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Special Issue on 'Circular Economy initiatives and solutions in the steel sector', edited by Valentina Colla and Ismael Matino

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EDITORIAL

Circular Economy initiatives and solutions in the steel sector

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The concept of Circular Economy (CE) is at the backbone of the steel industry, as part of its production is obtained by re-melting and transforming steel from end-of-life goods. CE also entails design of steel products with durability and longevity in mind, waste minimization at every stage of the value chain, and improved recycling and waste management practices. Nowadays circularity encompasses not only secondary raw materials and residues, but also other streams, such as energy carriers and water, and can be implemented in cooperation with other industrial sectors also through Industrial Symbiosis (IS) solutions. The advantages of CE in terms of resource conservation and energy efficiency are widely recognized and lead to considerable economic and environmental benefits. While CE adoption is gaining momentum, the steel sector is committed to face existing challenges related, for instance, to the need for updated infrastructures, lack of homogeneity in regulations concerning residues across Europe, upscaling and full deployment of novel technologies. However, this shift toward circularity represents a promising avenue for creating a more sustainable and responsible steel industry that aligns with global efforts to combat climate change and reduce the environmental footprint of industrial processes. The European Steel Technology Platform (ESTEP) is highly involved in supporting CE actions in the steelmaking sector and promoting IS, and believes in the potential of knowledge dissemination and discussions between experts. For this reason, ESTEP organized its annual event in autumn 2023 focusing it on CE. This 3 days long event, entitled "*A Circular Economy driven by European Steel*" was hosted by CELSA Group in Barcelona (Spain). The first day was dedicated to a visit to CELSA's facilities, while in the other two days a total of 33 presentations, opening and keynote lectures were provided by expert researchers from steelmaking, equipment and technology providers, feedstocks suppliers, research centers and academia. A total of 7 sessions were held, where the audience had the opportunity to discuss with speakers for a fruitful brainstorming. In addition, the European Commission participated to the event and provided an opening lecture through the appreciated presence of the REA B1 Head of Unit. The present special issue collects a selection of the themes discussed during the above-mentioned Conference, which were provided on a voluntary basis by the authors and passed a further peer-reviewing stage.

A comprehensive overview of ways and means for residue valorization, by-products recycling and resource efficient exploitation in the iron and steelmaking industry is provided in the review article entitled "*Roadmap for Recycling Practices and Resource Utilization in the Iron and Steelmaking Industry: A Case Studies*". By summarizing the most interesting topics presented and discussed in the mentioned event, the paper discusses several research results on metals and metal oxides, slags, dusts, process gases, and water recycling in iron and steel sector, and on the exploitations of alternative carbon bearing materials. The overall aim of this analysis is to highlight achieved targets as well as existing gaps for an extensive application of CE and IS solutions, whose importance is highly underlined in the paper. Furthermore, the paper points out the significance of digitalization and workforce upskilling for application of recycling practices and maximization of resource efficiency.

The use of alternative non-fossil carbon sources in the Electric Arc Furnace (EAF) to reduce the environmental impact and the dependency from fossil energy and C-sources is further discussed in the paper entitled "*An advanced simulation tool to support adoption of alternative non-fossil Carbon sources in electric steelworks*", where the potential of digital tools in investigations related to novel applications in the steelmaking fields is presented. An advanced model of the electric steelmaking route is presented, which derives from the adaptation of a previous model of the standard EAF-based route tailored to the investigation of the effects of the use of alternative non-fossil carbon bearing materials in EAF. Adapted model tests show the suitability of the model for the scope and preliminary simulations results are depicted, which show

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that a decrease between 3% and 20% of fossil CO_2 emissions from the EAF can be achieved through the substitution of fossil carbon with such alternative materials. In addition, the results of a survey were presented related to the perception of the use of these kinds of tools within the European steel sector. Its outcomes were used to make the model more appealing to the stakeholders to facilitate the application of novel environmental friendly solutions in electric steelworks.

Finally, the production of high-performance steel through the scrap-based steelmaking route is discussed in this special issue, which indeed represents one of the investigated path to reduce emissions related to the production of these materials and to promote CE. To this aim, issues concerning residual or tramp elements must be solved. This topic is addressed in the paper entitled "*Circular boron steel: a case study on high performance materials for a zero emission automobile industry*" where the authors focus on the production of Boron steel sheets that has become fundamental for automotive industry. A preliminary study is presented on the concept of circular boron steel produced through the EAF-scrap route; effects of the most critical residuals on metallurgical aspects were determined and the production of a 4mm thick sheet was obtained. The sheet presented similar performances compared to the commercial sheets produced via the standard integrated route, by demonstrating the feasibility of producing scrap-intensive high performance boron steel trough the EAF-based steelmaking route.

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