Prospective LCA on the Design of New Refractories for a Greener Steelmaking Process

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Objectives:

Investigate, model and quantify the environmental burdens generated by the production and the usage of refractory materials in the steelmaking through a life cycle perspective.

- Find the most sustainable option for both producers and users

In relation to three pillars of circular economy:

- **design the loop**: modelling and optimising relevant production routes of several refractories in an eco-design perspective;
- **slow down the loop**: optimised environmental footprint of the refractories once applied in the steel industry;
- **close the loop**: integration of recycled materials in the production route.

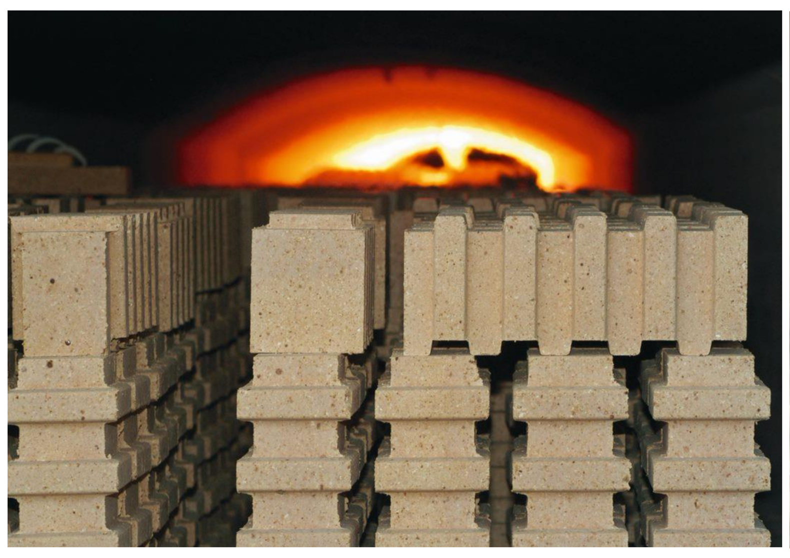

Figure 1. Refractory

Figure 2. Electric Arc Furnace (EAF)

Context:

The iron and steel sector is responsible for around 8% of global final energy use and 7% of global direct energy-related CO2 emissions [1]. Within the European **CESAREF** DN, the project confronts the challenge of green steel by designing energy-efficient refractories and new materials appropriate for the major technological and operational changes related to the conversion from carbon-based fuels to clean burning hydrogen-based mixes.

