Circular valorization of steelmaking by-products: the Italian case study in the HEPHAESTUS project

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The **HEPHAESTUS project** represents a key initiative for the circular economy within the steel industry, focusing on the valorization of Electric Arc Furnace (EAF) solid residues. The Italian case study integrates **innovative technologies** to recover metallic fractions and high-purity zinc while achieving environmental and energy efficiency goals. The core of the Italian pilot is the **CleanTech electric furnace**, which utilizes **carbothermic reduction** to transform austenitic and ferritic EAF dust, generated from inox and carbon steel production, into valuable products. This process reduces waste generation and optimizes resource use, ensuring the treated materials can be reintegrated as products.

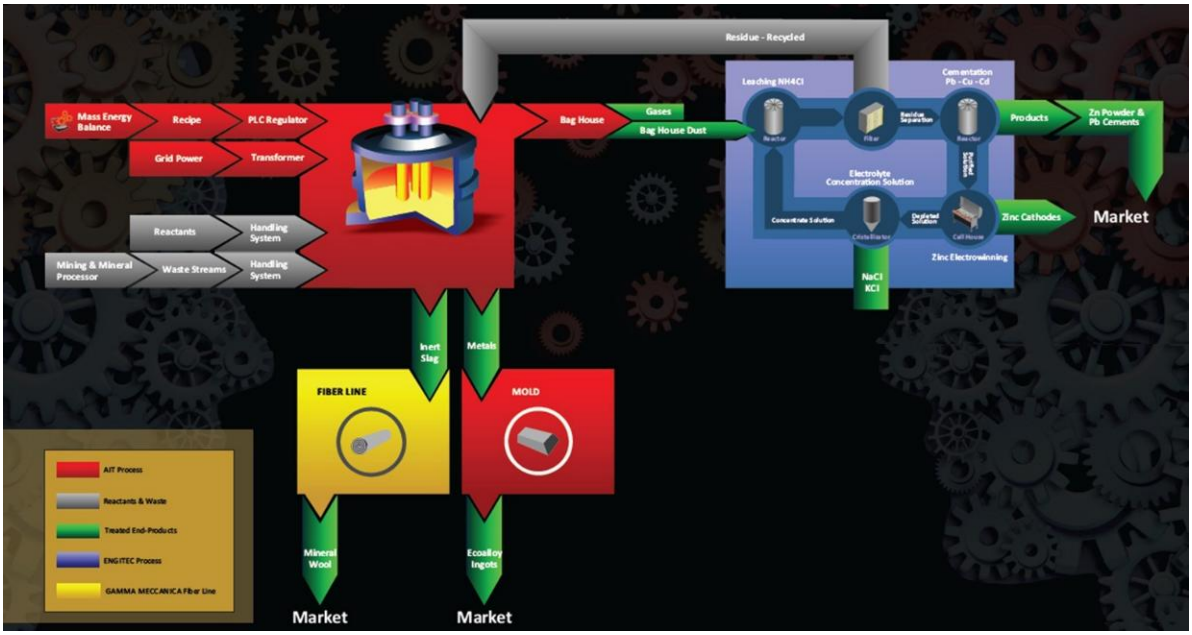

Figure 1: CleanTech process flow

A preliminary **mass and energy balance**[1] of the furnace highlights its efficiency and energy-saving potential.

[1] HEPHAESTUS. Grant Agreement n. 101058696. Deliverable 1.2 “Process to achieve circularity from steel dust wastes”.

