

HYDRA: An Open Innovation & Experimental HUB Bridging Research and Pilot Demonstration for Low-Carbon Iron and Steel Technologies Industrial Deployment"

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Our experience. Your growth.

Content of the presentation

- Company presentation
- General Introduction
- Project description
- First results
- Highlights
- Conclusions





A long journey

1861 — Registro Italiano Navale was established

1968 — RINA is a founding member of the International Association of Classification Societies (IACS) foundation

2000 — RINA S.p.A was born: 700 colleagues, 90 mln euro revenues

2011 — RINA enters the consulting engineering sector: acquisition of D'Appolonia

2013 — RINA expands its expertise in testing and laboratories: acquisition of Centro Sviluppo Materiali

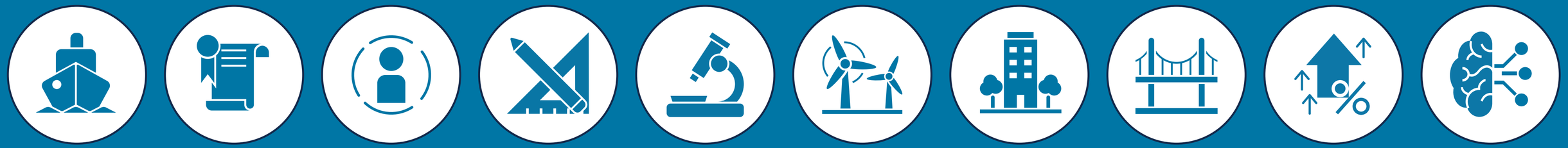
2016 — RINA expands into the UK market: acquisition of Edif

2018 — RINA grows into the Real Estate sector and African market: acquisition of RINA Prime and Comete

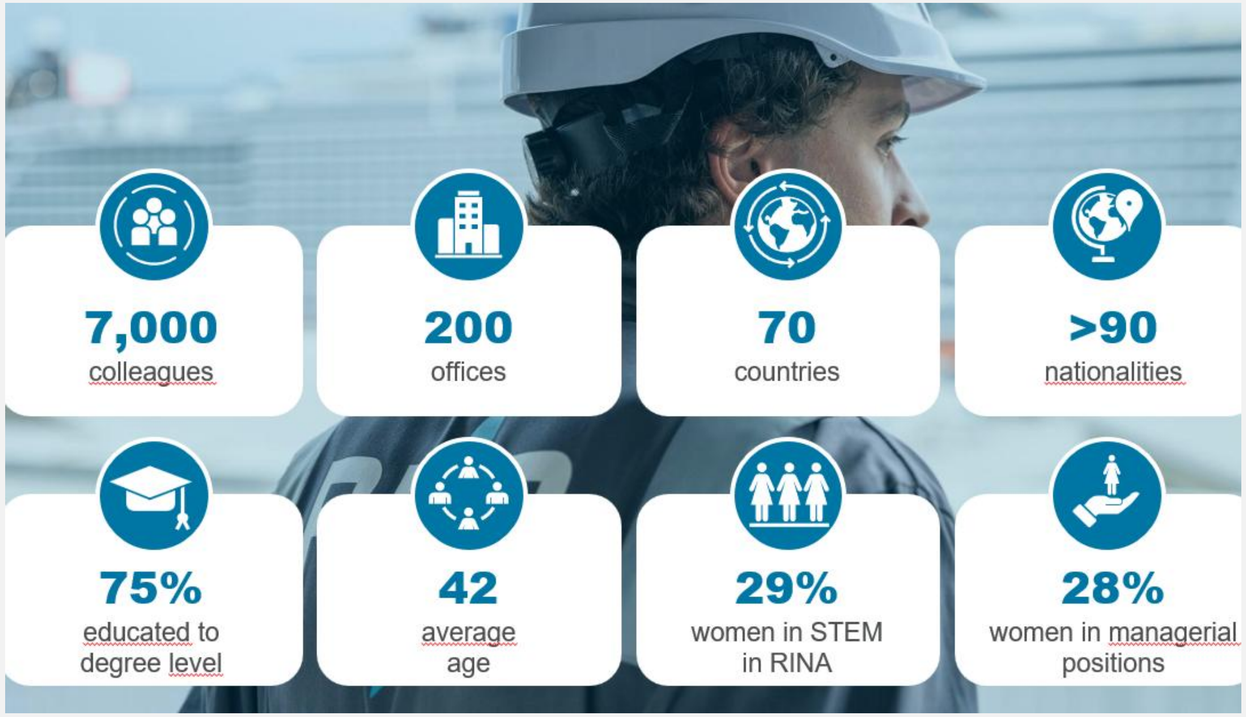
2021 — RINA consolidates its presence in the US market: acquisition of Patrick Engineering

2023 — Incorporation of the financial partner Fondo Italiano d'Investimento

2024 — RINA strengthens its positioning as a knowledge company



RINA Today





Our business unites

Energy

RINA's energy team offers global expertise in site characterization, advisory, engineering, inspections & supervision, supporting energy projects from development to decommissioning, ensuring safety and efficiency.

Industry

RINA's industry team provides highly qualified services, thank to its multidisciplinary approach and outstanding application expertise across all industrial sectors - including A&D, hard-to-abate industries, management consulting, and cybersecurity.

Infrastructure & Mobility

RINA's infrastructure & mobility team supports the path to the next generation of infrastructures and buildings by ensuring their safety and efficiency.

Marine

RINA's marine team provides ship classification, statutory certification, advisory, digital and technical services for safety, sustainability, and innovation across commercial, naval, and yachting sectors.

