

ESTEP 2025 Annual Event

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How decarbonisation, digitisation
and circular solutions forge the
sustainable European steel future?



Funded by
the European Union
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HYDRA PROJECT: STATUS OF ACTIVITIES AND FIRST OPERATIONAL RESULTS



DIGIMET



DANIEMI AUTOMATION



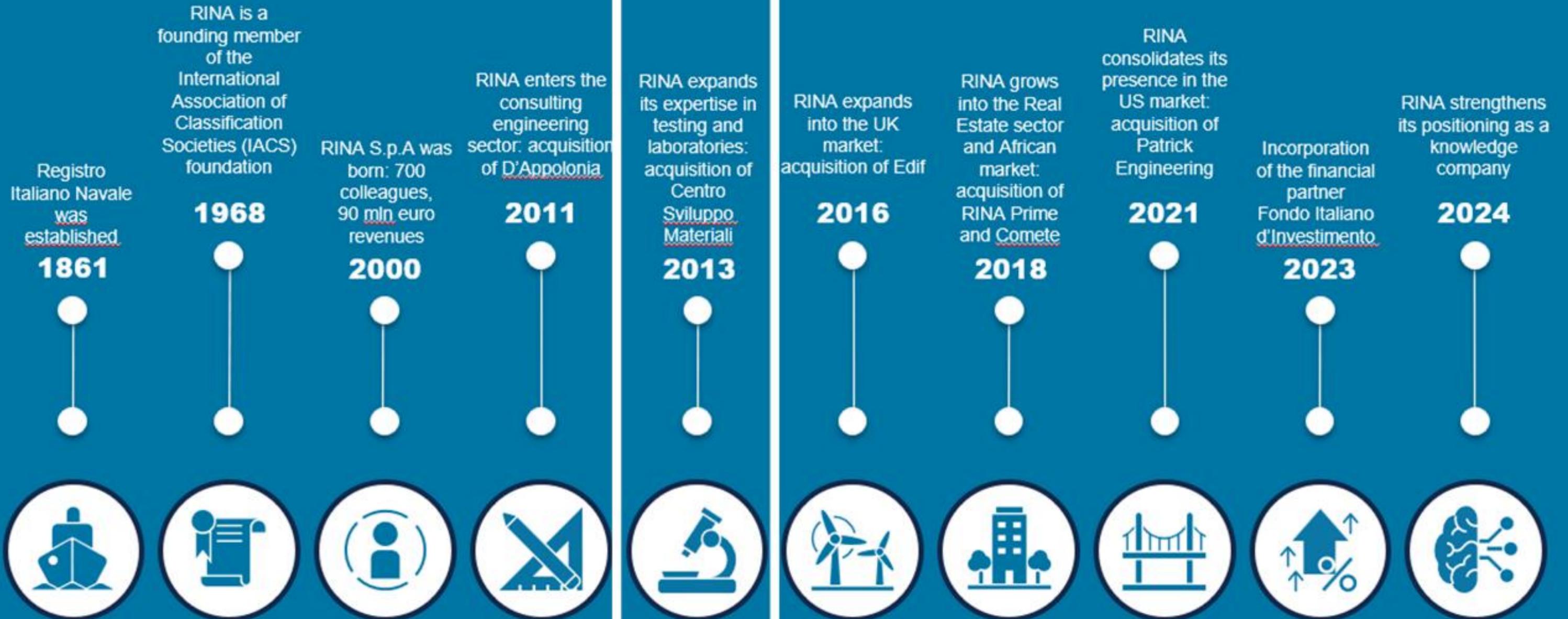
**UNIVERSITÀ
DEGLI STUDI
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A long journey



RINA Today



6,400
colleagues



200
offices



70
countries



>90
nationalities



75%
educated to
degree level



42
average
age



29%
women in STEM
in RINA

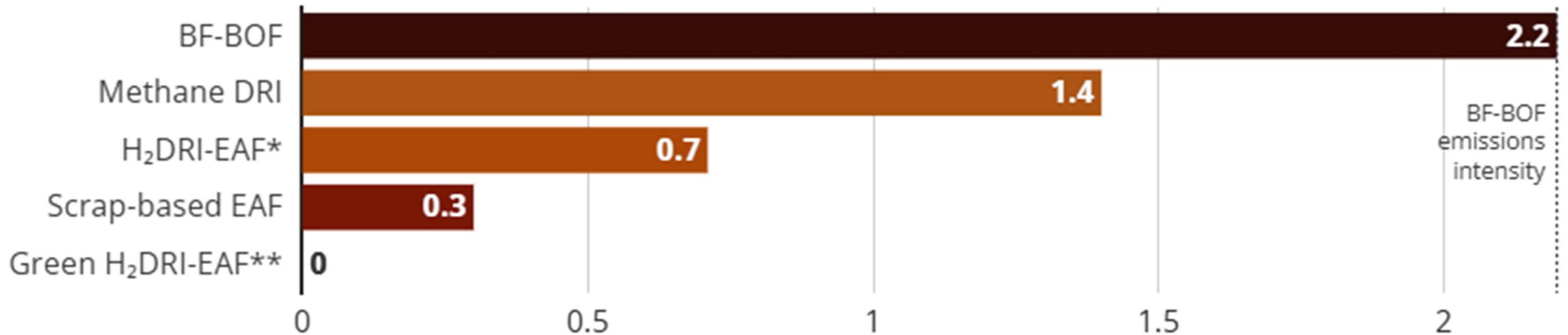


28%
women in managerial
positions

- Steel production decarbonization requires innovative technologies
- This implies alternative iron ore reducing process, new operating practices in the Electric Furnace, new combustion technologies in the downstream processes and fossil substitutes.
- The production route based on DRP-EAF fed by hydrogen is recognized as a valuable alternative to BF-BOF based route (Lowcarbonfuture, GreenSteel..)
- The average age of European Integrated route plant is generally high (average world age 24 years; average age without China 42, according to globalenergymonitor.org)
- The decarbonization target at 2050 is fixed by many States and Companies (complete overview reported in worldsteel publication: Status and Prospects of CCUS Technology in the Iron and Steel Industry)

