HYDRA project: a solution to stakeholders paving the way for DR-EAF route hydrogen-based for carbon neutral steel production

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worldsteel ASSOCIATION
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COMPANY PRESENTATION

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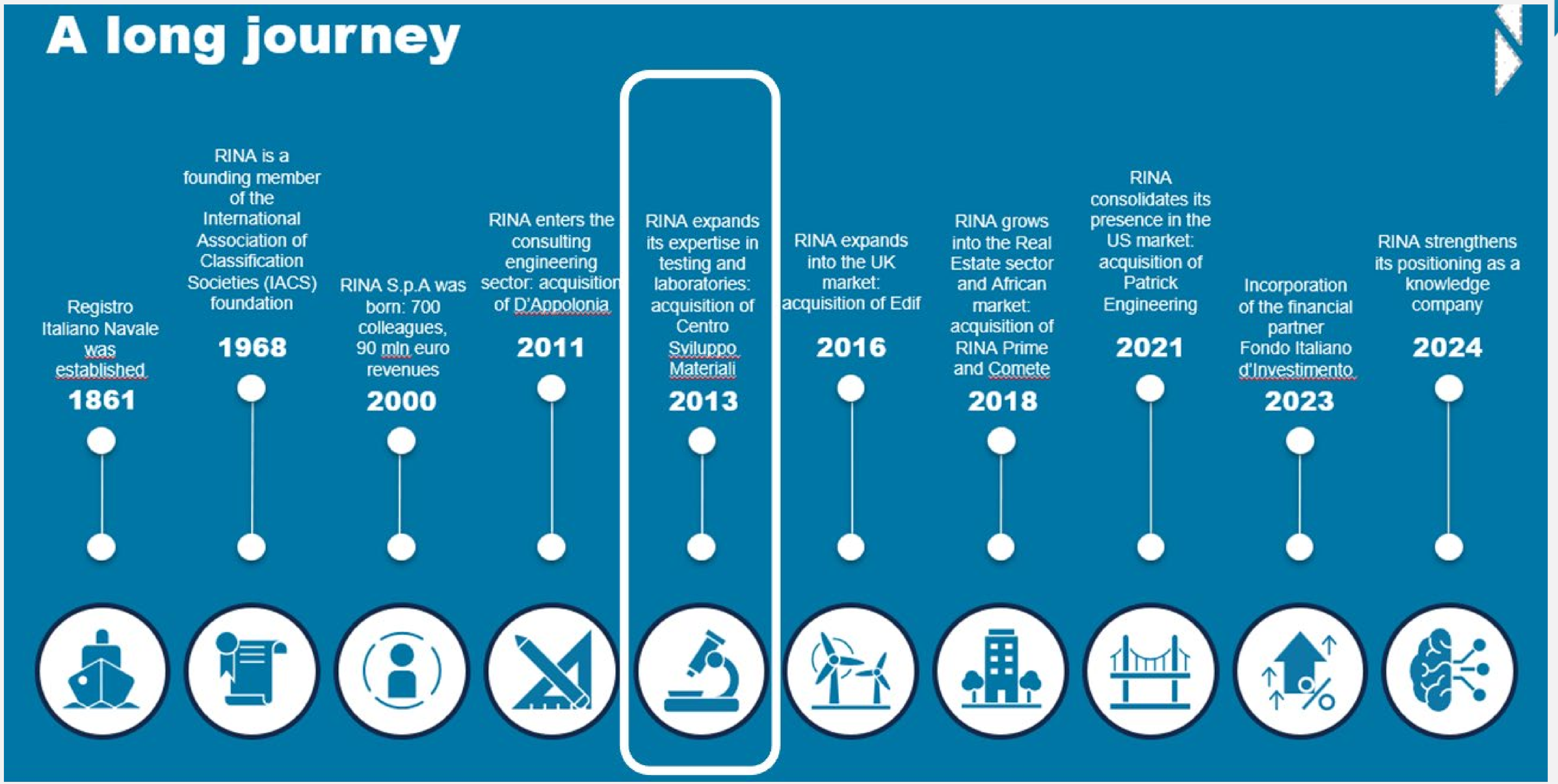
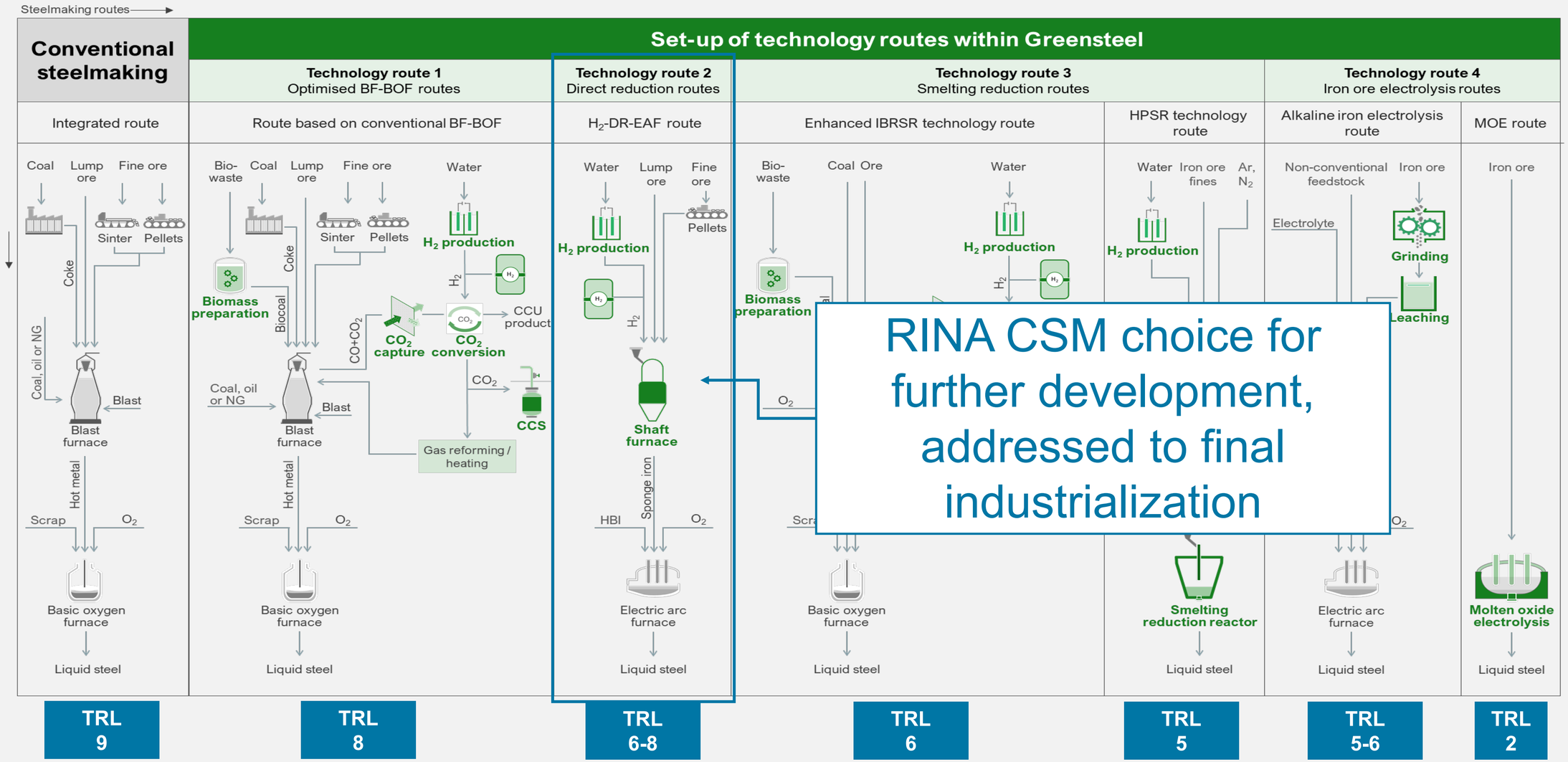


