Editorial

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Sustainable development in the 21st century is perhaps one of our most pressing challenges. With increasing population, and concomitant increase in consumption, from a societal perspective, we are using much of our critical materials without focusing on the development of viable means for the recovery of material resources and their reuse. The *Journal of Sustainable Metallurgy* aspires to contribute in advancing the science but also to be a catalyst for tangible change toward more sustainable practices in the metallurgical industrial sector.

This journal is dedicated to presenting and archiving metallurgical processes and related research aimed at improving the sustainability of metal-producing industries, with a particular emphasis on materials recovery, reuse, and recycling. Its editorial scope encompasses new techniques, as well as optimization of existing processes, including utilization, treatment, and management of metallurgical residues. Articles on non-technical barriers and drivers that affect sustainability will also be featured as these are pivotal to the execution of sustainable practices. The three Editors in Chief and the Managing Editor are strategically located in three continents—North America, Europe, and Asia/Pacific Rim. Also on the editorial team are fourteen Associate Editors who bring complementary expertise from various parts of the world. The initiative of launching the journal is supported by The Minerals, Metals

& Materials Society, a vibrant global materials community, and Springer, a respected scientific publisher.

The first issue is a testament that the *Journal of Sustainable Metallurgy* is addressing existing needs, with eight high-quality papers, showing not only scientific robustness but also novelty and creativity. These papers were all invited, and set the stage for subsequent issues.

In the first paper, Reuter and van Schaik illustrate how a product-centric simulation approach to recycling is core to Design for Recycling (DfR) & Design for Resource Efficiency (DfRE), and contributes to material sustainability. Recycling rate calculations, know-how and tools of classical minerals and metallurgical processes support this approach. Process simulation and design tools were applied to quantify critical DfR rules for a particular product as well as to quantify the recycling rates of all materials and elements in a product. The 10 DfR rules, developed for a case on Waste Electric and Electronic Waste (WEEE) recycling, were now applied to LED lamps. The produced results include recycling and recovery rates, recyclate qualities and quantities, as well as losses and emissions of materials during recycling for various LED lamp redesigns. Metallurgical processing was also briefly discussed, showing that, in many cases, element recoveries were reduced to zero due to product complexity and ppm levels in the products. Simulation models were linked to life cycle assessment (LCA) and exergy, demonstrating how the applied simulation basis provides the detail to innovate the system. In addition, rigorous environmental assessment was a further outcome of the approach, while at the same time revealing the development that has to occur in LCA databases to improve their value for Ecodesign.

In the work of Binnemans and Jones, the focus is placed on rare-earth elements (REEs). The authors address the so-called Balance Problem between market demands and the

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natural abundance of REEs in ores. The Balance Problem implicates that the rare-earth industry has to either find new applications for REEs that are available in excess, or needs to search for substitutions for REEs that have limited availability and are in high demand. Different solutions are proposed to solve the Balance Problem: diversification of REE resources, recycling and urban/landfill mining, substitution, reduced use, and new high-volume applications. It appears that no single solution can mitigate the Balance Problem, but a combination of different strategies may be required.

From a different perspective and focusing on steel, Lee and Sohn used the global scrap commodity trading data and ascertained steel scrap network relationships between countries, during the period 1990–2013. By connecting the various steel scrap trading countries and forming relationship subgroups, the scrap centrality of trading countries was identified from the Katz status index. Visualization of the scrap network allowed an intuitive understanding of the global scrap exchange and the main trading countries. Countries such as the United States and Germany ship significant amounts of scrap and also have comparatively high centrality. Countries like the Russian Federation and the United Kingdom also ship significant amounts of scrap, but the number of countries shipped to is limited compared to the United States and Germany; the latter suggests possible future expansion of their trade network. This expansion allows greater flexibility in scrap supply and also increases availability in the global scrap market, thus increasing scrap utilization and also the sustainability of the steel industry. Other countries, such as Turkey and Korea, have a high centrality for importing steel scrap in the network. The steel scrap utilization correlated well with the steel production according to Pearson's model. Steel forecasting based on the time-series analysis shows global steel demand in 2018 to be approximately 750 MT with 1.75 BT expected for overall steel production, which suggests scrap supply should match the demand.

