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Metals Fuel the Circular Economy: Process Metallurgy a Key Enabler

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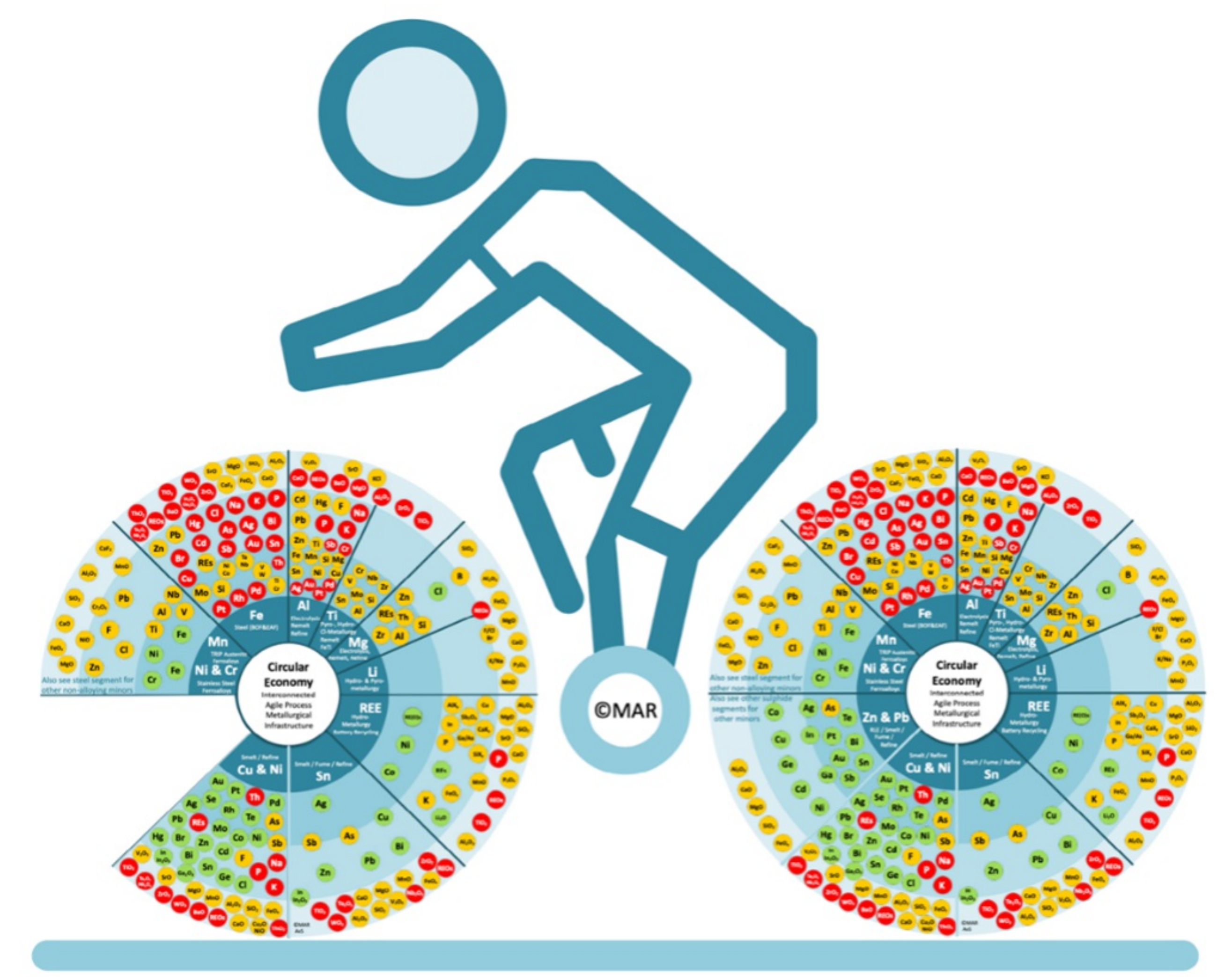
Metals lie at the heart of the circular economy as the Metal Wheel explains[1]. Process metallurgy is therefore a key enabler of a circular economy (CE); its digitalization is the metallurgical Internet of Things (m-IoT)[2]. Metallurgy and its reactors are therefore at the heart of an economically functioning CE, particularly also as metals have strong intrinsic recycling potentials and have key enabling functional roles, as these are the fabric of the renewable energy and sustainable societal infrastructures.

The wheels of a sustainable society are based on a multitude of elements as the figure above shows[3], all segments from the processing system, i.e., the carrier metallurgy of steel, aluminum, copper, zinc, lead, tin, etc., are required for a smoothing cycling through the circular economy, not only globally but especially also locally or within a larger economic region. Embracing policy that ensures no segment breaks form the wheel is of utmost importance. The metallurgical process reactors recover the green elements in the segments of each metal processing infrastructure and require a processing segment, called the carrier metal processing infrastructure. The yellow elements are recovered into alloys or intermediate materials/compounds if the economics make sense, and red if the elements are lost in intermediate materials, alloys, or residues (including dissipative losses) and inevitable losses from the system.