Certification

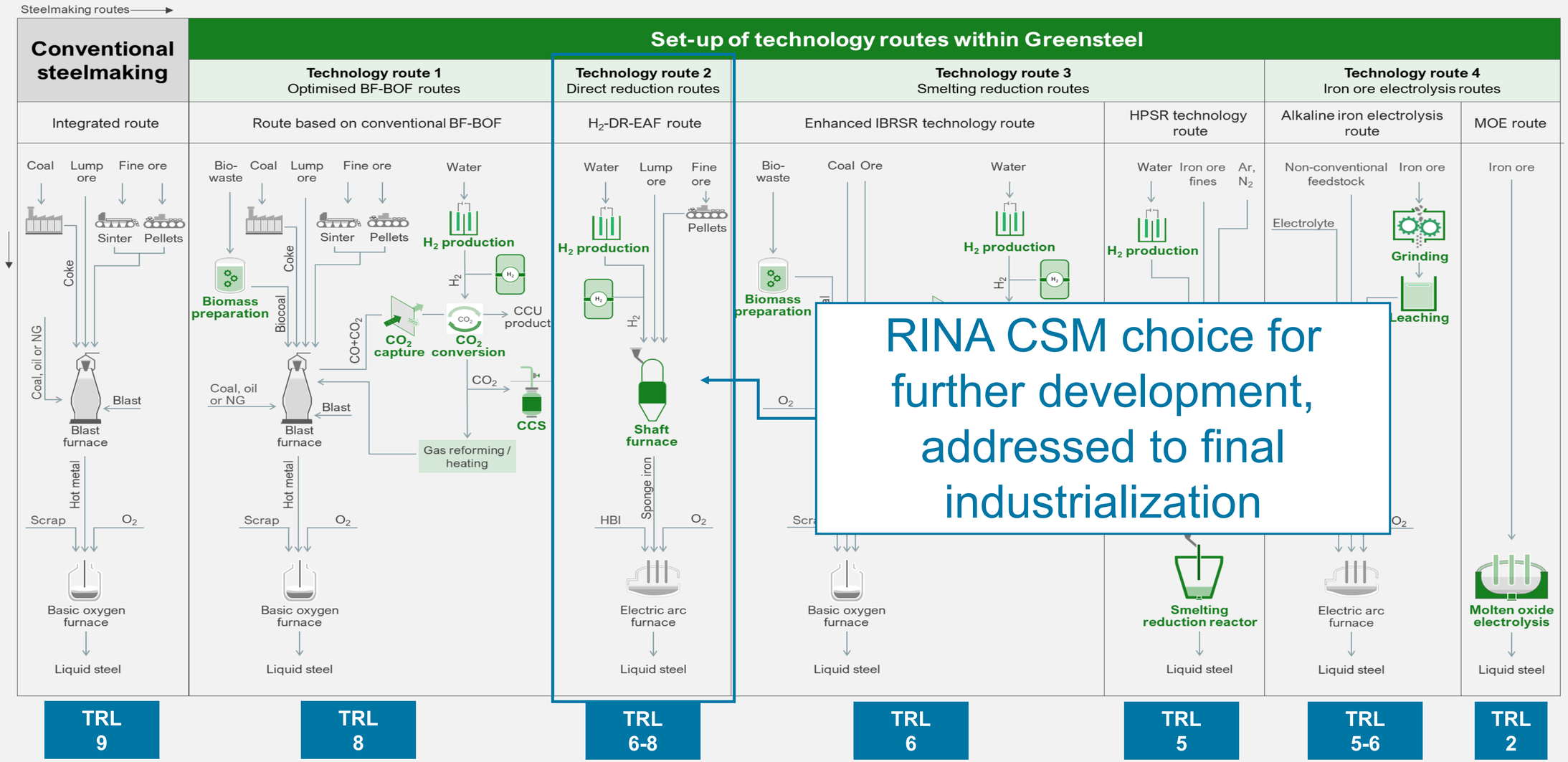
RINA's certification team guides companies on their journey toward continuous improvement and excellence, by certifying organizations' genuine dedication to best practices.

Real Estate

RINA's real estate team supports public and private market operators with innovative services aimed at protecting and enhancing real estate capital value at every stage of the investment.

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

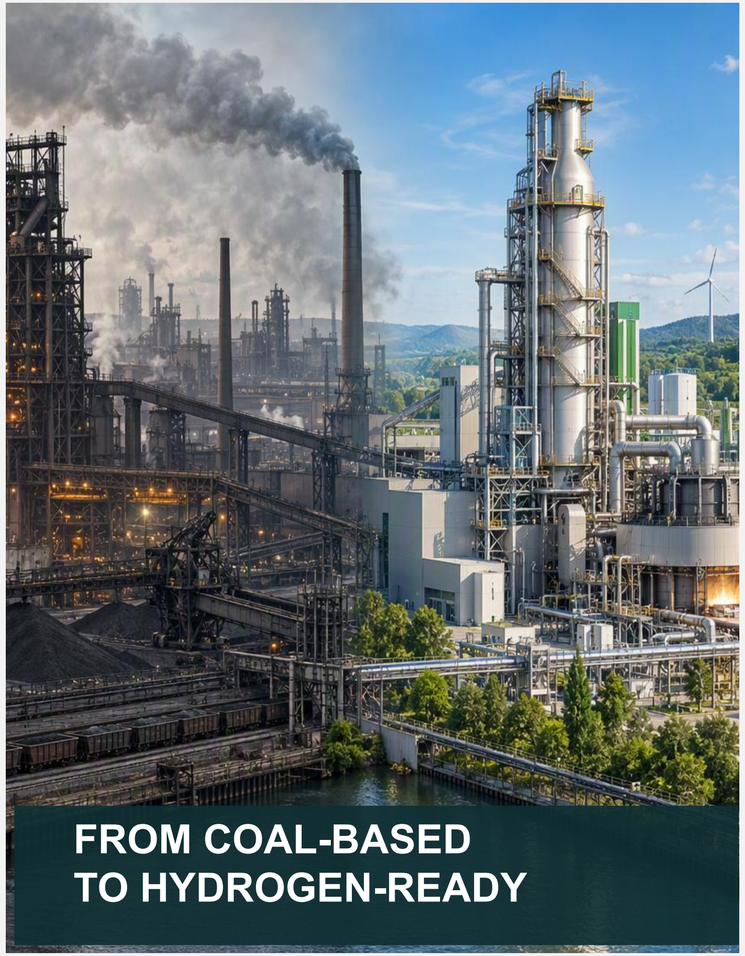
General Introduction
Key findings from technological scouting

- Carbon neutral Steel production requires breaktrough technologies.
- The production route based on DRP-EAF fed by hydrogen is recognized as a valuable alternative to BF-BOF based route.
- Several technologies are available at different TRL and a coesistence of different technolgoical solutions is in anycase to be expected in the incoming years
- Anyhow, Hydrogen utilization will play a crucial important role.

Net zero production 2050 is a target of many States and Steelmaking Companies: even if with different velocities and level of penetration in the different national economies, the decarbonization process in an unavoidable transformation in steel production

General Introduction

A progressive transition from natural gas to green hydrogen can decouple ironmaking from fossil coal



Market direction to 2030 and 2050

>80 Mt new production capacity announced for 2030

About 400 Mt iron capacity announced for 2050

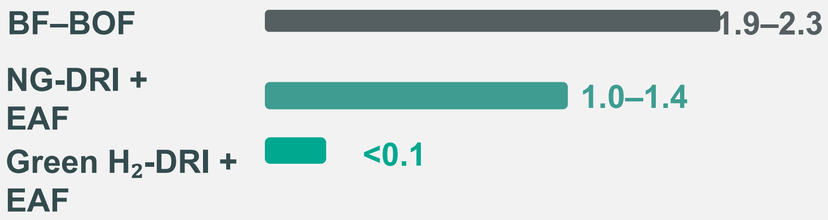
TODAY
Commercial NG-DRI
Proven at scale; lower-carbon virgin iron for EAFs.

2026–30
Hydrogen-ready build-out
New shafts start on natural gas or blends, then switch as H_2 supply grows.