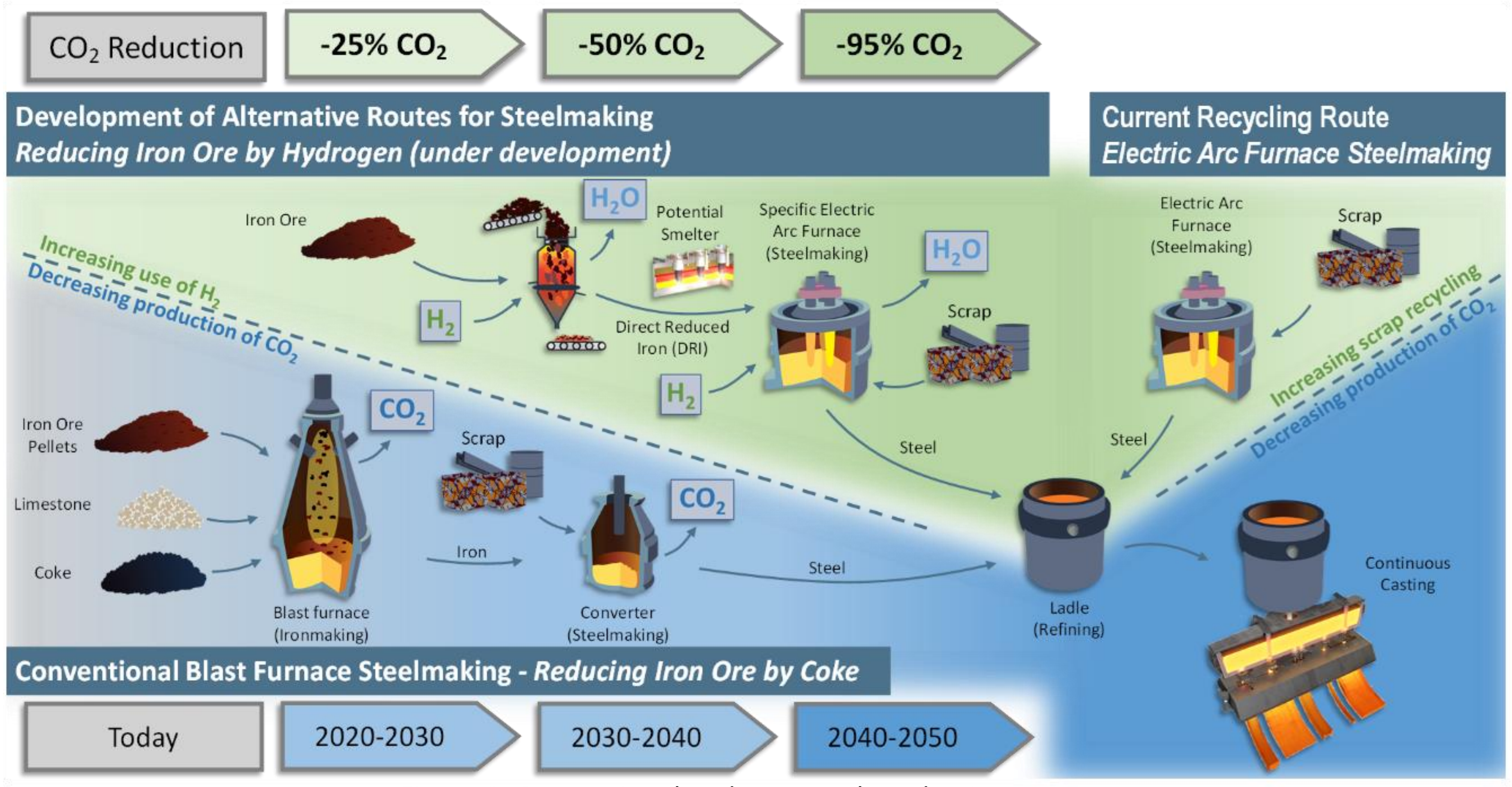

Figure 3. Conventional and new steel production routes

Materials and method:

Materials

Refractories are advanced ceramic materials that withstand high temperatures and are resistant to severe service conditions in terms of pressure or chemical attack. About 70% of all refractory products are used in the steel industry, where they constitute the internal linings of furnaces, kilns, reactors and other vessels [2].

Reminding the **green steel** goal, the **emerging technology** of hydrogen-based Direct Reduction of Iron (H_2DRI) coupled with the Electric Arc Furnace (EAF) has been identified as one of the most mature technological routes capable of reducing CO_2 emissions [3]. In the EAF, steel scraps ad DRI are melted to produce steel using electric power.

Comparative LCAs are proposed for two couples of refractories used as the lining of the most critical areas in terms of corrosion of these technologies:

Application	Lining area	Refractory	Production route
Hydrogen-based DRI	Tuyere	Mullite-alumina	Sintered brick
		Alumina-silica	Fused cast brick
EAF with DRI and scrap feed	Slag line	Magnesia-carbon	Cured brick
		Under discussion	

Figure 4. Mullite-alumina bricks

Method

The **Life Cycle Assessment** (LCA) methodology is a scientific multi-step procedure which has become a standard environmental evaluation tool [4 ,5]. It allows a systematic analysis of the potential environmental impacts of a product or a service during its entire life cycle.

Goal and scope
Software LCA FE (previously GaBi)
Primary data, Ecoinvent 3.8 database
EF 3.0 impact assessment method

The overall life cycle of the refractory is studied in three steps:

- **Expansion** of the system boundaries with the gradual inclusion of all the stages of the life cycle of the refractory.