This paper will discuss within the context of circular economy, as shown in the figure below, the simulation of metallurgical process reactors that produce and recycle different metals. To maximize the recovery of the elements into appropriate phases in the metallurgical reactors, a deep understanding of the energy and mass transfer between very complex multielement/compound molten (can reach above 2,000°C) and gas phases is required. CFD simulation and dynamic reactor models will show the state of the art based on copper bath smelting (concentrate, scrap, eWaste, batteries, slags, etc.) reactors[4]. Various fundamental parameters effecting mass and energy transfer in the reactors is among others discussed. This is embedded in system simulation models for the CE that quantifies the environmental footprint and exergy dissipation of large CE systems[5]. Of special importance is understanding the downward spiral of the system and, therefore, understanding how to mitigate the exergy dissipation. Large-scale system simulation models provide this detail understanding and will be discussed also in relationship of minerals be these geologically created minerals or the “minerals” called consumer products, energy infrastructure, etc.

References:

1. MA Reuter et al. (2019): Challenges of the Circular Economy - A material, metallurgical and product design perspective. Annual Review of Materials Research, 49, 253-274.
2. MA Reuter (2016): Digitalizing the Circular Economy - Circular Economy Engineering defined by the metallurgical Internet of Things-, 2016 TMS EPD Distinguished Lecture, USA, Metallurgical Transactions B, 47(6), 3194-3220.
3. https://kuleuven.sim2.be/wp-content/uploads/2019/02/SOCRATES-Policy-Brief-2019-Lead.pdf & https://new-mine.eu/wp-content/uploads/2021/02/SOCRATES-Policy-Brief-2020-final.pdf
4. SMS Blue Technologies: https://www.sms-group.com/br/press-media/media/downloads/#item:987
5. NJ Bartie, YL Cobos-Becerra, M Fröhling, R Schlatmann, MA Reuter (2021): The resources, exergetic and environmental footprint of the silicon photovoltaic circular economy: Assessment and opportunities, Environmental Impacts, Resources, Conservation and Recycling, 49 169, 105516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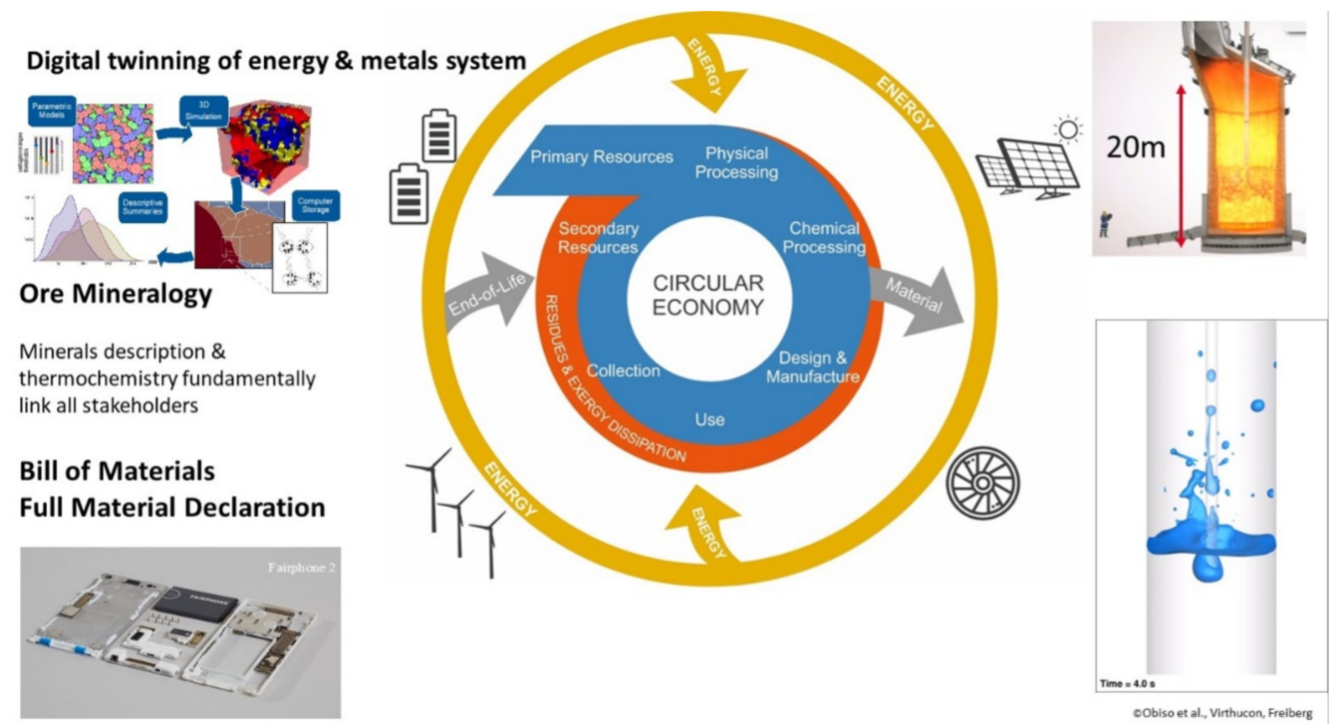
Circular Economy
Interconnected Agile Process Metallurgical Infrastructure
Fe
Al
Ti
Mg
Li
REE
Sn
Cu & Ni
Ni & Cr
Mn
Zn & Pb


Digital twinning of energy & metals system
Parametric Models
3D Simulation
Descriptive Summaries
Computer Storage
Ore Mineralogy
Minerals description & thermochemistry fundamentally link all stakeholders
Bill of Materials
Full Material Declaration
Fairphone 2
ENERGY
ENERGY
ENERGY
ENERGY
Primary Resources
Physical Processing
Chemical Processing
Secondary Resources
CIRCULAR ECONOMY
Collection
Design & Manufacture
Use
RESIDUES & EXERGY DISSIPATION
End-of-Life
Material
20m
Time = 4.0 s
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