2030+
Near-zero H_2-DRI
Renewable power + low-emission H_2 enable deep decarbonisation.

2050
H_2-DRI expansion
Leading role of DRI /EAF/ESF technologies.

Indicative full-chain CO_2 intensity

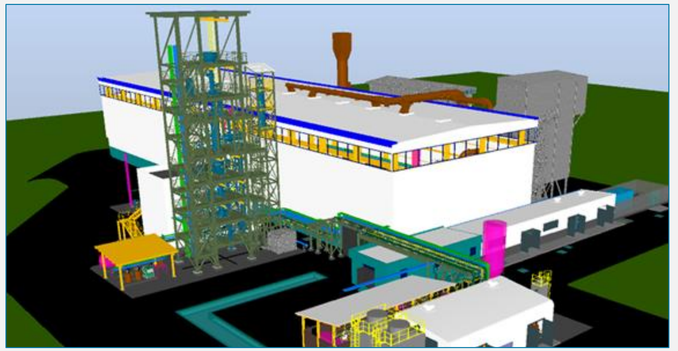


Beyond CO_2: structural environmental benefits

- **No coke ovens / sinter plant:** Lower SO_x, NO_x, dust, PAHs and diffuse emissions
- **Solid-state reduction:** Less process complexity and a smaller local emissions footprint
- **EAF integration:** Flexible use of DRI/HBI and scrap supports circularity

DRI is not a single end-state technology: it is a transition platform. Build hydrogen-ready assets now, while securing low-carbon power and H_2

HYDRA – Hydrogen Green Steel



It is open R&D facility for **GREEN STEEL** production.

Realised under a European funding scheme IPCEI funding scheme (**I**mportant **P**rojects of **C**ommon **E**uropean **I**nterest



HYDRA aims at developing an industrial open platform with pilot plants and labs with two main targets:

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

Funded by the European Union
NextGenerationEU

Project description

The ENERGIRON Technology has been selected for the HYDRA project

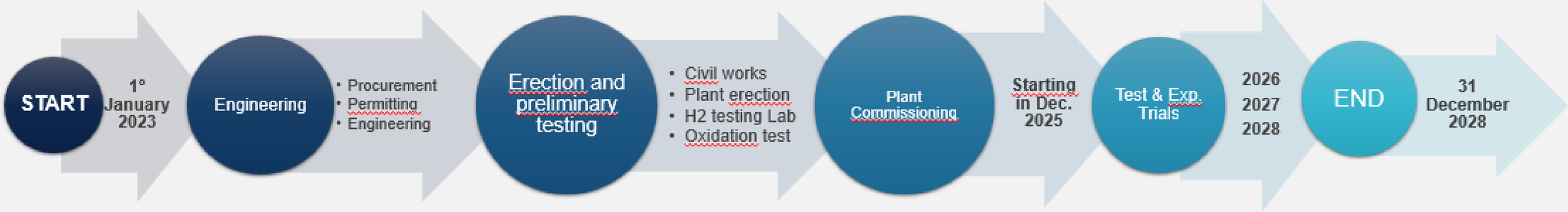
The plants (DRP & EAF) are supplied by Tenova
Plant erection by Danieli
Gas company Sapio



HYDRA – Hydrogen Green Steel

Funded by the European Union
NextGenerationEU

- Project officially started on the 1° January 2023 and will last six years
- DRP based on ENERGIRON technology
- DRP and EAF provided by Tenova, Gas line and installation by Danieli, gas system by Sapio
- All the facilities almost completed
- The first heat with pilot EAF carried out in December 2025
- Commissioning of DRP ongoing (completed in 2026)
- Downstream tests and kinetic analysis carried out



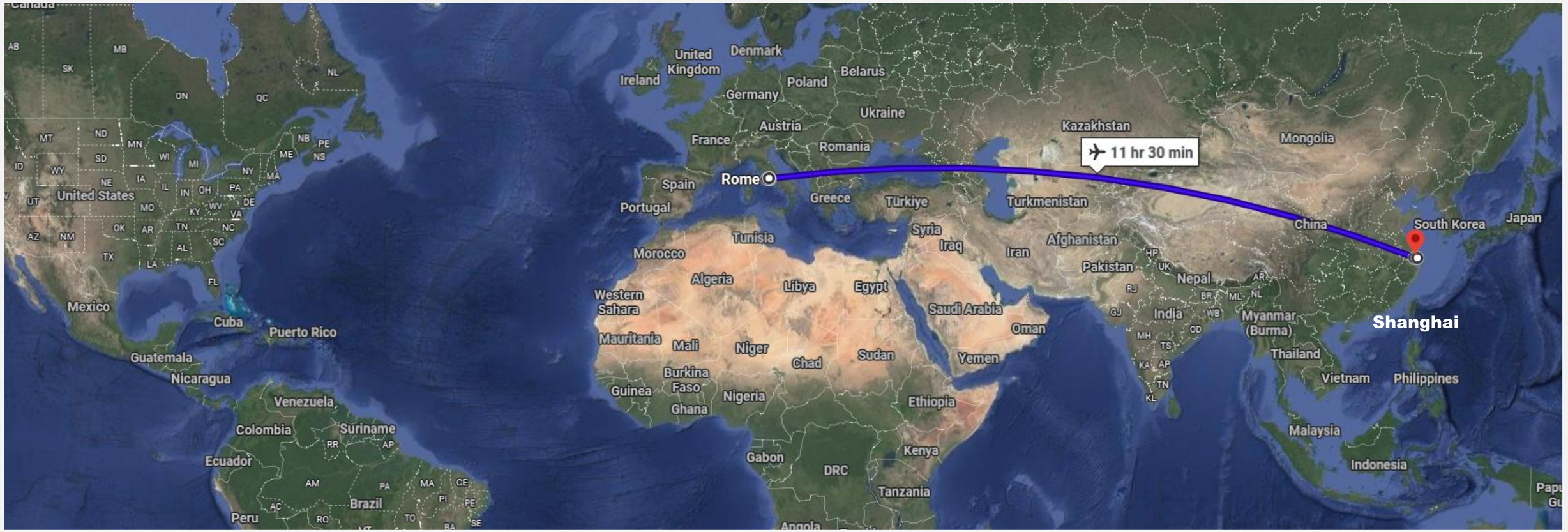
Project description

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 pilot EAF for DRI/scrap melting trials;
- **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