COMPANY PRESENTATION

- Centro Sviluppo Materiali (CSM) was founded in 1963 by Italy's major steel manufacturers and end-users
- CSM’s activities cover the entire cycle of innovation from basic applied research (physical, chemical and mechanical properties, new alloys and innovative coatings) to design, engineering, processing, prototype production, process/system automation and control, components and structures safety assessment, environmental issues and materials recycling.
- Core business is linked to the development and application of steels, light alloys (titanium, aluminum), Ni and Co-base super alloys as well as ceramics and cermets, special surface-engineered products, metal matrix and polymeric composites, intermetallics, hybrid products and organic coatings.
- Headquarter in Rome, since 2014 100% **integrated in RINA Group**

General Introduction

- The decarbonization at 2050 is a common target of States and Companies
- Steel production decarbonization requires innovative technologies.



RINA CSM choice for further development, addressed to final industrialization

Project description

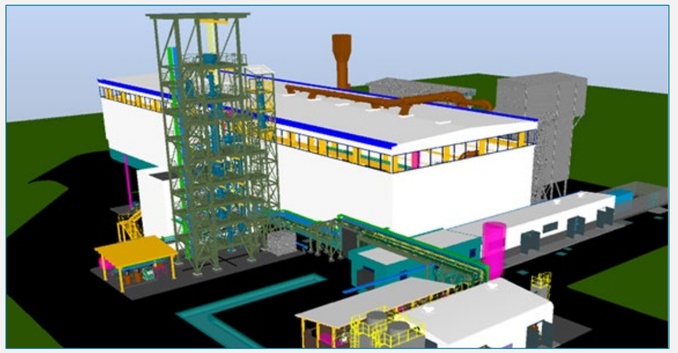
The ENERGIRON Technology has been selected for the HYDRA project

The plants (DRP & EAF) are supplied by Tenova
Plant erection by Danieli
Gas company Sapio

Project description

Funded by the European Union
NextGenerationEU

In this context HYDRA project has been lauched
It is open R&D facility for **GREEN STEEL** production.



Realised under the IPCEI funding scheme (**I**mportant **P**rojects of **C**ommon **E**uropean **I**nterest): approved by European Union and financially supported by Italian Minister.
HYDRA aims at developing an industrial open platform (with pilot plants and labs) in which develop, with two main targets:

- The development of a first-of-a-kind experimental line of DRI and EAF
- The acquisition of deep industrial knowledge in the metallurgical aspects related up to 100% hydrogen steel production

Keywords: Hydrogen, flexibility, integrated approach

Project description

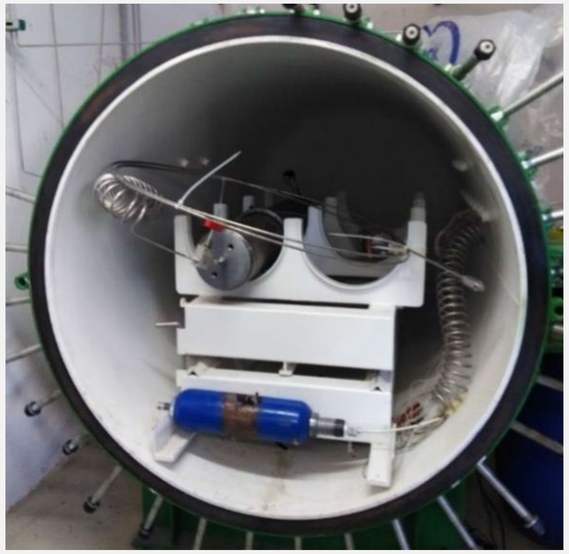
The project is divided into 4 lines of activity (global approach), which have been called *Work Packages* (WP):

- **WP1:** labs to study and development methodologies for testing and qualification of materials and components in hydrogen environment;
- **WP2:** the construction and development of the hydrogen-fed direct reduction pilot plant and process (DRP);
- **WP3:** the construction and development of an EAF for DRI melting obtained with hydrogen;
- **WP4:** the study and development of the ‘downstream’ use of hydrogen in reheating and heat treatment furnaces and its impact on steel quality.

Project description

WP1 (***Development of green hydrogen use in iron and steelmaking'***) **is aimed to:**

- to define the guidelines and procedure for a safe and reliable use of H_2 within the industrial steelmaking plants
- to give confidence to the steelmakers about the feasibility of introducing H_2 in the industrial steelmaking process
- to evaluate the impact of H_2 percentage in a CH_4/H_2 blended mixture on the industrial steelmaking plant (targeting 100% H_2)
- to make deeper knowledge and to upgrade the standards and regulation framework for the design and realization of dedicated hydrogen components in the steel making plant, with the HSE related issues.
- To provide training support (training HUB)



Project description

WP2 is focused on the **Direct Reduction process** in a pilot plant.

