existing and new alternative solutions and provides a response to the question which technology has the highest economic and environmental efficiency.

Future studies of the eco-efficiency assessment of alternative and innovative steel production technologies are recommended.

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