Int Emissions intensities of select steelmaking production routes

In tonnes CO₂ equivalent per tonne of steel



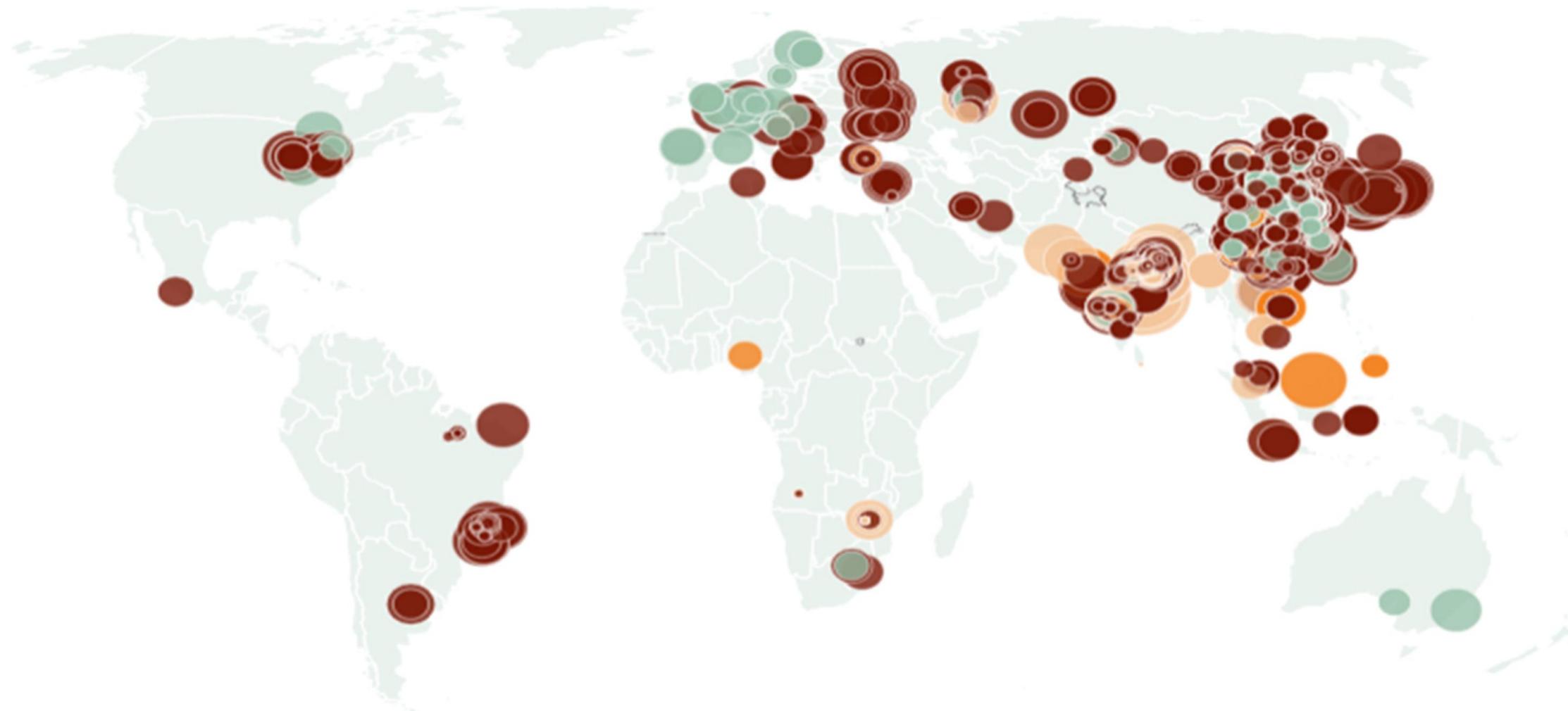
Source: [IEA Iron and Steel Technology Roadmap](#)

*This estimate uses an electricity CO₂ intensity of 144 g CO₂ / kWh, which is the global average CO₂ intensity assumed under the IEA's Sustainable Development Scenario in 2035.

**This near-zero estimate assumes electricity generated by renewables.

90 ttpa ◦ 900 ttpa

■ operating ■ operating pre-retirement ■ construction ■ announced



2.2

BF-BOF
Emissions
Intensity

Global
Energy
Monitor

Source: Global Iron and Steel Tracker, Global Energy Monitor

Note: 'Operating pre-retirement' capacity is currently operating, but has a publicly announced plan for retirement at a future date



Project description



An open R&D facility for **GREEN STEEL** production.

Realised under the IPCEI funding scheme (Important **P**rojects of **C**ommon **E**uropean Interest).