The pilot plant has been designed to investigate phenomena governing the Direct Reduction process, simulating in a reliable scale what occurring in industrial plants

DRP tower of about 30 m height

100 kg/h DRI produced (about 2 t per day)

Gas input by wagon tank (slot for four tanks foreseein)

Gas treament line equipped with CO2 capture

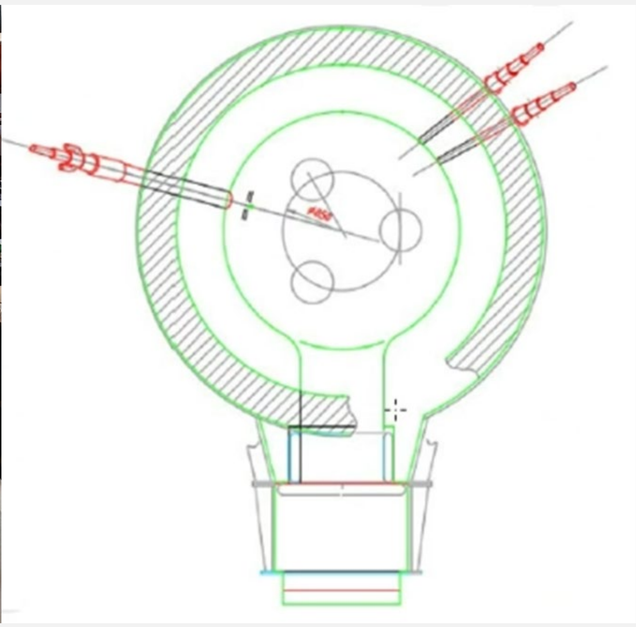
NG injection in the lower part of the furnace

Project description

WP3 is focused on the DRI melting will be investigate with a state- of-the-art electrical furnace pilot plant, of capacity of 7 t/heat.

Main characteristics of the furnace are:

- 7 t capacity, with 4 m^3 internal volume
- AC three electrodes
- Scrap and DRI charge
- Continuous charging of DRI
- Injection of solid materials (additive, coal, alternative carbonaceous materials)
- KT lance working as Hydrogen burner or Oxygen injector
- Furnace shell refractory insulated



Project description

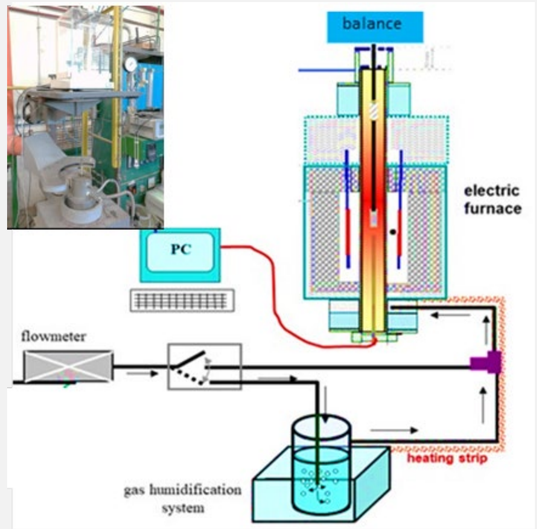
WP4 is focused on the use of hydrogen in furnaces for re-heating and treatment of the steel

This stream of activities uses the already existing facilities (experimental combustion station in Dalmine and high temperature labs in Rome

The aim of WP4 is to support the diffusion of the technology and investigating the effect of H_2 combustion both on the products quality and performance/life of the plant components


Combustion station


Horizontal furnace for annealing simulation



TGA to simulate steel oxidation

Project description

The project is located in Rina CSM site of Rome - Italy

Project description

H2 labs (WP1)

DRP pilot (WP2)

HYDRA working sites

Materials handling & gas treatment line (WP2 & WP3)

EAF pilot (WP3)

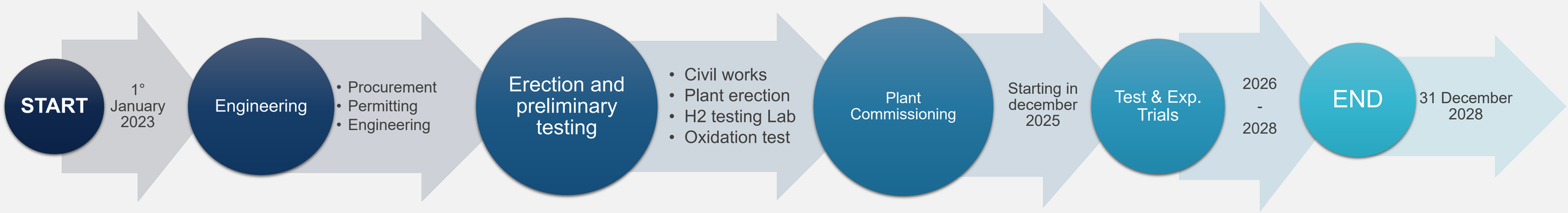
Training center

RINA Consulting Centro Sviluppo Materiali

HYDRA – Project timing

Project officially started on the 1° January 2023 and will last six years

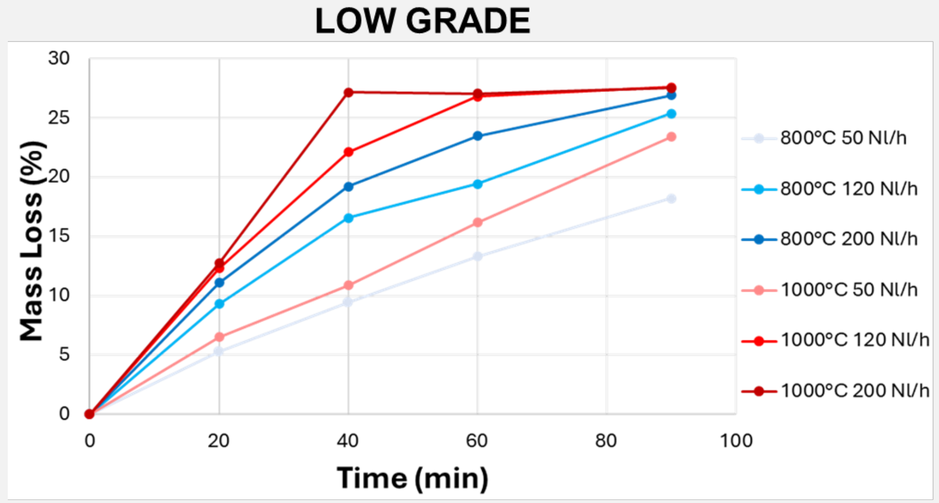
- All the facilities will be completed between end of 2025 and beginning 2026
- The first heat with pilot EAF scheduled in December 2025
- Commissioning of DRP will start in February 2026
- Full operativity of the whole experimental platform June 2026

