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Editorial

Challenges and Prospects of Steelmaking towards the Year 2050

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1. Introduction

The world is experiencing a period of imminent threat owing to climate change. The 2018 IPCC report defined the jointly approved target of limiting global warming to 1.5 °C by 2050, which means deep cutting of CO_2 emissions comprehensively. "Rapid and far-reaching transitions in land, energy, industry, buildings, transport, and cities are required". These challenges concern all human activities, including steel production.

Steel is a central material to modern society. It is necessary for infrastructure, buildings, transportation vehicles, and energy production. The annual consumption of steel has exceeded 1.8 billion tons and is further growing due to global development. Steel production is an energy-intensive branch of industry. Due to the central role of coal/coke in ironmaking, carbon dioxide emissions are large, corresponding to approximately 7% of the total anthropogenic CO_2 emissions. On the other hand, steel is a necessary material and enabler in solving the global dilemma of radically decreasing the use of fossil energy and increasing the share of renewable energy. Thus, the challenge is dual. On one hand, the industry must strongly cut its own CO_2 emissions by improving and developing the process route towards carbon neutrality. On the other hand, it has the role of a problem solver as a material supplier and by developing new steel grades with improved product properties which result in material and energy savings, longer life cycle and better recyclability.

This Special Issue was initiated to review the present situation of steel production, energy consumption, and CO_2 emissions. The potential methods to decrease CO_2 emissions in current processes via improved energy and materials efficiency, increasing recycling, and utilizing alternative energy sources including hydrogen were considered. Achievements in current processes and potentials of alternative energy sources as well as novel innovative processes were surveyed. In addition, the role of steel as an integral part of the global circular economy was discussed. En bloc the target of the Issue is to give a holistic overview of the current situation and challenges, and a comprehensive cross-section of the potential technologies and solutions for the global CO_2 emissions problem.

2. Contributions

The review article by Jean-Pierre Birat [1] is an extensive overview on the multifold influences of steel production. It does not confine itself only to CO_2 emissions but includes all noteworthy emissions, environmental effects as well as materials and energy issues. Different possible ways to cut CO_2 emissions from iron and steel production are reviewed with main emphasis on the experiences and results of European research projects (ULCOS). At the same time the article reflects on the efforts and prospects of the European steel industry, which accounts for 8.4% of the world production.

The next two papers highlight the situation in the two biggest steel-producing countries [2,3]. China is the overwhelming producer nearing one billion tons per year. After very rapid growth the facilities are mostly rather new, but production is based on blast furnaces with relatively low energy efficiency and high CO_2 emissions. Coal plays a major role also in the power sector and electricity generation. For structural reasons availability of recycled steel scrap is minimal, approximately 10% of the iron raw material. Substantial

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improvements in energy intensity and specific emissions have been achieved. Notwithstanding, the Chinese steel industry is facing big problems in trying to peak the emissions, cutting them down in accordance with the national policy and carbon neutrality targets [2]. Similar problems affect India which has risen to second place among steel-producing countries [3]. Its production structure is, however, totally different. A "conventional" BF-BOF production route accounts for 45% of the production, whereas a bigger share comes from electric furnaces, mini EAFs and a huge number of "micro mills" with induction furnaces. Their main raw material is direct reduced iron from rotary kilns. Altogether, the industry is strongly reliant on coal. India is an exception also in that regard; it has firm plans to strongly enhance steel production from the current level 111 Mt in 2019 to 250 Mt/year in 2030. This makes the target to peak the CO_2 emissions, suppressing them down to acceptable levels, extremely challenging.

Biofuels are regarded as low CO_2 emitting energy sources due to the carbon cycle. Historically, charcoal was used in ironmaking until the late 19th century when coke fully replaced it. Nowadays, the endeavors to get away from fossil energy have raised interest in charcoal again as a reductant and fuel in ironmaking. Brazil, with many eucalyptus plantations is producing and using large amounts of charcoal in metallurgical industries. Mini blast furnaces can operate with charcoal alone, and in big furnaces injection of powdered charcoal can substitute for injected fossil coal [4]. The paper by Adilson de Castro et al. describes recent research on mini blast furnace operation with possible applications of charcoal. Substitution of metallurgical coke and coal injection with bioenergy in conventional blast furnaces has been discussed in several papers in the issue.

Suspension smelting is an established technology for processing of non-ferrous sulfidic concentrates. The same principle has been applied in flash iron making by H-Y. Sohn at the University of Utah [5]. This technology might surpass fine ore agglomeration and coke making by using fine concentrates and natural gas as the main inputs resulting in remarkable energy saving. It has been tested on a pilot-scale and even with pure hydrogen but has not yet been commercialized.

Full decarbonization of steel making is possible only by discarding carbon containing fossil energy in iron and steel processes. An axiomatic solution is hydrogen. The principle of hydrogen reduction is well-known and even industrially proven in shaft furnace processes by using hydrogen instead of natural gas. The core problem is that hydrogen is not available as a natural resource like coal but has to be produced. Natural gas is a possible raw material, but it is a fossil fuel and not carbon free. Water is thus the obvious resource and water splitting by electrolysis the method to produce hydrogen gas on a mass scale. Patisson et al. give an overview on bases of hydrogen reduction [6] and Pei et al. [7] describe an ambitious project "Toward a Fossil Free Future with HYBRIT-Development of Iron and Steelmaking Technology in Sweden and Finland". Accordingly, iron and steelmaking will make a stepwise transition from the BF–BOF route to direct hydrogen reduction–electric melting route until the 2040s. The plan even includes massive hydrogen production and fossil-free electricity for water electrolysis, steel melting and other processes.

As the transition from coal to hydrogen in the global steel industry entails huge investment and cost with limited time, all rapid actions to mitigate CO_2 emissions are precious. Capture, utilization and storage of CO_2 are important issues. Mineralization of CO_2 by reacting it with steelmaking slag to form precipitated calcium carbonate product is an example of "from waste to valuable by-product" [8]. Further examples of reuse, recycling and productization of wastes via industrial symbiosis are described by Branca et al. [9]. In another article, recent European research activities in iron and steel making from the viewpoint of digitalization are reviewed with a strong focus on sustainability and low-carbon technologies [10].

The final chapter is a kind of summarizing review of the whole issue area [11]. First, the current state of the global steel industry and potentials for energy saving and emissions mitigation by retrofitting existing plants with the best available technologies and by utilizing energy sources with the smallest emissions are discussed. New and emerging means, such as CO_2 capture and storage, increasing recycling ratios and anticipated breakthroughs in hydrogen technology are reviewed as well. The review ends with a hybrid scenario to the year 2050 in which CO_2 emissions would be cut by 70% from the current level although steel production is predicted to grow by up to 2.5 billion tons/year. It is a challenging goal, but only an intermediate point toward carbon-neutral steel.

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