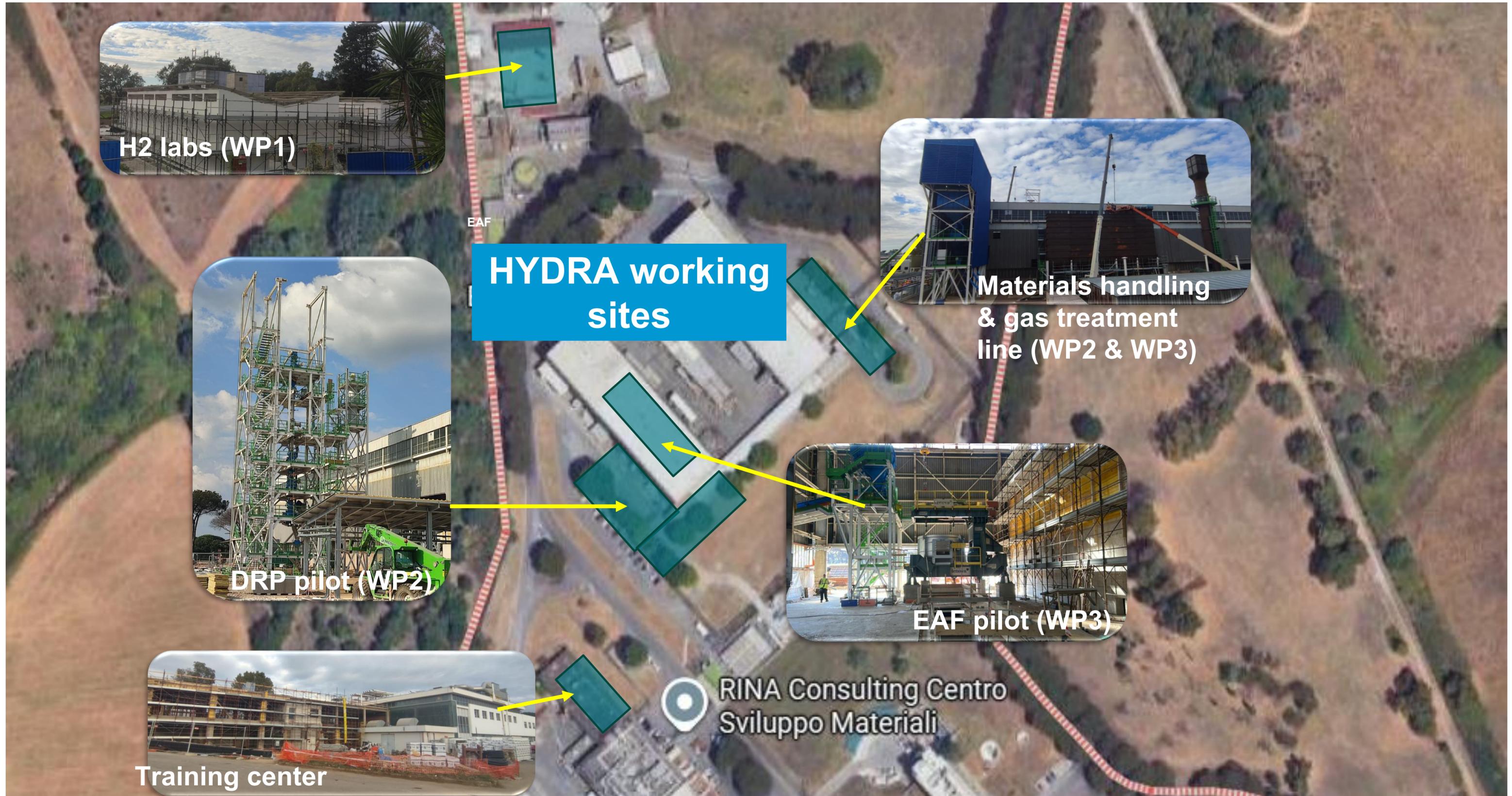
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HYDRA aims at developing an industrial open platform (with pilot plants and labs) in which develop, qualify and validate the use of hydrogen in steel industry.

The platform will support the decarbonization in the steelmaking processes.

Keywords: Hydrogen, flexibility, integrated approach

Project description

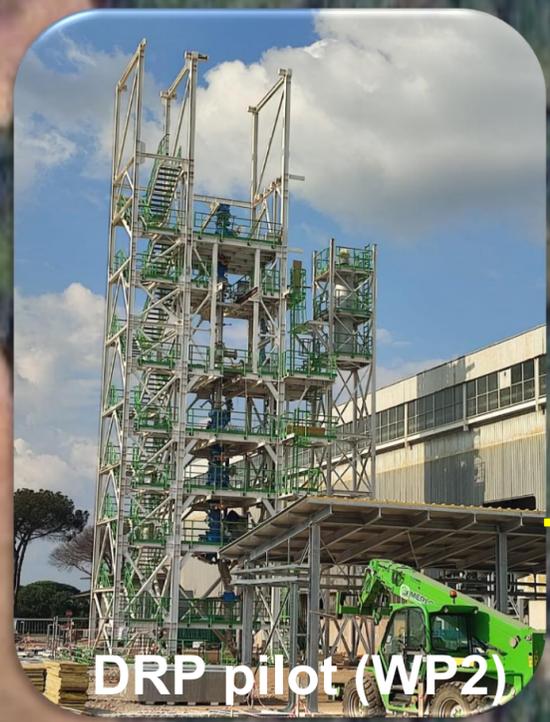


H2 labs (WP1)

HYDRA working sites



Materials handling & gas treatment line (WP2 & WP3)



DRP pilot (WP2)



EAF pilot (WP3)



Training center

RINA Consulting Centro Sviluppo Materiali

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 process metallurgy 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 H₂ within the industrial steelmaking plants
- to give confidence to the steelmakers about the feasibility of introducing H₂ in the industrial steelmaking process
- to evaluate the impact of H₂ percentage in a CH₄/H₂ blended mixture on the industrial steelmaking plant (targeting 100% H₂)
- 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. Main application of the pilot:

- 1) To study the Direct Reduction process under **different process conditions** (e.g with raw materials of different quality, pellets/briquettes, reducing gas blends H₂/CO/CH₄..)
- 2) **Further applications:** process modelling, new physical and virtual sensors, new monitoring strategies, training center

Moreover, the pilot plant will make tailored production batches for the 'subsequent' melting furnace

Project description



The ENERGIIRON Technology has been selected for the HYDRA project

The plants (DRP & EAF) are supplied by Tenova

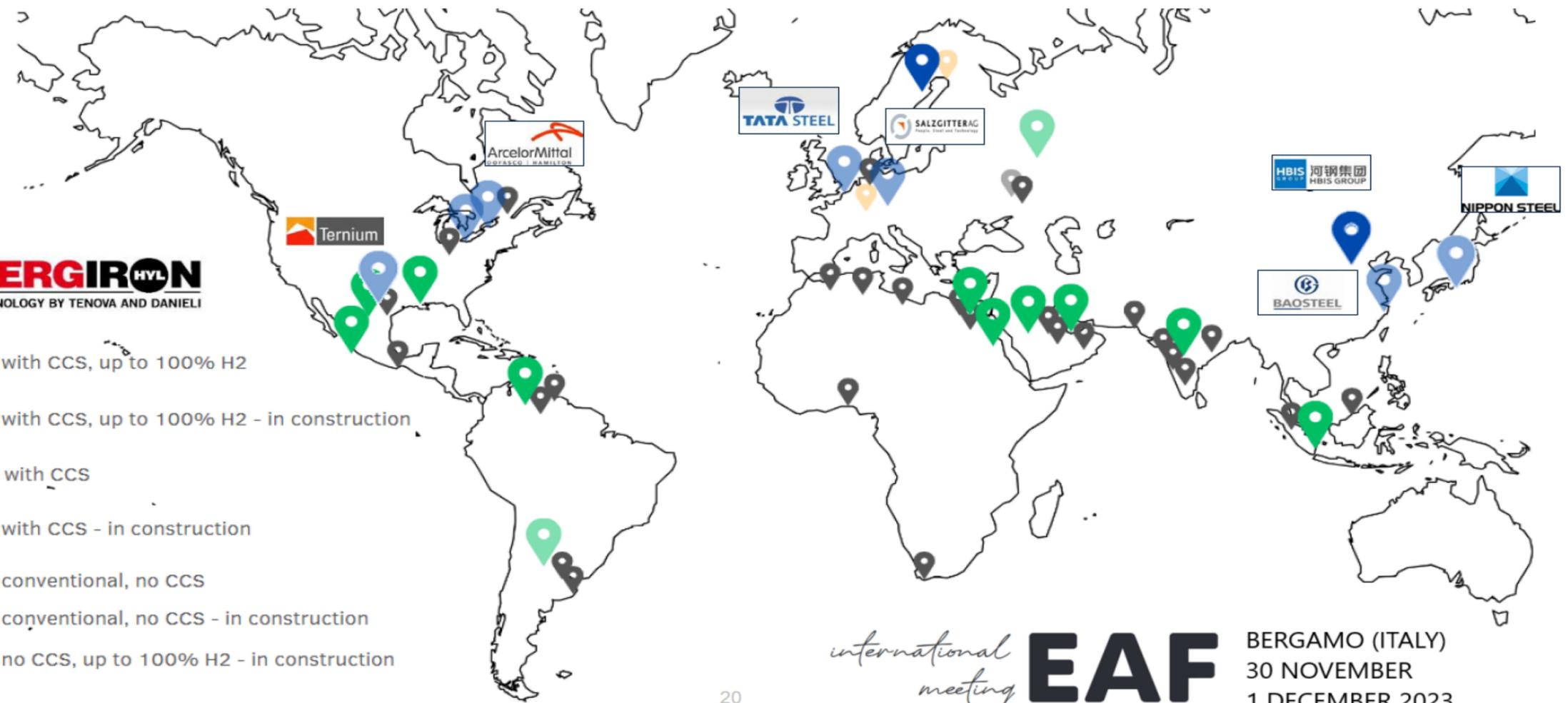
Plant erection by Danieli

Gas company Sapiro



ENERGIIRON
DRI TECHNOLOGY BY TENOVA AND DANIELI

- with CCS, up to 100% H2
- with CCS, up to 100% H2 - in construction
- with CCS
- with CCS - in construction
- conventional, no CCS
- conventional, no CCS - in construction
- no CCS, up to 100% H2 - in construction



WP2

appl

1) T

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C

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2) F

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S

tr

DRP tower of about 30 m height

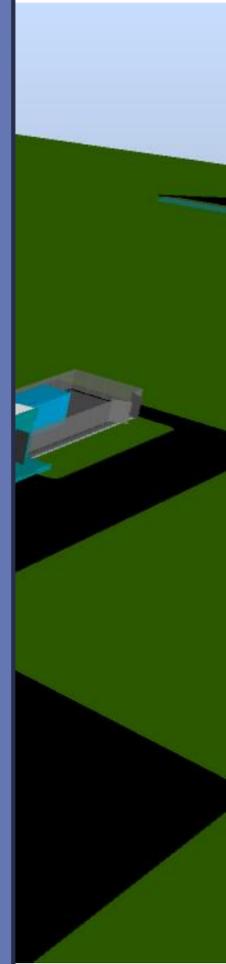
100 kg/h DRI produced (about 2 t per day)

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

Gas treatment line equipped with CO2 capture

Scrap charging and continuous DRI charging

NG injection in the lower part of the furnace



Moreover, the pilot will make tailored production batches for the ‘subsequent’ melting furnace in the pilot line.