The pilot plants are located in Rome

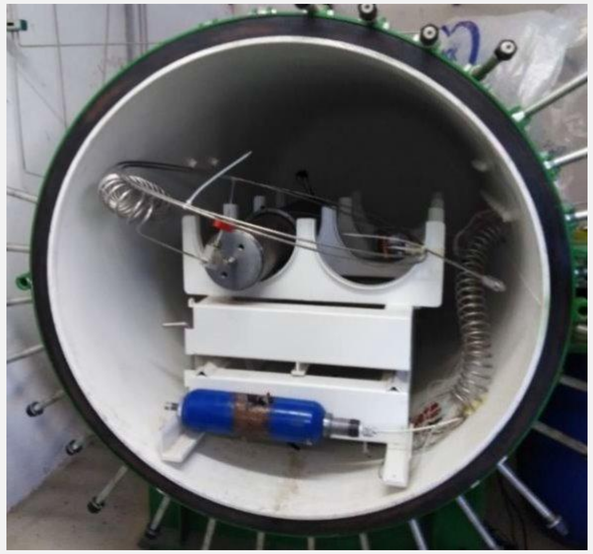


Project description

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 2,4 t per day)

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

Gas treament line equipped with CO_2 capture and gas recirculation

NG injection in the lower part of the furnace for carburization and cooling

DRI storage in inertised tanks



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



EAF pilot (WP3)


Materials handling & gas treatment line)

Project description

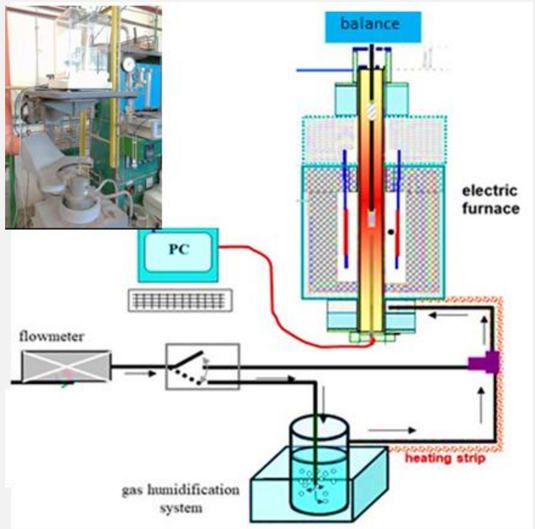
WP4 is focused on the use of hydrogen in furnaces for re-heating and treatment of the steel

This stream of activities uses the already existing facilities (experimental combustion station in North Italy - 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



Highlights & Key Topics

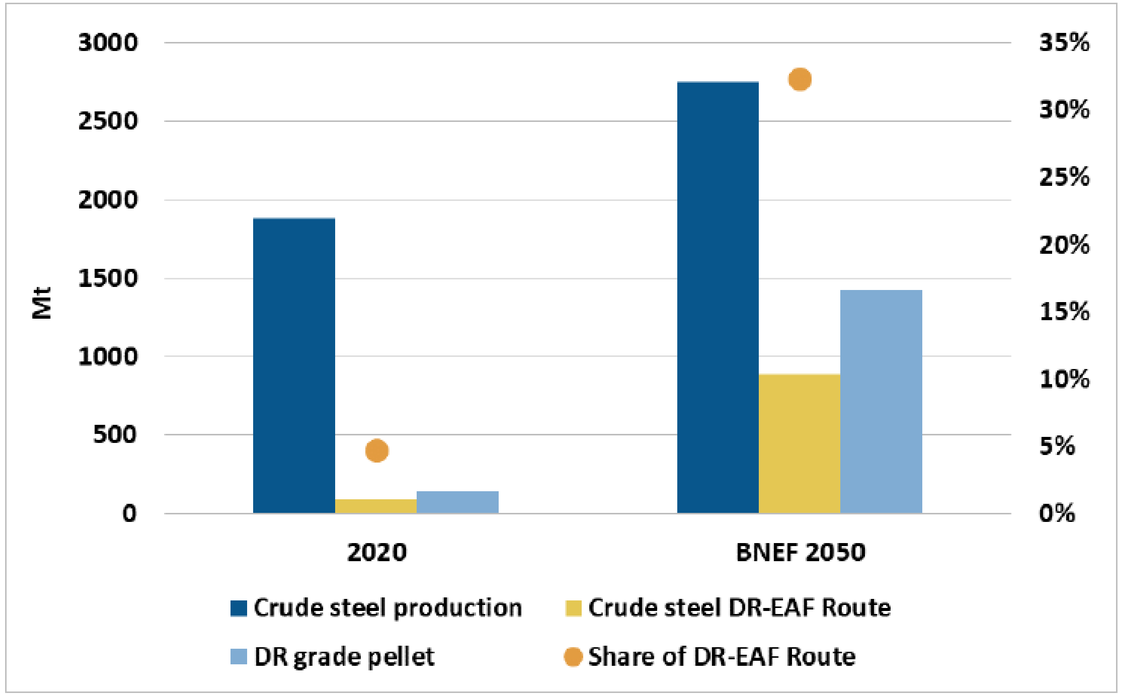
HYDRA – DRI & EAF H2 based steel production – highlights

Quality/availability of input materials (1/3)

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

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

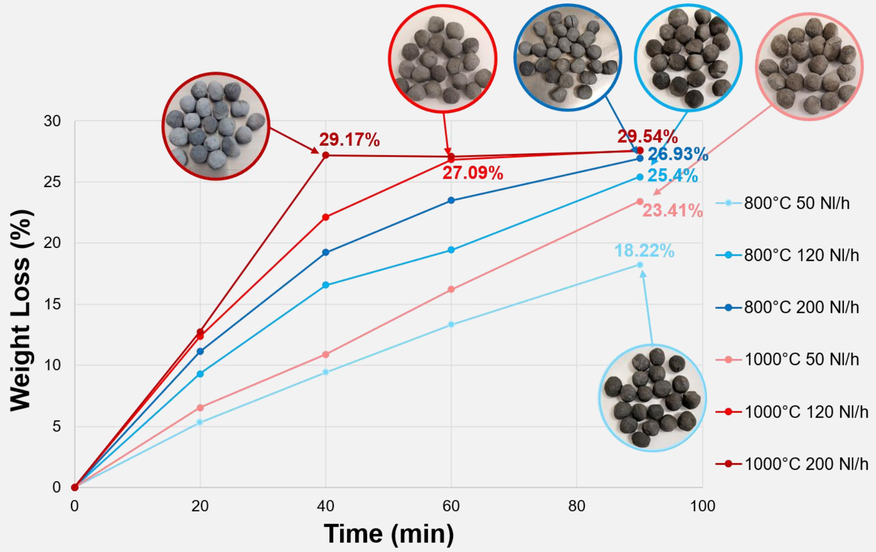


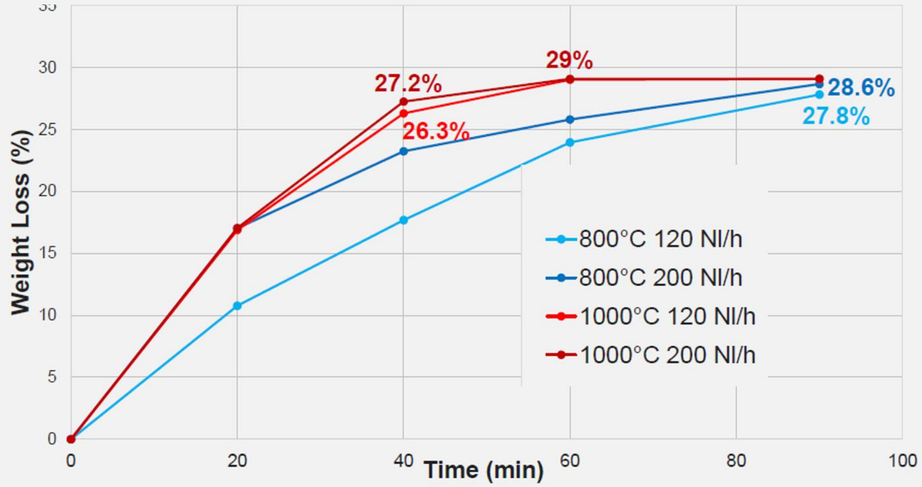
Source: BloombergNEF, Worldsteel, Midrex, IEEFA calculations.