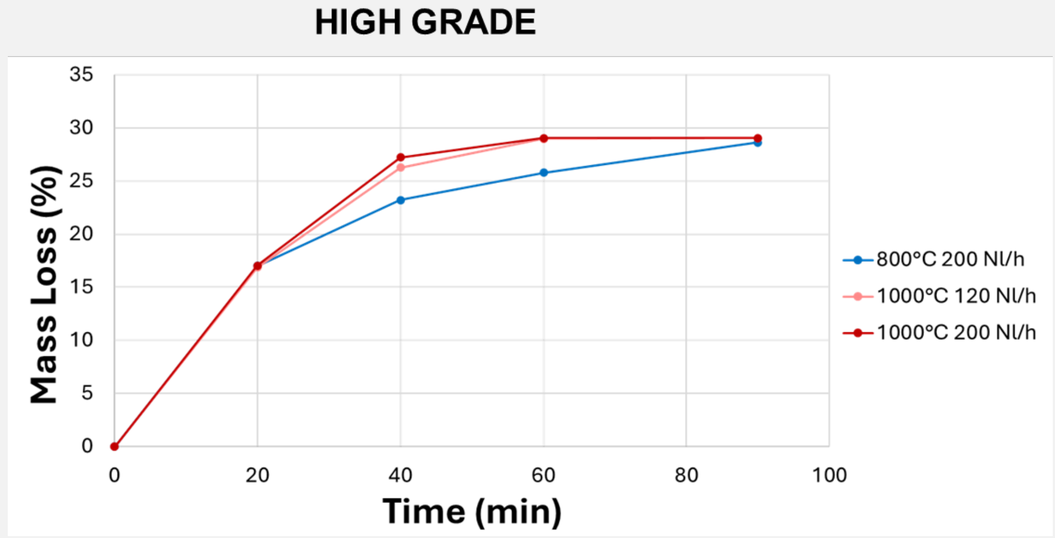


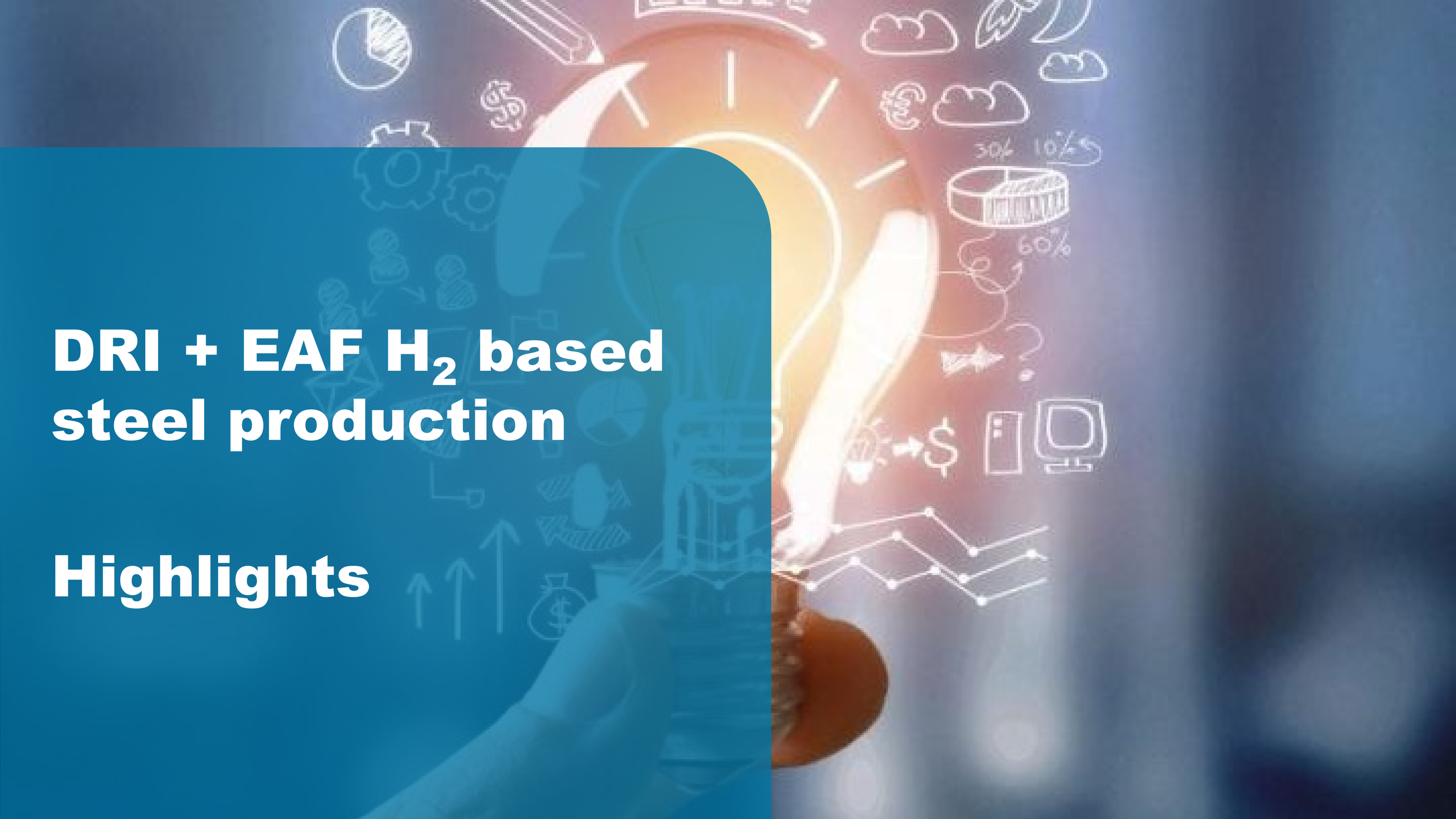
Ongoing interaction with industrial partners

Preliminary R&D activities

- Kinetic studies of pellets reduction: lab test on low and high materials carried out
- Impact of hydrogen combustion atmosphere on steel oxidation, descaling, annealing and pickling: completed
- Hydrogen utilization in downstream: compatibility and limits of existing plant configurations, burner testing and scenario analysis
- Cooperation with Universities: Graduate and PhD thesis ongoing
- Engagement with other EU projects to enable cross-project synergies and spillover effects
- Interaction with industrial partners