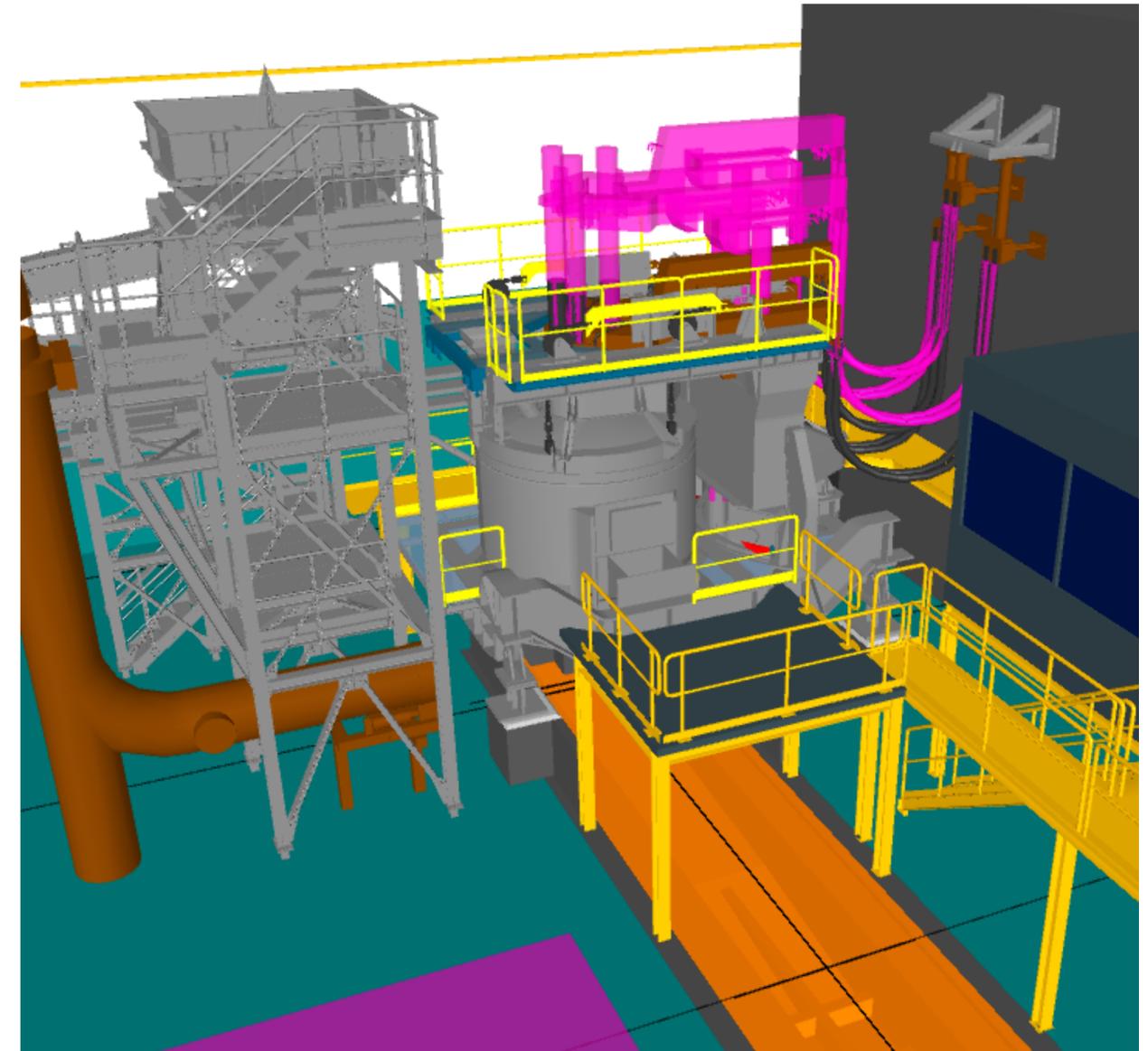
WP3 is focused on the DRI melting will be investigate with a state- of-the-art electrical furnace pilot plant, of capacity of **7 t/heat**. Main applications of the pilot:

DRI melting (energy demand, slag practice
Oxygen practice)

Energy input by hydrogen burning

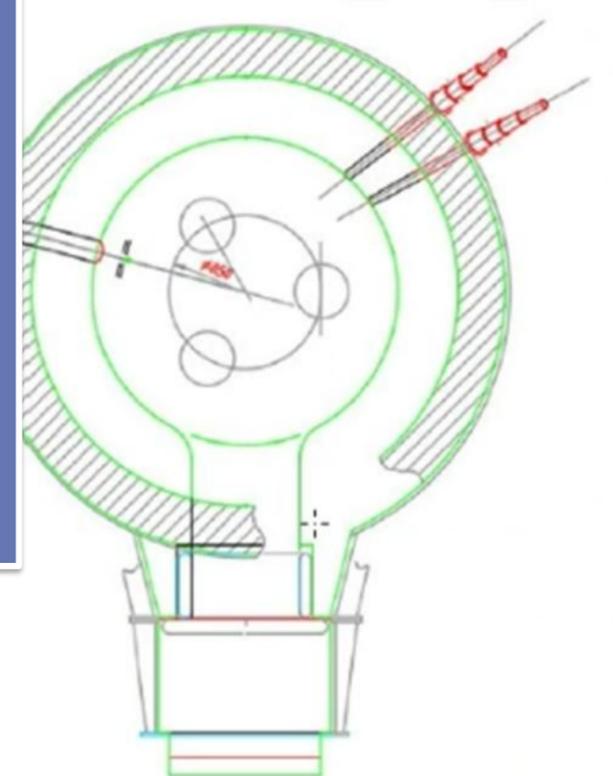
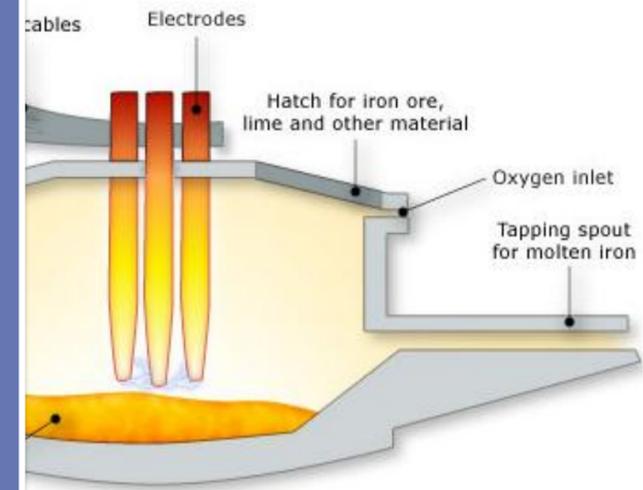
Bath carburization and foaming practice with
tailored pneumatic system and injection lances