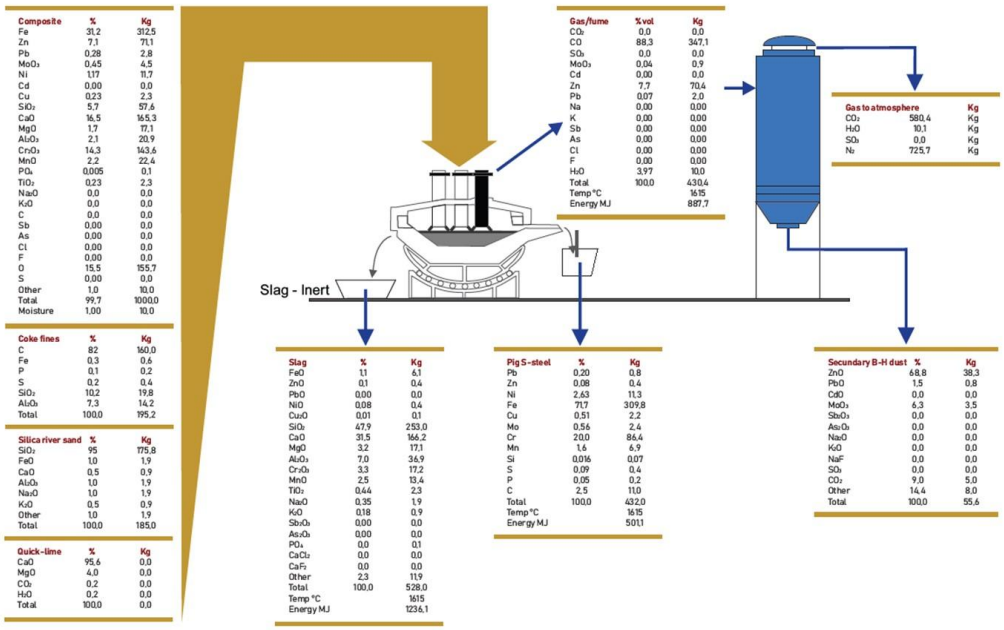

Figure 2: Preliminary mass balance of CleanTech arc furnace

Furnace balances:	
Total materials in:	1390,2 Kg
Total materials out:	1390,4 Kg
Energy in products:	2624,9 MJ
Heats of reaction:	2353,8 MJ
Total energy in:	4978,8 MJ
@ furnace efficiency:	6383,0 MJ
Electrical power in:	1773,1 kWh/t Dust composite

Slag properties:	
Melting point:	1135 °C
Viscosity:	6,2 cp
Basicity ratio:	0,72
Electrical resistivity:	10,3 ohm.cm

Table 1: Energy demand and main characteristics of the slag produced

Complementing this, the **EZINEX process** provides a sustainable pathway for the **recovery of zinc** from secondary dusts generated during furnace operation. The process, based on a hydrometallurgical route using **ammonium chloride electrolyte**, achieves high-purity zinc recovery without extensive pre-treatment, contributing to the circularity of critical materials.

The downstream valorization of molten slag is achieved through **fiberization**, converting it into **mineral wool**, a widely used thermal insulation material. By controlling the chemical composition and viscosity of the slag, the process ensures efficient solidification and fiber formation, producing high-quality material while achieving the **zero-waste objective**. From a sustainability perspective, the integration of these technologies demonstrates significant benefits. Preliminary results from the **mass and energy balances** indicate:

- Up to **3 tons of CO_2 emissions avoided per ton of EAF dust treated**[2] compared to conventional processes;
- Substantial energy savings through optimized furnace operation and waste heat recovery systems.

Furthermore, the Italian case highlights the scalability and replicability of the HEPHAESTUS process, which is designed for small-scale applications (from 8,000t to 20,000t EAF dust per year)[2]. This modular approach enables integration into existing steel production plants with low capital expenditure and operational costs, ensuring rapid return on investment (ROI). The HEPHAESTUS project aligns with the European Union's **Green Deal goals**, offering an innovative model for resource efficiency, emissions reduction, and waste valorization. By transforming by-products into valuable secondary materials and reducing reliance on primary raw resources, the project represents a major step toward achieving a **sustainable and circular steel industry**. The results of the Italian case study will serve as a benchmark for broader European adoption, demonstrating how industrial symbiosis and technological innovation can drive the decarbonization of the steelmaking sector.

[2] GRANT AGREEMENT. Project 101058696 - HEPHAESTUS