DRI + EAF H_2 based steel production

Highlights

HYDRA – DRI & EAF H2 based steel production – highlights

Low quality raw materials

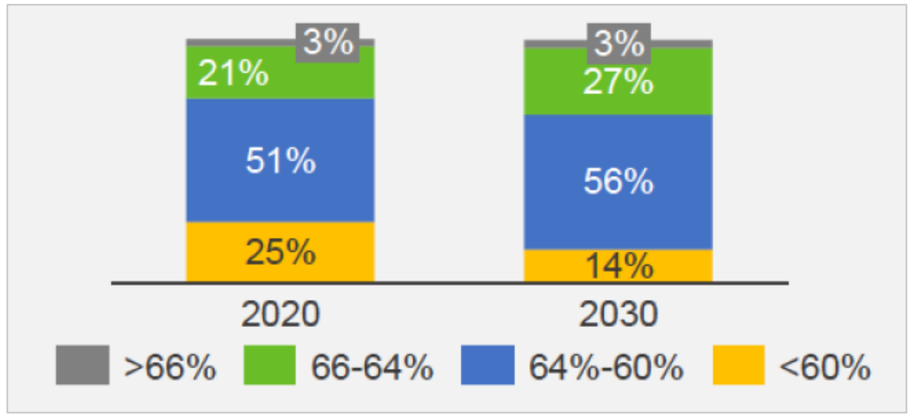
The diffusion DR process will decrease the availability and increase the cost of high-grade pellets (DR-grade), today commonly used for DR

The DR process must be optimized to guarantee target performance (e.g., metallization degree, productivity, energy balance DRP+EAF) in routine operations for different quality of the pellets

A proper slag management and scrap blending capability in EAF must be ensured to minimize the increasing of slag mass and volume

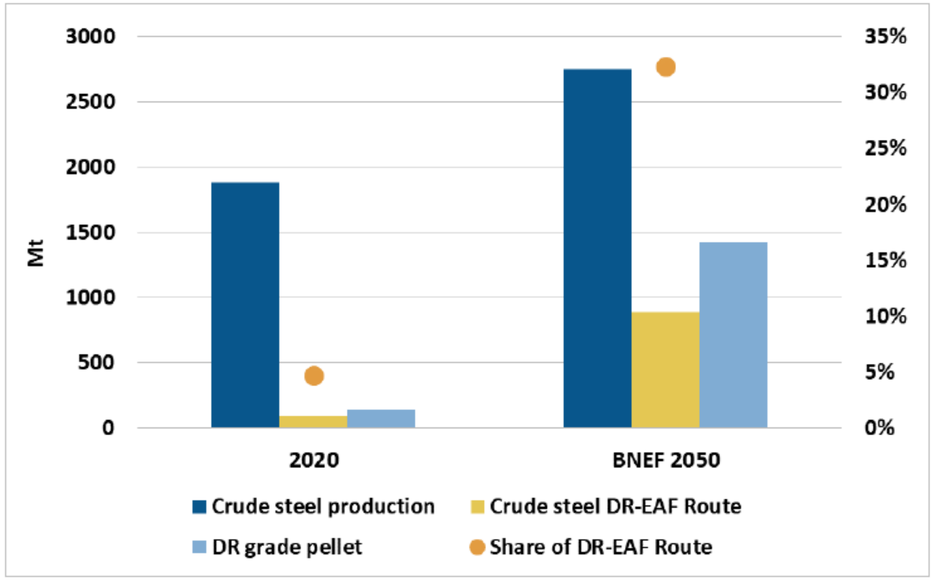
Iron Ore Quality a Potential Headwind to Green Steelmaking
Technology and Mining Options Are Available to Hit Net-Zero Steel Targets, paper from IEEFA.org

Figure A: Seaborne Iron Ore Supply by Fe Content (%)



Source: Vale.

Figure 7: DR-Grade Pellet Demand Under BNEF Net Zero Emissions 2050 Scenario (NZE 2050)



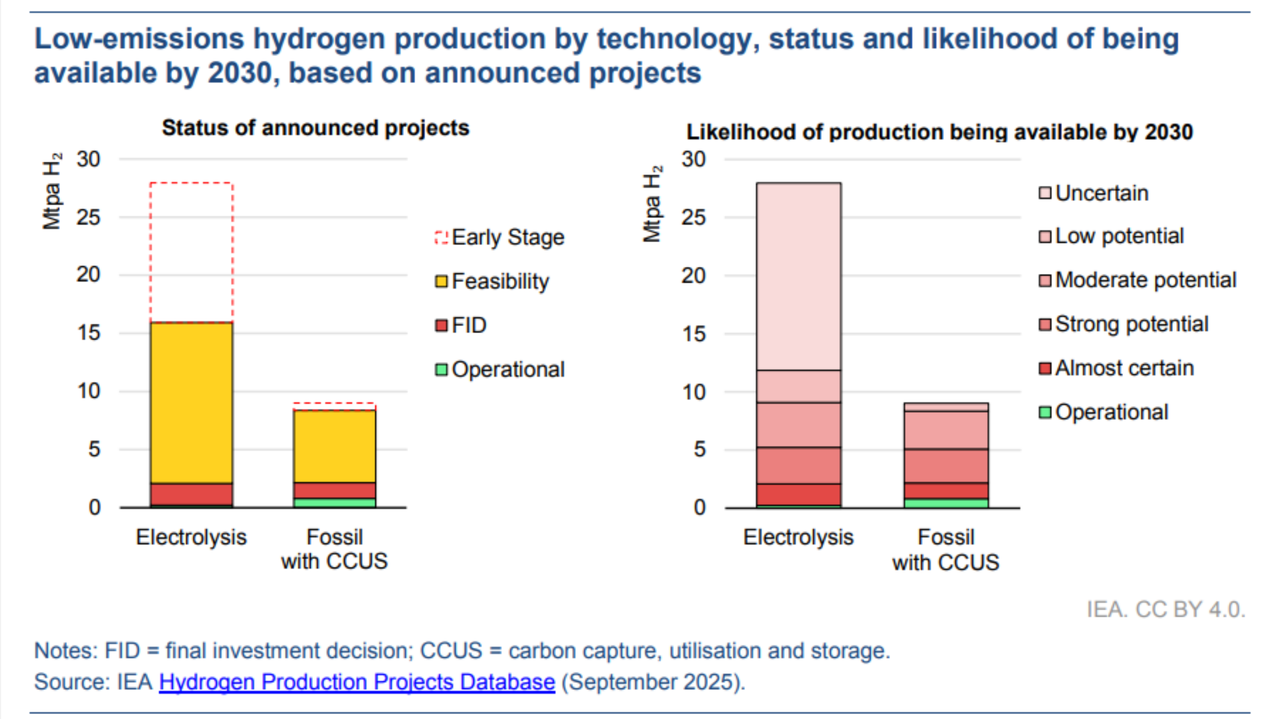
Source: BloombergNEF, Worldsteel, Midrex, IEEFA calculations.