HYDRA – DRI & EAF H2 based steel production – highlights

Quality/availability of input materials (2/3)

	BF-grade pellets	DR-grade pellets
Typical total Fe	~64%	~67–68%
SiO_2	~2–5%	~1.5%
Overall gangue content	High	low
Theoretical pellets required per 1 t Fe	1.54 t	1.48 t
Cost	lower	higher
Availability	higher	lower
Reduction kinetic (see Figure with RINA studies)	Could be reduced by gangue	In general higher
Sticking in DRP	Higher tendency	Lower





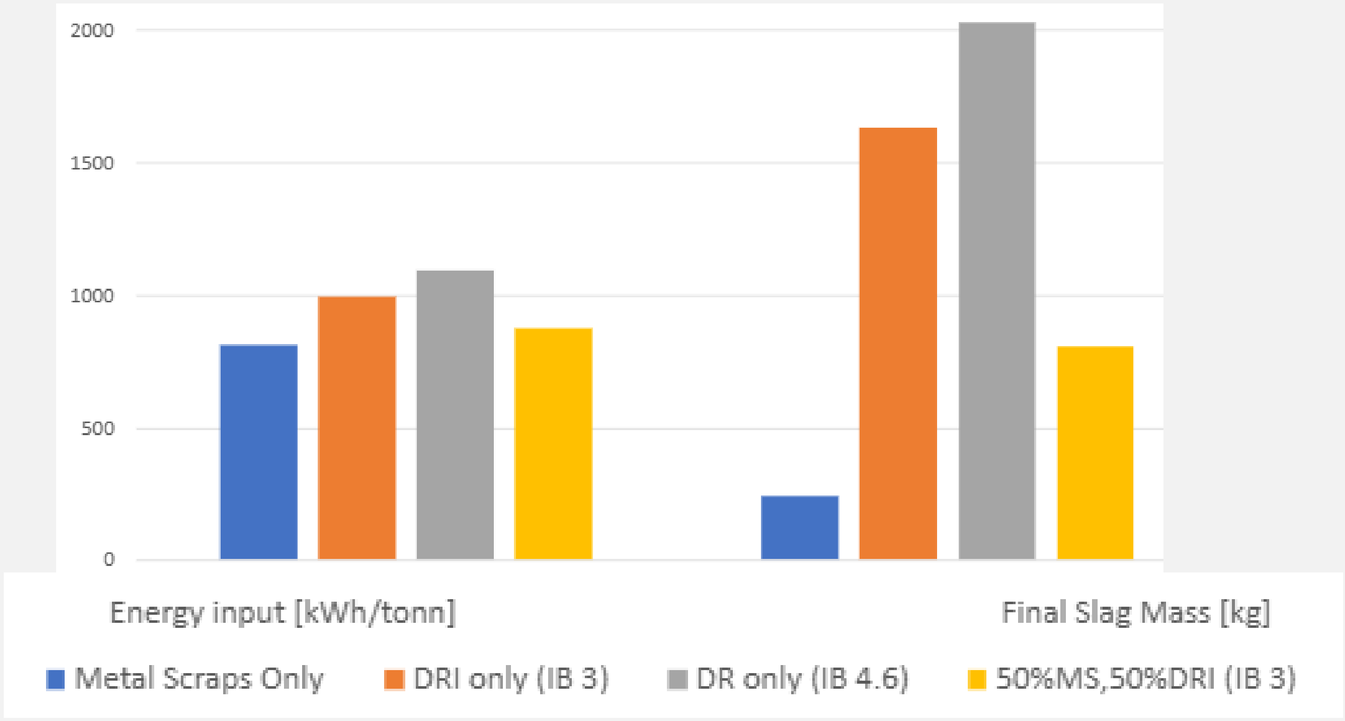
Which is the lowest and acceptable level of Fe content in the pellets?

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

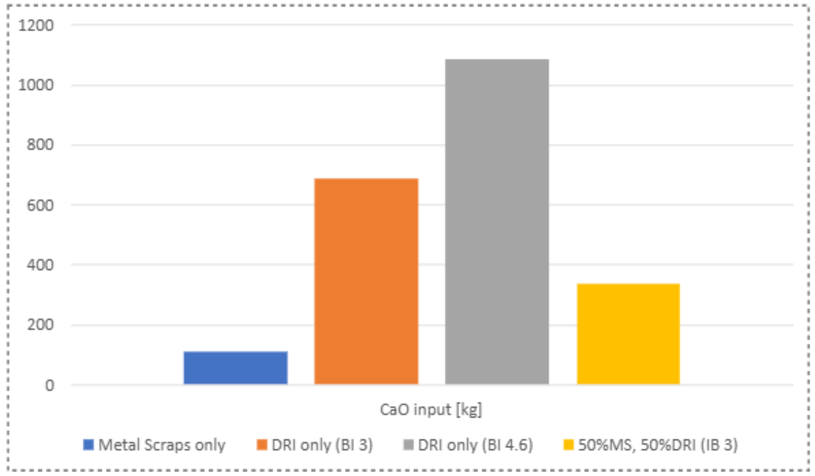
HYDRA – DRI & EAF H2 based steel production – highlights

Quality/availability of input materials (3/3)

EAF process model permitted a first estimation of the energy demand and formed slag and impact of scrap blending



	Metal Scraps Only	DRI only (BI 3)	DRI only (BI 4.6)	50% MS, 50% DRI (IB 3)
CaO input [kg]	110	686.4	1085.76	344.03



Specific pilot EAF energy demand higher respect industrial ones (no foaming and chemical energy used for these first trials heats)

HYDRA – DRI & EAF H2 based steel production – highlights

Pellets vs briquettes

The briquetting process is growing in interest due to:

- Possibility to use iron ore fines
- Reduction of embedded CO2 content due to the firing step in pellets preparation: briquettes are in general cold bonded or moderately heated