Further applications: process modelling, new
physical and virtual sensors, new monitoring
strategies, training center



Main characteristics of the furnace are:

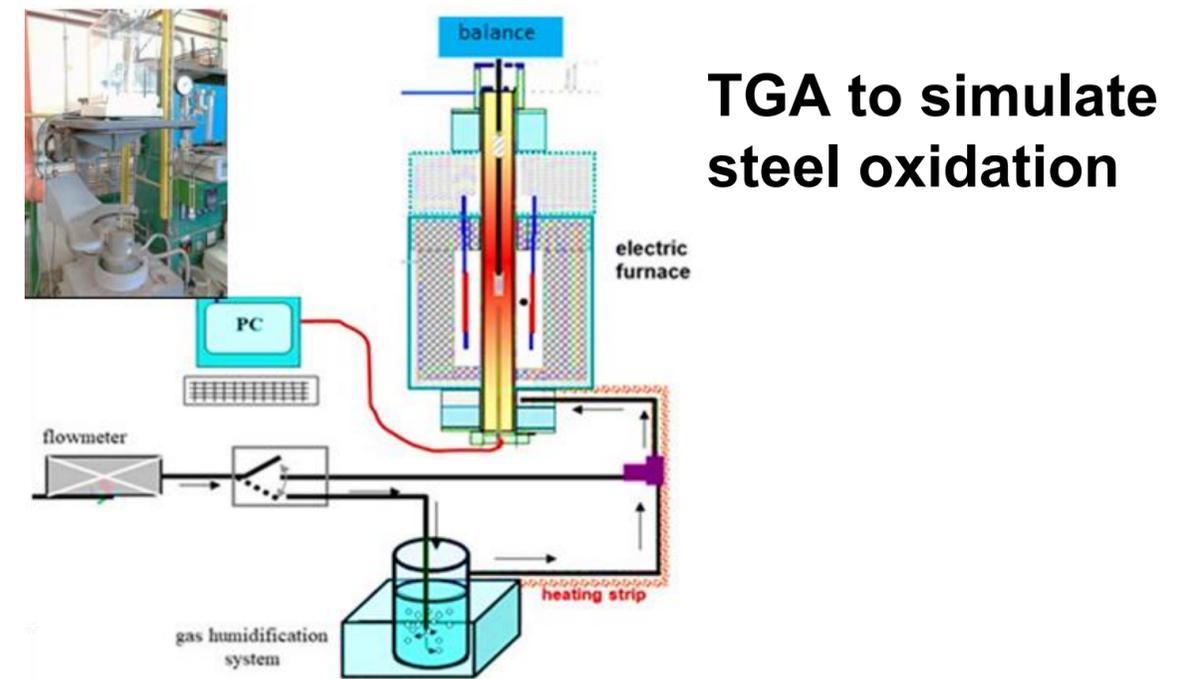
- 7 t capacity, with 4 m³ internal volume
- AC three electrodes
- Scrap and DRI charge
- Continuous charging of DRI
- Injection of solid materials (additive, coal, alternative carbonaceous materials)
- KT lance working as Hydrogen burner or Oxygen injector
- Furnace shell refractory insulated



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 H₂ combustion both on the products quality and performance/life of the plant components



HYDRA first results



- Kinetic studies of pellets reduction: 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 and scenario analysis: just started
- Two graduate thesis ongoing and one concluded
- Engagement with other IPCEI participants launched to enable cross-project synergies and spillover effects.