HYDRA – DRI & EAF H2 based steel production – highlights

Direct Reduction with variable H2/CH4 mix

The transition toward H2-DR will be gradual: availability of green hydrogen not yet ensured. High cost foreseen (about 5$/kg according to Hydrogen Council)

Gas blending is to be used, gradually replaced with H2/CH4/CO mix up to 100% H2



https://iea.blob.core.windows.net/assets/a6c466dd-b6f0-44bd-a60a-6940eccfb1c3/GlobalHydrogenReview2025.pdf

The real performance of the industrial DR process at variable composition mixes must be defined, as well as the realistic ranges of productivity, metallization degree, carbon content.

Subsequent impact on EAF melting process are evaluated

HYDRA – DRI & EAF H2 based steel production – highlights

Carbon management

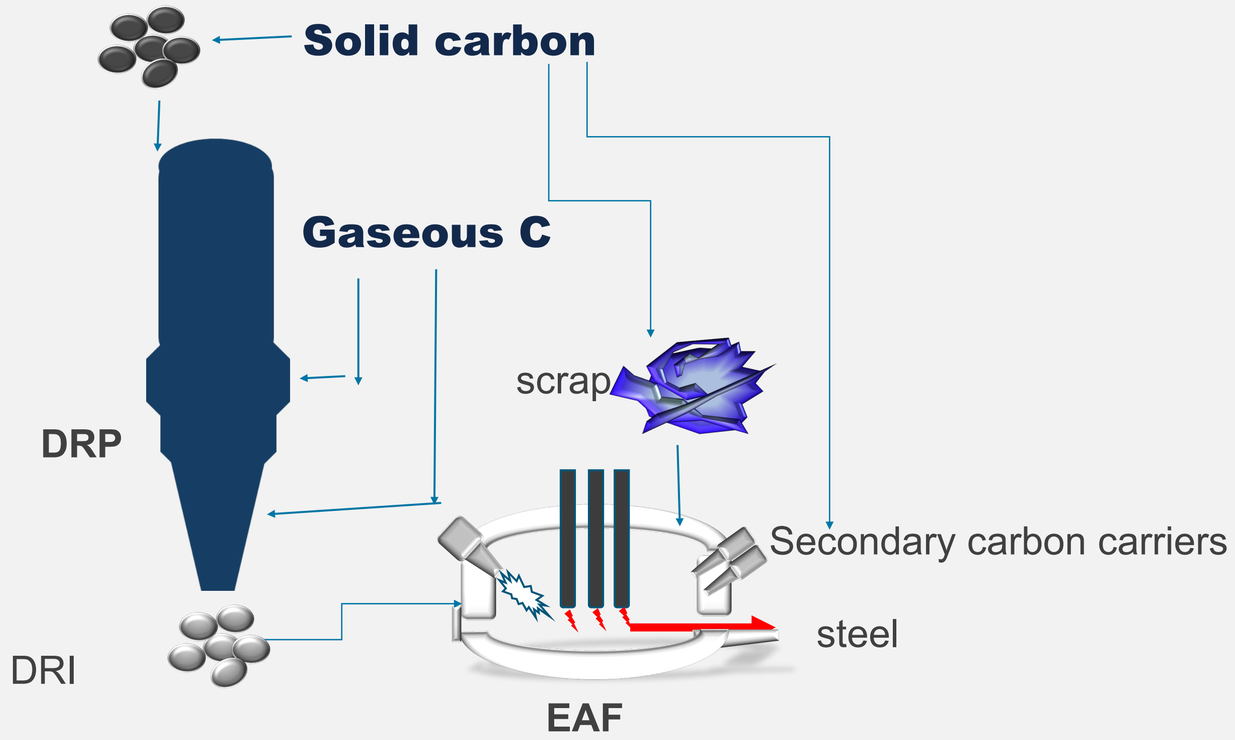
DRI carburization

-blending of H_2/NG with minimum amount of NG

-NG injection of the lower part of the furnace

-C addition in the pellets formulation (biogenic C)

-Injection of secondary carbon carriers in EAF



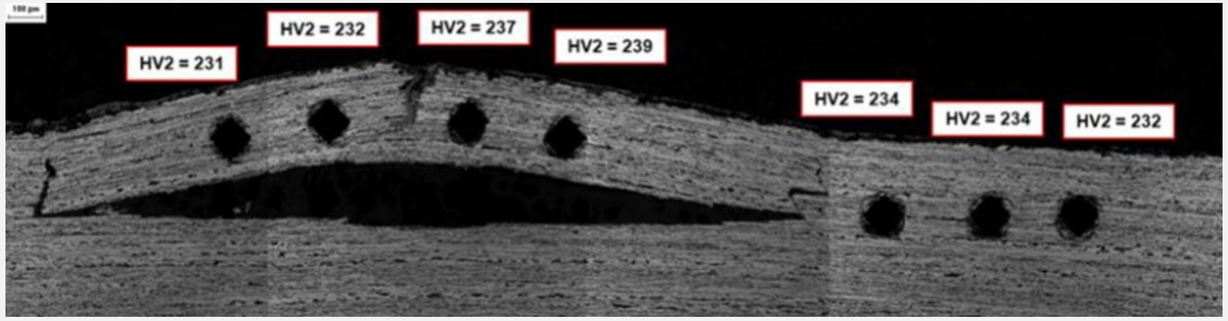
- Energetic balance of the whole process
- Plant productivity
- Impact on electrode and refractory

Possible ways of carbon utilization in the process
Evaluation of impacts, DSS development