<u>The beavhiour of briquettes in reducing process is far from industrial application and requires deeper understanding and testing activity both at lab and pilot scale</u>





https://www.hybritdevelopment.se/en/demonstration-of-fossil-free-production-of-dr-pellets/

https://www.mining.com/web/vale-greeniron-to-explore-decarbonization-projects-in-brazil-sweden/

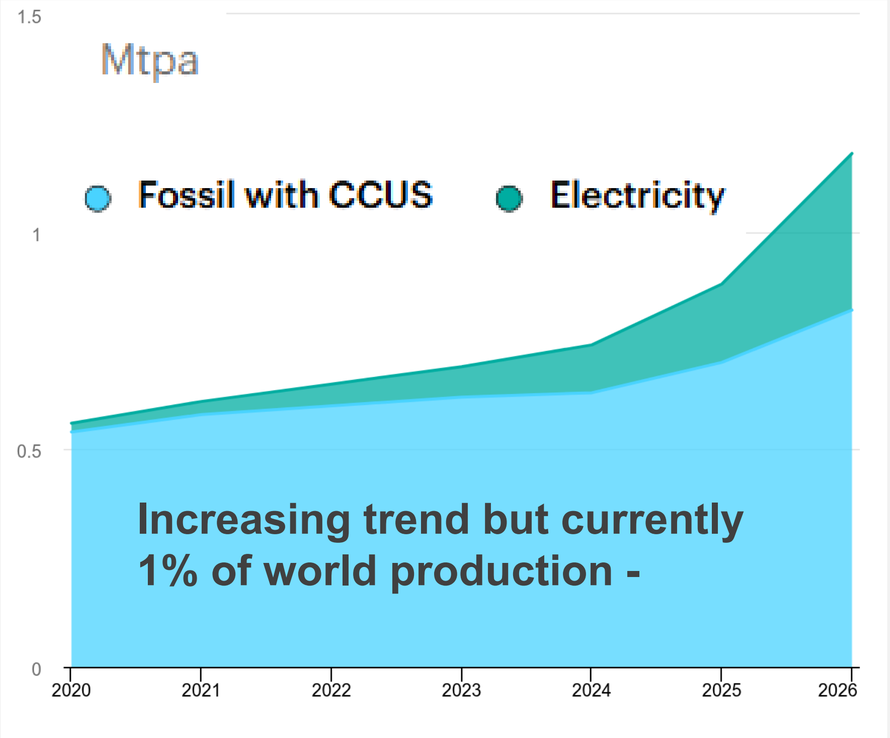
HYDRA – DRI & EAF H2 based steel production – highlights

Direct Reduction with variable H2/CH4 mix

The transition toward H2-DR will be gradual: availability of green hydrogen not yet ensured.
Gas blending is to be used, gradually replaced with H2/CH4/CO mix up to 100% H2

Biogas and other reducing gases (e.g. syngas from waste gasification) to be properly integrated in the process

Low-emissions hydrogen production by technology, 2020-2026 (IEA source)



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

Mass & Energy balance of the process as a whole

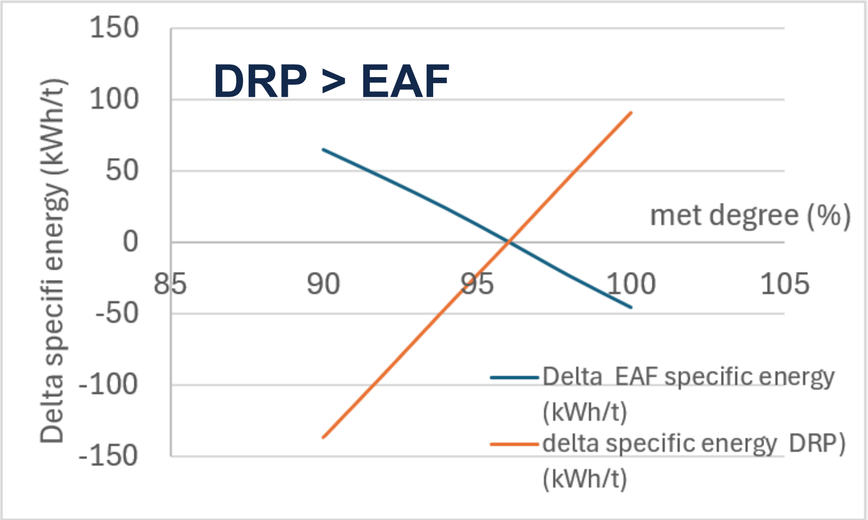
An integrated model of DRP + EAF + Hydrogen production allows to evaluate case by case the impact on energy consumption and CO2 emissions of different working conditions

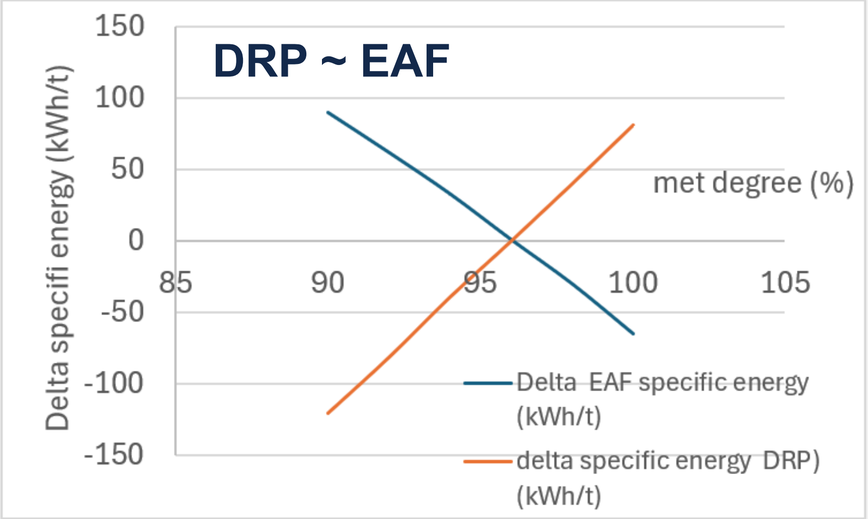
Lower metallization degree reduces the DRP energy demand while increases the energy demand in subsequent EAF step

An optimized DRI carburization process in DRP (minimal CH4 utilization) will increase the CO2 emission in reduction process but will reduce the energy demand in EAF process

An integrated model calibrated with performed tests can be used as Decision Support System (DSS)