LCA 1	Refractory	Cradle-to-gate
LCA 2	Steelmaking	Cradle-to-grave
LCA 3	Recycle	Cradle-to-cradle

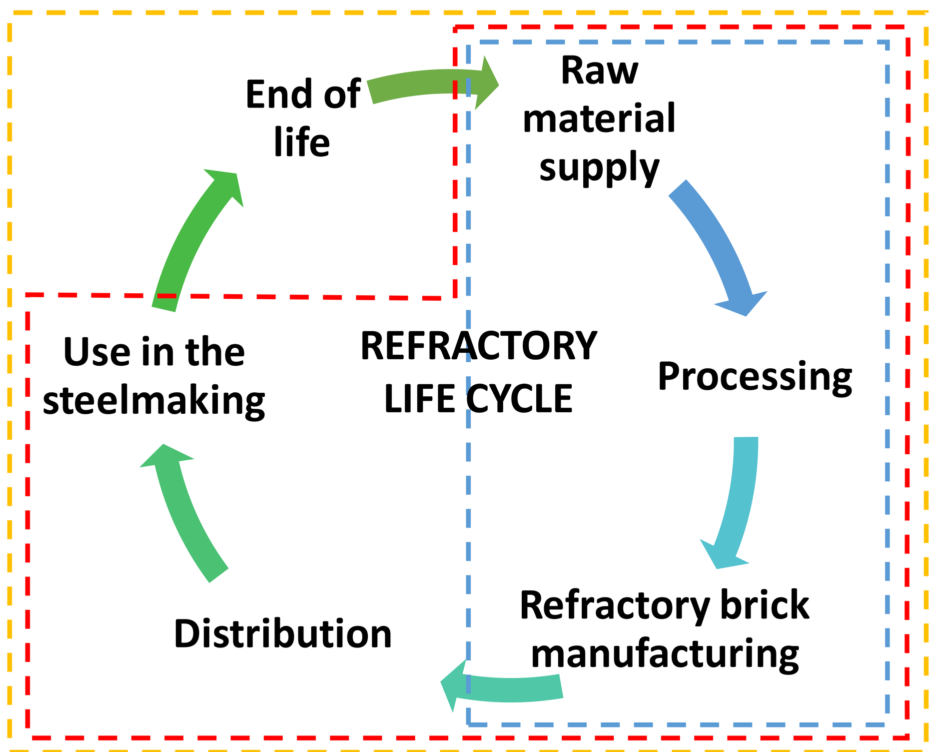

Figure 5. Refractory life cycle and related LCAs

Conclusions:

The novelty of the project relies on:

- **Filling** the actual **gaps of the LCAS** of refractories
  - Analysis of the entire life cycle (cradle-to-gate)
  - Full modelling of 3 production routes (curing, sintering and fused casting)
  - Enhancement of the eco-design conception and the recyclability potential
  - Improvement of the LCA database with process level data collection
- Provide **new methodological approaches** for the LCA challenges of:
  - Emerging technologies (prospective LCA)
  - Shift of the impact of refractory to the steel production.

References:

[1] IEA. (2020). *Iron and Steel Technology Roadmap. IEA*. https://www.iea.org/reports/iron-and-steel-technology-roadmap

[2] Biswas, S., & Sarkar, D. (2020). *Introduction to Refractories for Iron- and Steelmaking.* Springer International Publishing. https://doi.org/10.1007/978-3-030-43807-4

[3] Shahabuddin, M., Brooks, G., & Rhamdhani, M. A. (2023). *Decarbonisation and hydrogen integration of steel industries: Recent development, challenges and technoeconomic analysis.* Journal of Cleaner Production, 395, 136391. https://doi.org/10.1016/j.jclepro.2023.136391

[4] International Organization for Standardization (2006). ISO 14040:2006 *Environmental management—Life cycle assessment—Principles and framework.*

[5] International Organization for Standardization (2006). ISO 14044:2006 *Environmental management—Life cycle assessment—Requirements and guidelines.*

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Beneficiaries