HYDRA – DRI & EAF H2 based steel production – highlights

Materials

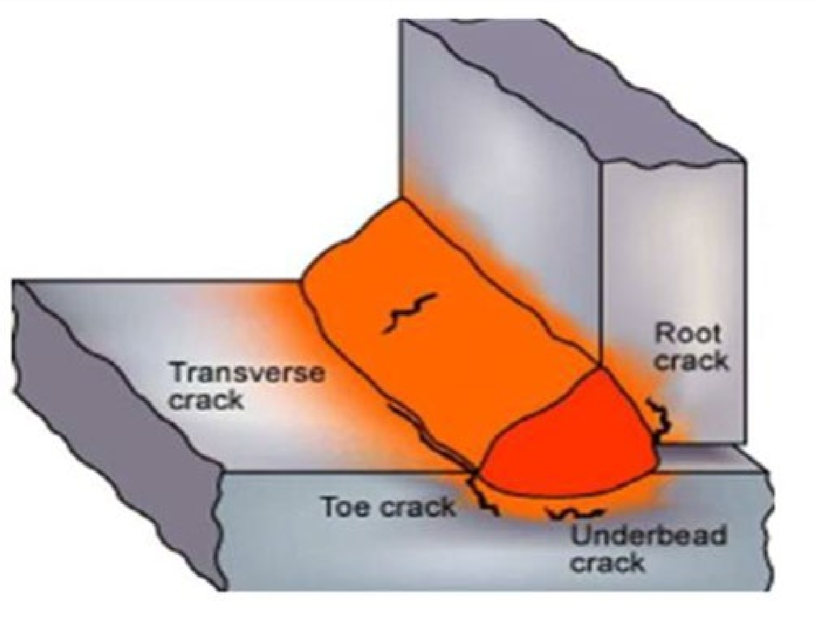
Using variable H2/CH4 mix, pure H2, products of H2 combustion can generate problems for materials life and cost



Identification of technical problems, selection of suitable materials, design and development of new materials

Mechanism of embrittlement and degradation for steels, metals, polymers, composites

Evaluation/individuation of mechanism, support to identification of materials, tests and qualification



Moreover, the quality of the produced steel can be potentially affected

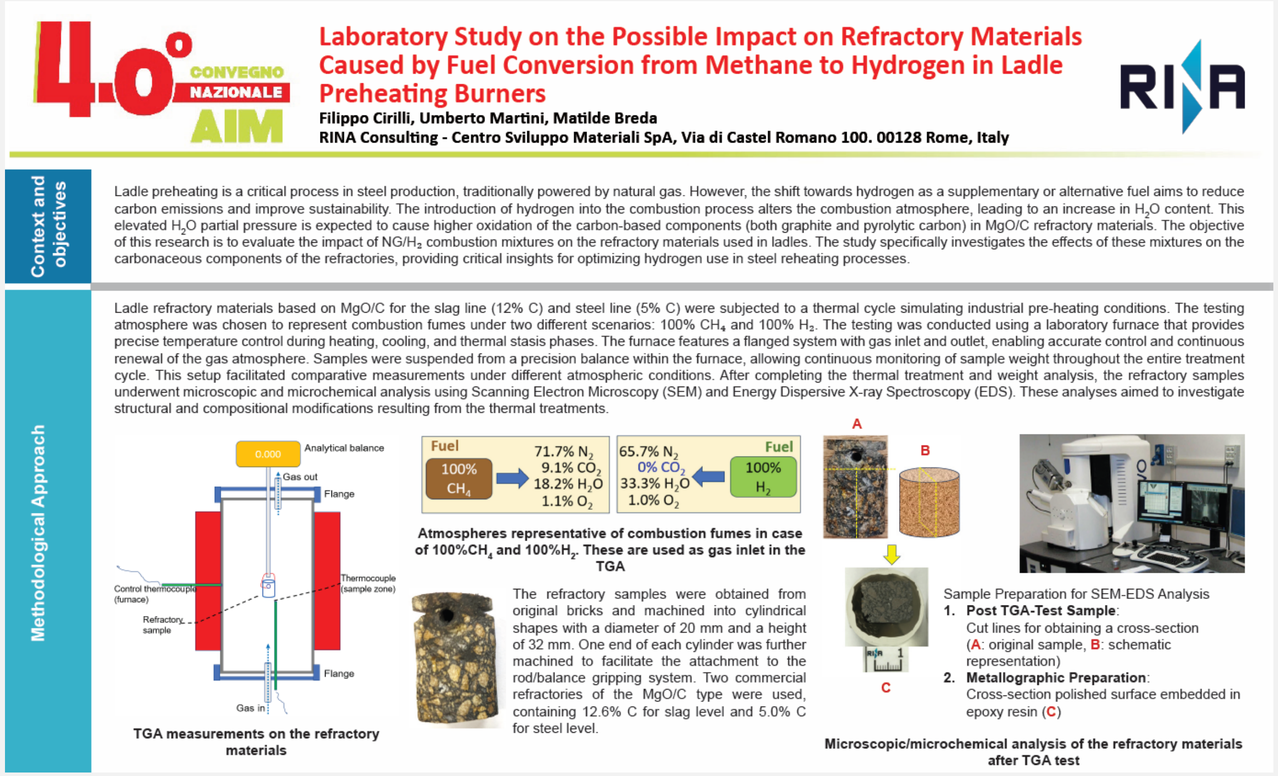
HYDRA – DRI & EAF H2 based steel production – highlights

Refractories

Hydrogen utilization (reducing agent and energy vector) can reduce the service life of refractory materials, in DRP, EAF and reheating furnaces

H2/H2O/CO can react with C, carbides and oxides degrading the refractory material

Interaction mechanisms can be identified through thermodynamic modelling and experimental activity purposely designed and validated with pilot facilities



4.0° CONVEGNO NAZIONALE AIM

Laboratory Study on the Possible Impact on Refractory Materials Caused by Fuel Conversion from Methane to Hydrogen in Ladle Preheating Burners

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RINA

Context and objectives

Ladle preheating is a critical process in steel production, traditionally powered by natural gas. However, the shift towards hydrogen as a supplementary or alternative fuel aims to reduce carbon emissions and improve sustainability. The introduction of hydrogen into the combustion process alters the combustion atmosphere, leading to an increase in H_2O content. This elevated H_2O partial pressure is expected to cause higher oxidation of the carbon-based components (both graphite and pyrolytic carbon) in MgO/C refractory materials. The objective of this research is to evaluate the impact of NG/H_2 combustion mixtures on the refractory materials used in ladles. The study specifically investigates the effects of these mixtures on the carbonaceous components of the refractories, providing critical insights for optimizing hydrogen use in steel reheating processes.