Addressing the barriers that limit recycling, Chang et al., focus on identification and grouping of secondary (or scrap) material. In their work, they suggest the use of data mining as a strategy to manage raw materials with uncertain quality, while using existing data from the recycling industry. A clustering analysis was used to recognize the pattern of raw materials across a broad compositional range in order to provide criteria for grouping (binning) raw materials. This strategy was applied to an industrial case of aluminum recycling to explore the benefits and limitations in terms of secondary material usage. Recycling industrial by-products (e.g., dross in aluminum production) is the case they focused on and investigated. They show that binning strategy obtained by the clustering analysis can significantly reduce material costs by increasing the

compositional homogeneity and distinctiveness of uncertain raw materials. As a result, there is a potential opportunity to increase low-quality secondary raw material usage before investment in expensive sorting technology.

In the work of Farzana and Sahajwalla, silicon carbide (SiC)-bearing materials were synthesized by utilizing waste automotive glass and plastic. The reduction of silica in glass by a blend of graphite and plastic (bakelite) to produce SiC was studied experimentally under inert atmosphere at 1,550 °C. The results, from a range of complementary techniques, confirmed the formation of SiC. The reaction kinetics constant for the initial stage of overall silica reduction was found to be $k = 12.8 \times 10^{-4} \text{ s}^{-1}$ and the mechanism is predominantly controlled by chemical reactions. The authors concluded that this process has two significant advantages: it is a major step toward transforming non-metallic automotive waste into valuable resources, like SiC-containing refractory materials, and it reduces the industry's reliance on conventional raw materials including quartz and coke, which are typically used as silicon- and carbon-bearing resources.

The work on plastics continues with the study of Sahajwalla et al. The focus herein is on polymer-rich waste printed circuit boards and the associated metal recovery. Experiments were conducted in argon atmosphere in the temperature range of 750–1,350 °C. Copper-rich metallic fractions started to separate out as foils/droplets at temperatures above 950 °C, leading up to 25 % of total weight recovery of carbons. In-depth characterization of the residue revealed that these carbons generally had a disordered structure with 3–4 layers stacking along the c-axis. The presence of metals in the carbonaceous residue became negligibly small at 1,350 °C, significantly enhancing the quality of the carbonaceous product (carbon content: 52–74 wt%). This work demonstrates that both carbons and metals can be recovered from e-waste.

Carbon recovery is in fact already taking place industrially. In the work of Nomura, the process developed by Nippon Steel & Sumitomo Metal Corporation, already in operation since 2000, is presented. In this process, the waste plastics collected from households are agglomerated to a size of 20–30 mm in diameter and charged into coke ovens with coal at the blending ratio of about 1 %. Waste plastics are thermally decomposed into approximately 20 % coke, 40 % hydrocarbon oil (tar and light oil), and 40 % coke-oven gas, which are utilized as iron ore reducing agent in blast furnaces, raw materials for the chemical industry, and a fuel for power plants, respectively. Moreover, 92 % of the chlorine in waste plastics is released and absorbed by the ammonia liquor spray for cooling hot coke-oven gas and converted to ammonium chloride. Approximately 200 thousand tons per year of waste plastics are processed in coke oven in Japan.

In the last paper of the first issue, a summary of more than a decade of work is presented by Sharif et al., focused on the development of know-how and processes that could result in substantial reduction in net CO₂ emission by the steel industry. The processes that are featured cover renewable carbon and energy sources as well as minimizing waste heat. In the area of renewable carbon, the authors cover the use of charcoal from sustainable sources such as plantations of biomass species or forest wastes. To achieve that, a new pyrolysis process, which operates continuously and autogenously has been developed and piloted. In addition, LCA is presented and discusses the potential

reduction in net CO₂ emissions. The work of Sharif et al. presents a novel dry slag granulation process, with integrated heat recovery, and process design and optimization.

The *Journal of Sustainable Metallurgy* will be published on a quarterly basis. Our promise is to publish high-quality articles with scientific robustness. The journal will earn its place as a respected archival reference and a forum for a community of learners dedicated to sustainable development. We welcome new submissions of articles by colleagues working in all fields related to metals and by-products and residues of metallurgical processes.