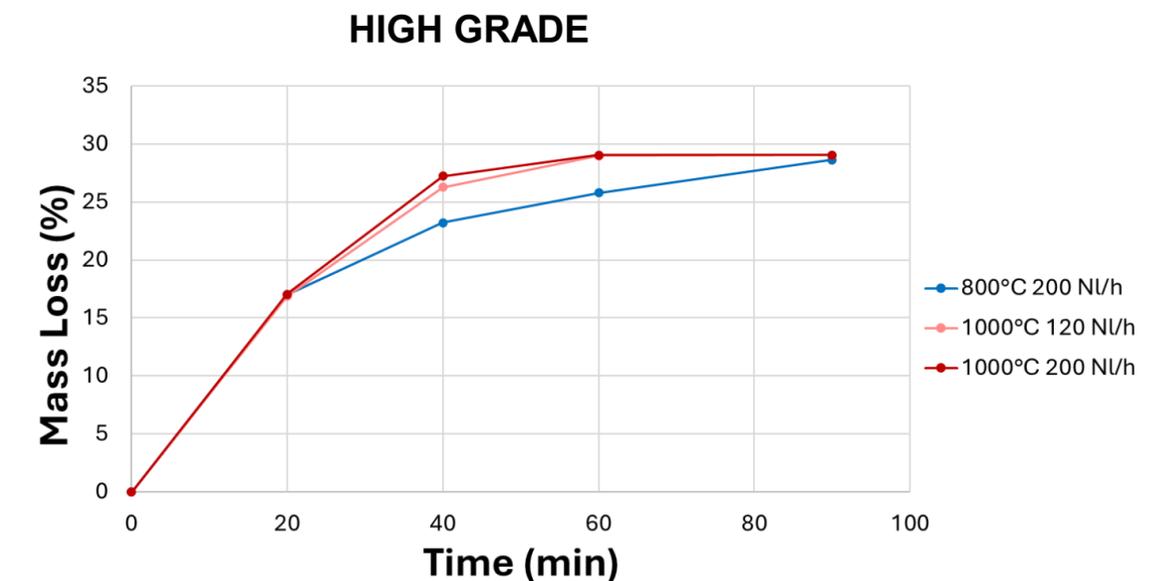
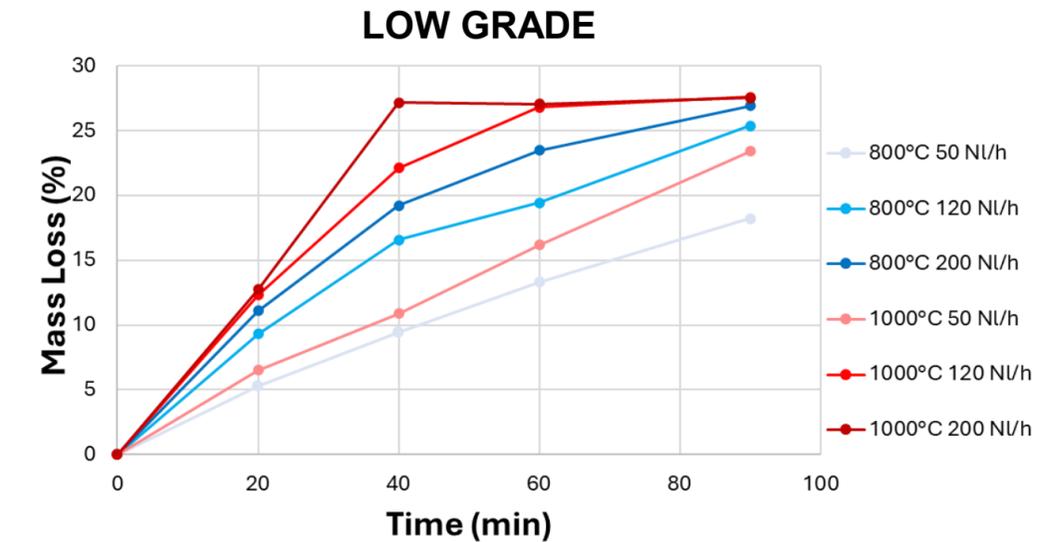
HYDRA first results



WP2 - Kinetic studies of pellets reduction

- Investigated pellets materials: low grade (Fe 64%, SiO₂ 5%) and high grade (Fe 67%, SiO₂ 2%)
- Atmospheres: pure hydrogen at three different flowrates (velocity)
- Temperatures 800°C, 1000°C, 1200°C
- Time from 20 to 90 minutes

- Significant dependency of reduction kinetic on all operating parameters with hydrogen flow rate and residence time playing a significant role.
- High grade material shows faster kinetic and less dispersion of data
- Porosity requires further investigation (analysis with Micro CT ongoing)



First results: (WP4) Impact of hydrogen combustion atmosphere on steel oxidation, descaling and annealing and pickling

Results from annealing tests simulating industrial thermal profiles and NG/H₂ combustion atmosphere reported as representative example

| Gas mix | 100% GN | 100% H ₂ |
|------------------|---------|---------------------|
| | % | |
| O ₂ | 2 | 2 |
| CO ₂ | 9 | 0 |
| N ₂ | 71 | 66 |
| H ₂ O | 18 | 32 |