Methodological Approach

Ladle refractory materials based on MgO/C for the slag line (12% C) and steel line (5% C) were subjected to a thermal cycle simulating industrial pre-heating conditions. The testing atmosphere was chosen to represent combustion fumes under two different scenarios: 100% CH_4 and 100% H_2. The testing was conducted using a laboratory furnace that provides precise temperature control during heating, cooling, and thermal stasis phases. The furnace features a flanged system with gas inlet and outlet, enabling accurate control and continuous renewal of the gas atmosphere. Samples were suspended from a precision balance within the furnace, allowing continuous monitoring of sample weight throughout the entire treatment cycle. This setup facilitated comparative measurements under different atmospheric conditions. After completing the thermal treatment and weight analysis, the refractory samples underwent microscopic and microchemical analysis using Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS). These analyses aimed to investigate structural and compositional modifications resulting from the thermal treatments.

TGA measurements on the refractory materials

Atmospheres representative of combustion fumes in case of 100%CH_4 and 100%H_2. These are used as gas inlet in the TGA

The refractory samples were obtained from original bricks and machined into cylindrical shapes with a diameter of 20 mm and a height of 32 mm. One end of each cylinder was further machined to facilitate the attachment to the rod/balance gripping system. Two commercial refractories of the MgO/C type were used, containing 12.6% C for slag level and 5.0% C for steel level.

Sample Preparation for SEM-EDS Analysis

1. **Post TGA-Test Sample**: Cut lines for obtaining a cross-section (**A**: original sample, **B**: schematic representation)
2. **Metallographic Preparation**: Cross-section polished surface embedded in epoxy resin (**C**)

Microscopic/microchemical analysis of the refractory materials after TGA test

The issues of durability must be addressed, and refractories that guarantee performance not inferior to current ones must be selected and developed.

HYDRA – DRI & EAF H2 based steel production – further application of experimental platform

Interaction with grid and coupling with plant production scheduling

Hydrogen production technologies: electrolysers, testing and performances under variable conditions, Methane pyrolysis, Biomass and waste gasification, blending with biogas

Flexible management of CO2 capture unit

Testing of innovative sensors and control technologies

Testing of new plant components and refractories

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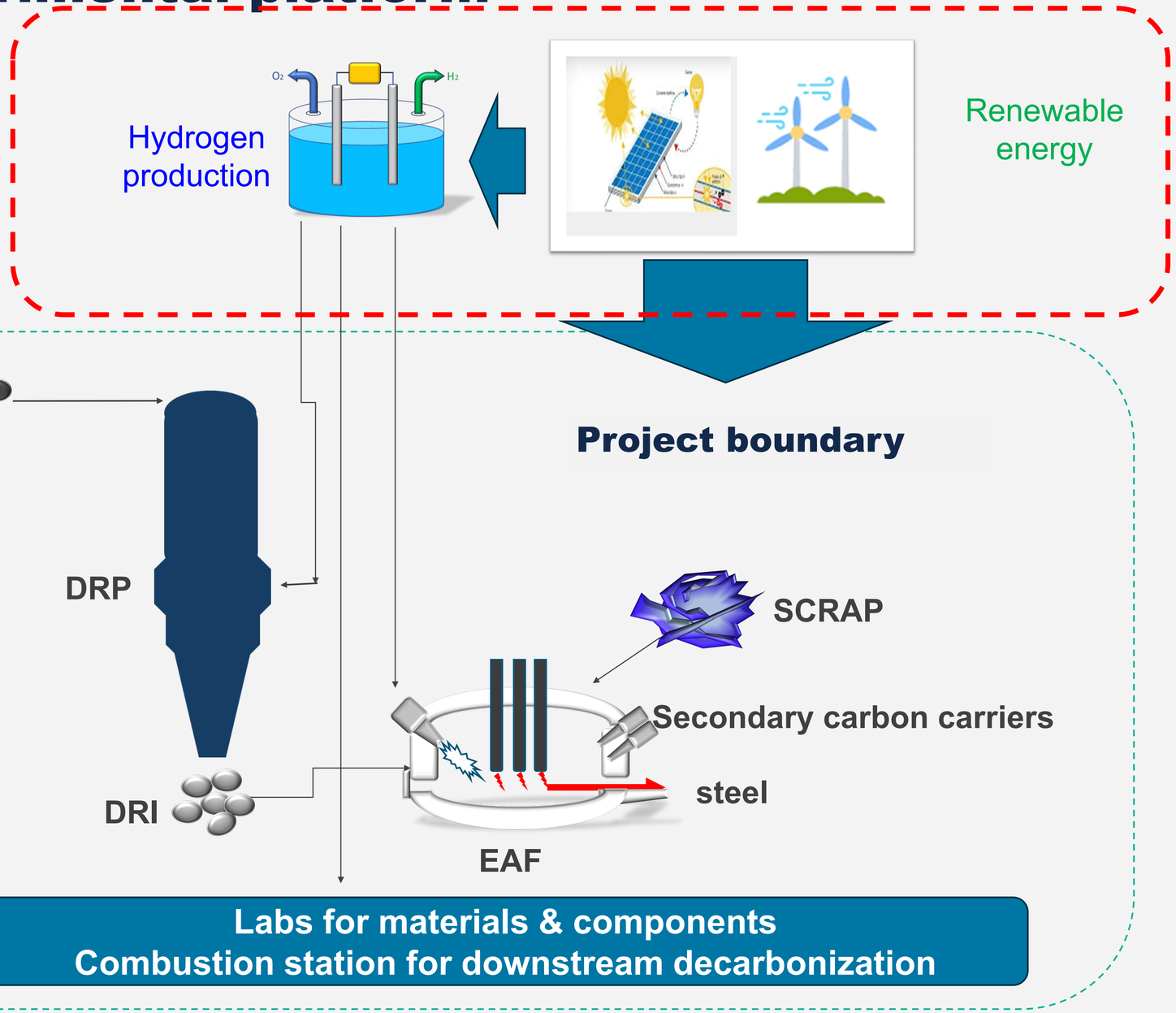

General conclusions

- The HYDRA project is aimed to support steel decarbonization with integrated approach linking pilot plants and labs

- The experimental facilities will be in operation end of 2025 beginning of 2026 and experimental campaigns at pilot facilities will start in spring 2026

- Possibility to visit the facility during tests and to discuss results and performances

- Fully open to technical interactions with steelmakers and technology providers and to perfom tailored experimental campaign at European and International level


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For more info:

Thank you for your attention

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