METAL INTERACTIONS AND SYMBIOSES: OPTIMIZATION OF QUALITY, QUANTITY AND SUSTAINABILITY

Neill Bartie[1], Alejandro Abadias-Llamas[1], Magdalena Heibeck[1], Markus Reuter[1]

[1]*Helmholtz Institute Freiberg for Resource Technology, Chemnitzer Straße 40, 09599 Freiberg, Germany*

Metals make modern societies function, and increasingly so in terms of various *high-purity* special and precious *by-product* metals that afford advanced technologies specific functionalities. Despite being used in very small quantities in hi-tech applications such as smart phones or semiconductors in photovoltaic systems, a number of these metals are considered critical based on future supply risk, and increasing resource intensity and cost of extraction. Therefore, maximizing not only the quantities, but also the qualities of metals and associated compounds recovered for re-use in further life cycles are required to reduce losses and the need for final sinks.

To analyze the quantities of stocks and flows in product life cycles, and the degree to which material loops are closed, the laws of conservation are most often applied to energy streams and substances in isolation. But how are *quality loops* quantified and closed? Unlike quantity, quality is not conserved infinitely, but is degraded in all transformation processes. Product manufacturing and recycling processes cause once-pure metals and compounds to become heavily intertwined, contaminating one another irreversibly to form complex urban minerals in which no elements are present in pure form. The quality of these recyclate streams can be upgraded at end-of-life, but only partially due to inevitable losses, and at the expense of other material and energetic resources. The assessment of quality thus requires something more than just the laws of conservation. The second law of thermodynamics, by way of exergy analysis, provides an elegant means for assessing and tracking resource quality and its degradation along life cycles.

Adopting a thermodynamic process simulation approach, we simultaneously assess the quantities and qualities of all primary and secondary process streams, residues, losses and emissions for an integrated Copper-Lead-Zinc production and recycling system. In addition to the carrier base metals, the system produces a range of by-products, amongst which are Cadmium and Tellurium that are used for the manufacture of Cadmium-Telluride photovoltaic systems. The system is shown schematically in Figure 1 below.

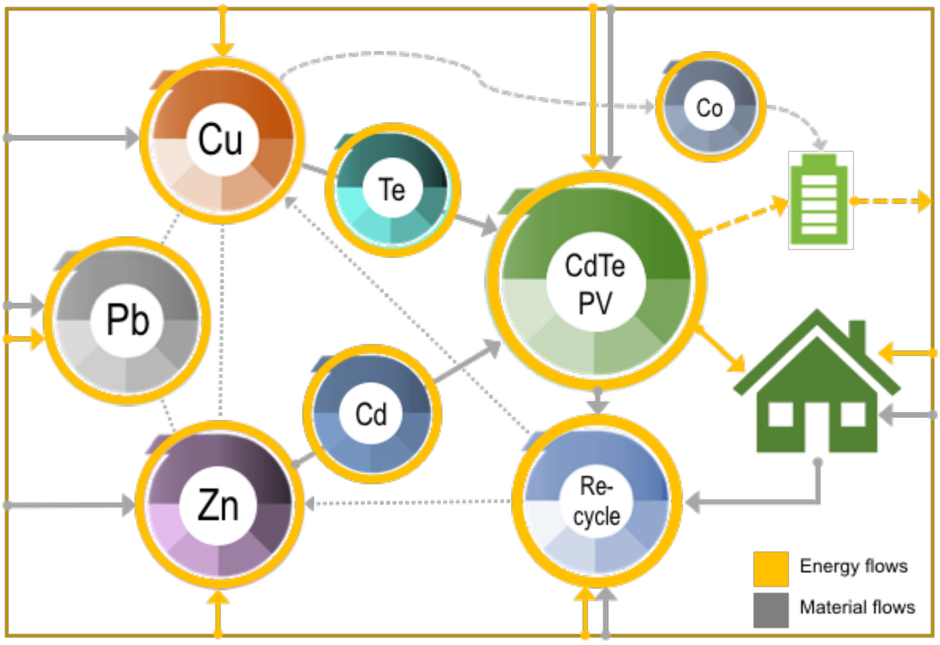

Figure 1: Integrated metal production and recycling symbiosis

The metal processing symbiosis facilitates evaluation of the potential system-wide benefits of various recycling and residue exchange scenarios, so as to exhaust as many as possible of the avenues available for countering resource quality degradation and for reducing wastes that require final sinks. Preliminary results from one such scenario is shown in Figure 2 below.

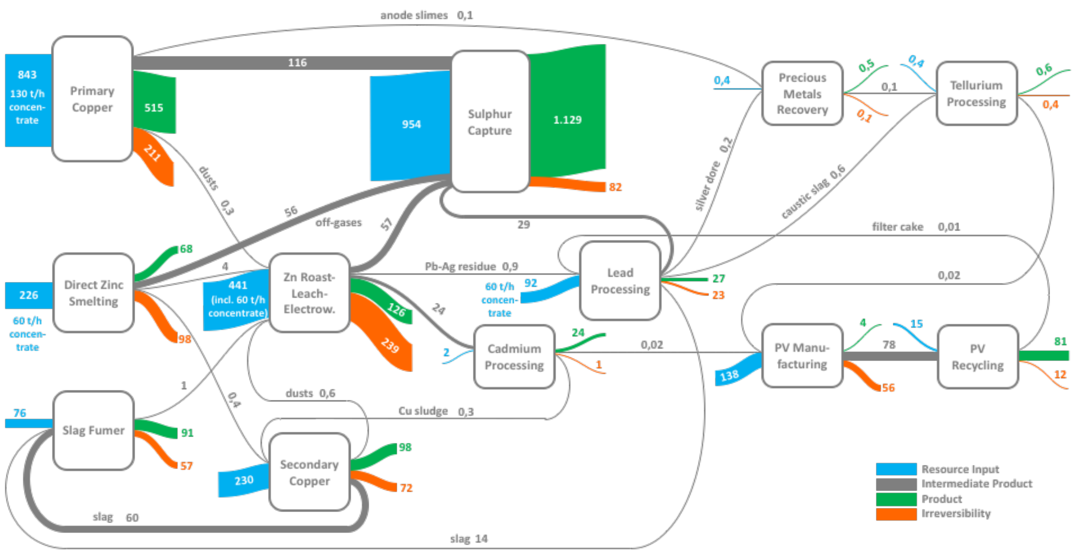

Figure 2: Resource quantities, qualities and losses via systemic exergy analysis

At the same time, detailed life cycle assessment is conducted to determine potential environmental impacts. The simultaneous assessment of primary and secondary resource consumption, efficiency and quality, and associated environmental impacts provide the platform upon which multiple objectives are optimized to achieve maximum system-wide sustainability. The latest results and scenario comparisons from the application of our approach will be presented.