Delta Energy vs metallization degree





HYDRA – DRI & EAF H2 based steel production – highlights

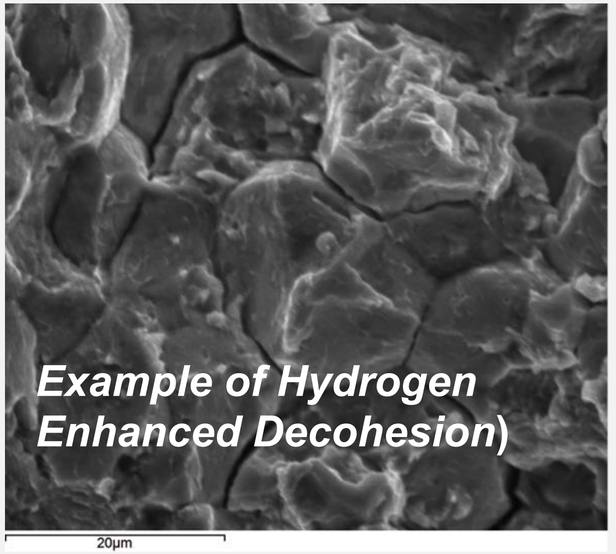
Materials

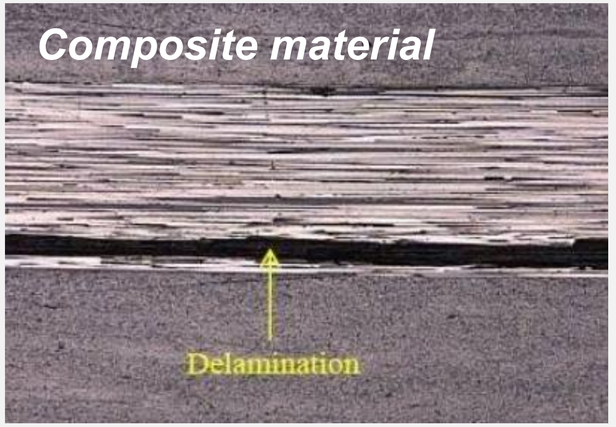
Using variable H2/CH4 mix, pure H2, products of H2 combustion can generate problems for materials life and cost

Identification of technical problems, selection of suitable materials, design and development of new materials (steel, alloys, refractories, composites)

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

Interaction of steel (scale formation) and refractories with H2/H2O atmospheres

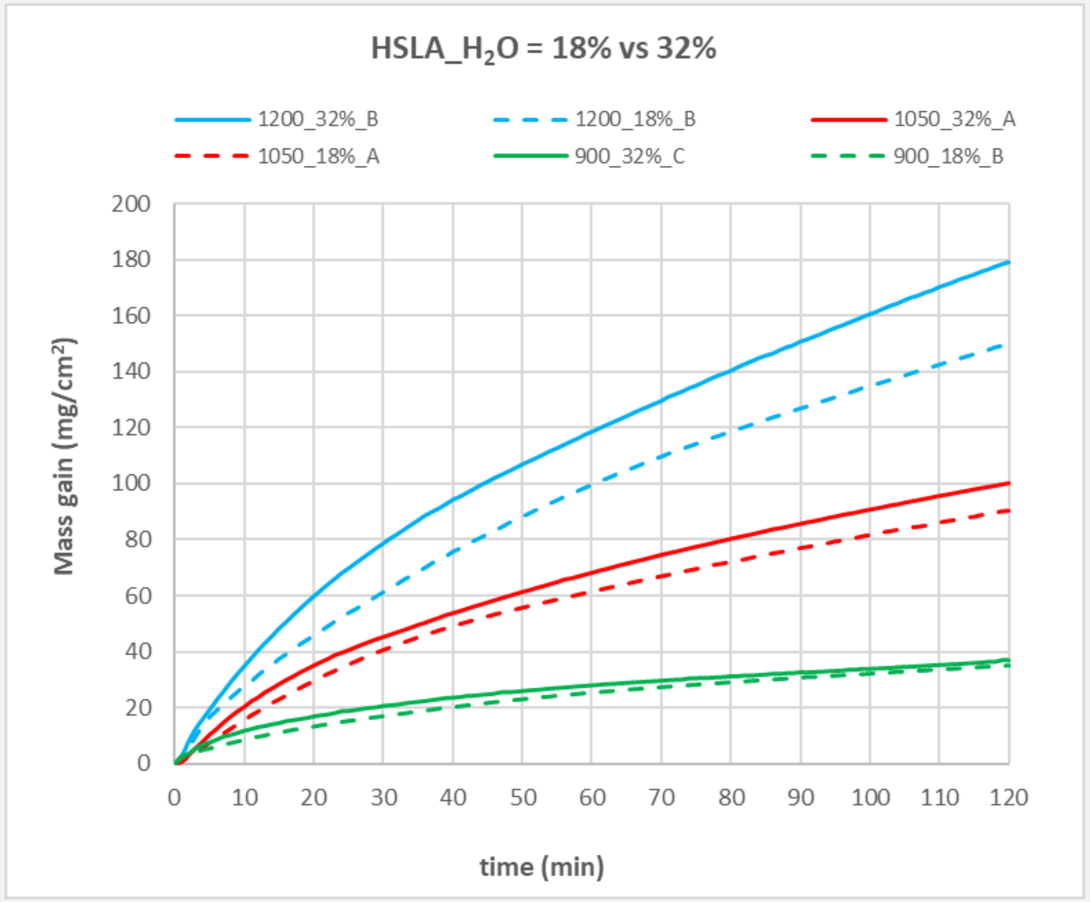


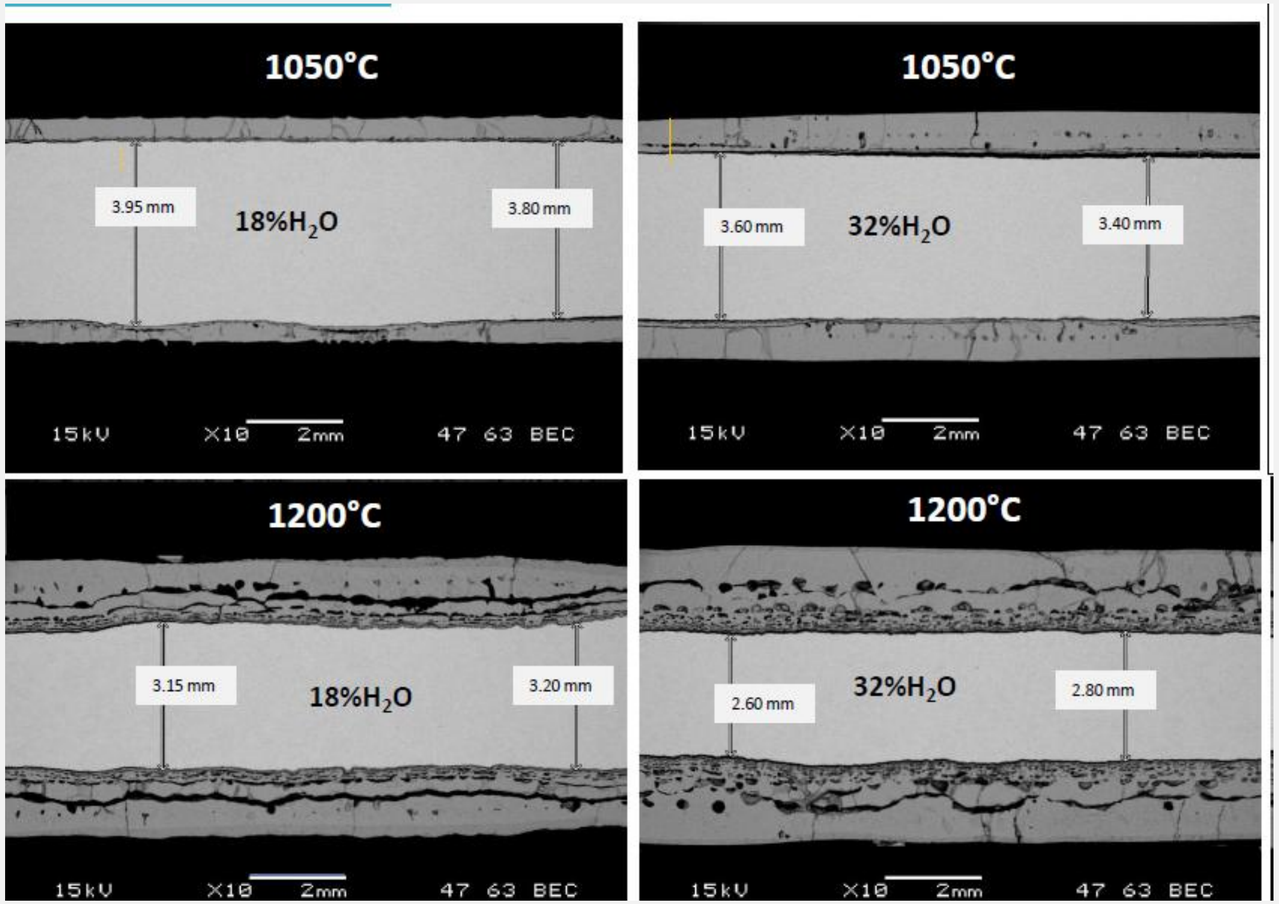


HYDRA – DRI & EAF H2 based steel production – highlights

Kinetic of scale formation comparing methane and hydrogen combustion atmosphere (18% H2O and a32% H2O) at 950°C, 1050°C and 1200°C

Example on low C steel: Scale mass increased of 30% with hydrogen combustion at 1200°C

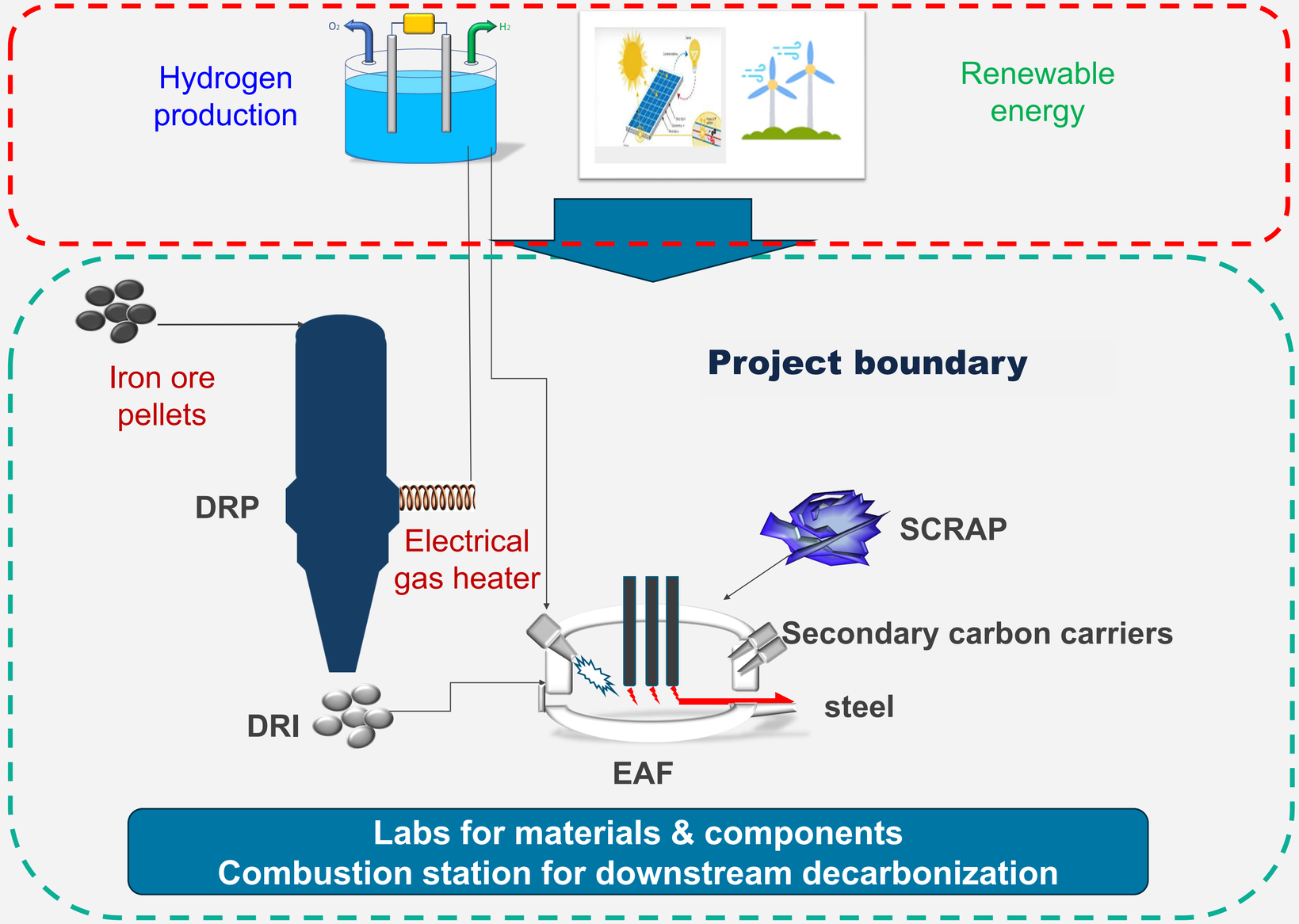




HYDRA – DRI & EAF H2 based steel production – highlights

The pilot platform allows further development of tools and processes:

- Electrical gas heating
- Testing of Hydrogen production technologies (e.g electrolysers, Methane pyrolysis, Biomass gasification)
- Grid management, energy and H2 storage
- CO2 capture technologies
- Innovative sensors and control technologies
- New plant components, materials and refractories
- Testing of new safety devices



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 full operation in 2026 (EAF pilot plant already commisisoned and in operation, DRP commissioning ongoing)

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

- Fully available for tests and customised activity Worldwide



For more info:

Thank you for your attention

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Our experience. Your growth.