Furnace atmosphere



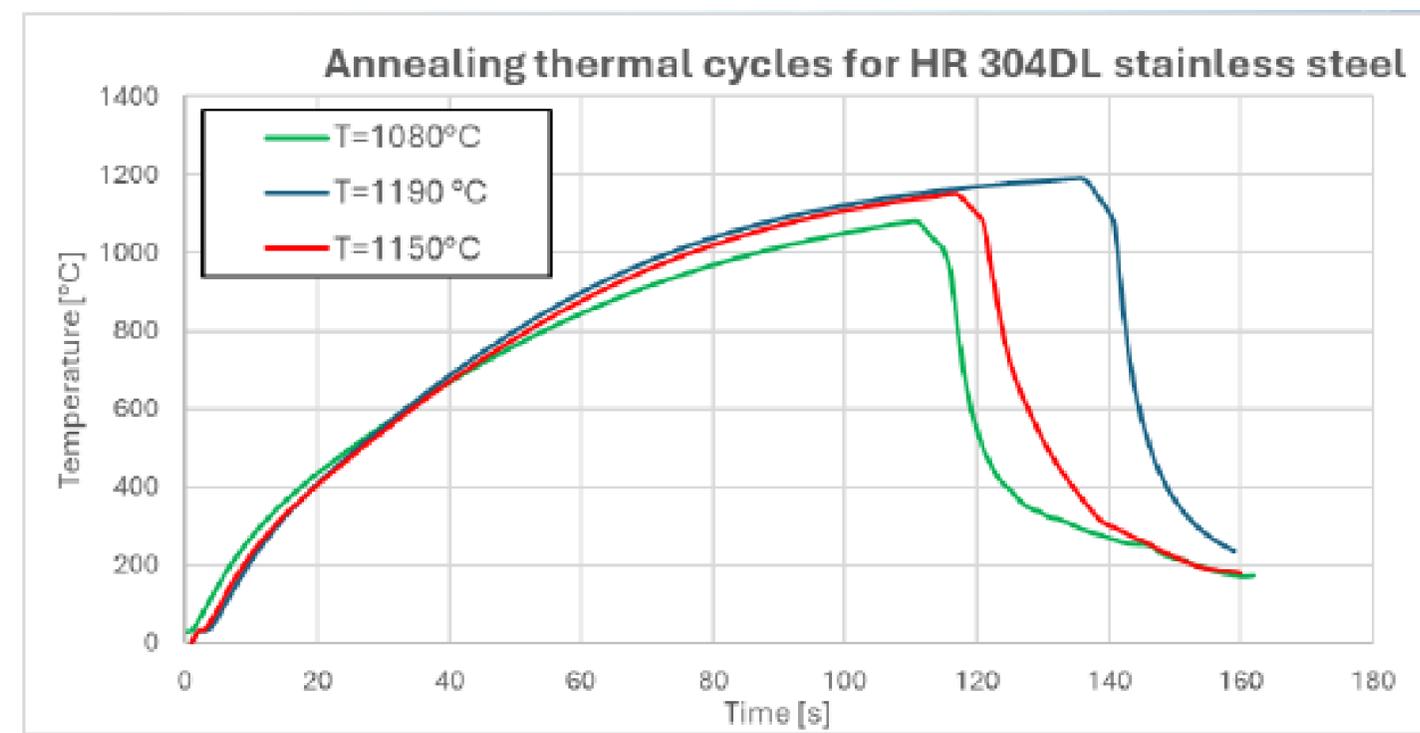
Horizontal furnace used for the tests

First results: (WP4) Impact of hydrogen combustion atmosphere on steel oxidation, descaling and annealing: experimental conditions

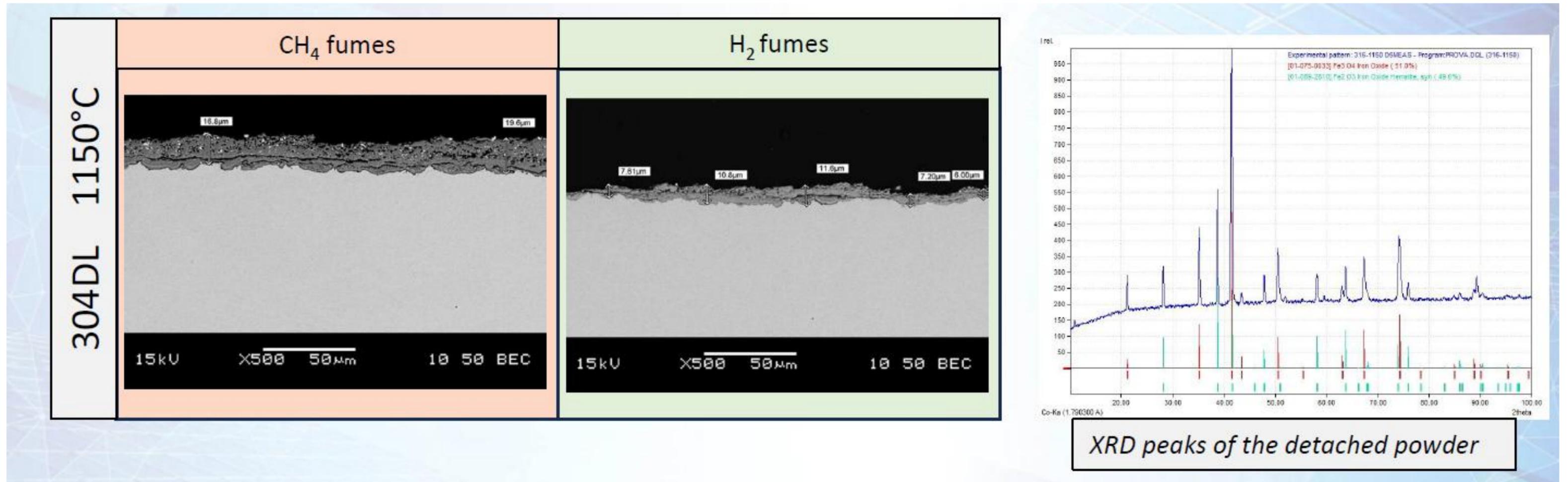
Two austenitic grades and one ferritic grade were selected both in the **Hot and Cold Rolled** state

| Steel Grade | Cr | Ni | Mo | Si | Mn | Ti | Nb | Cu |
|-------------|----|-----|-----|------|-----|------|------|-----|
| AISI 316L | 17 | 10 | 2 | 0.34 | 1 | - | - | 0.4 |
| AISI 304DL | 18 | 8 | 0.3 | 0.45 | 1 | - | - | 0.5 |
| Type 441 | 18 | 0.2 | - | 0.55 | 0.2 | 0.10 | 0.37 | - |

Three thermal cycles were adopted at increasing maximum temperature and time for the three steel grades



First results: (WP4) Impact of hydrogen combustion atmosphere on steel oxidation.
descaling and annealing: experimental conditions

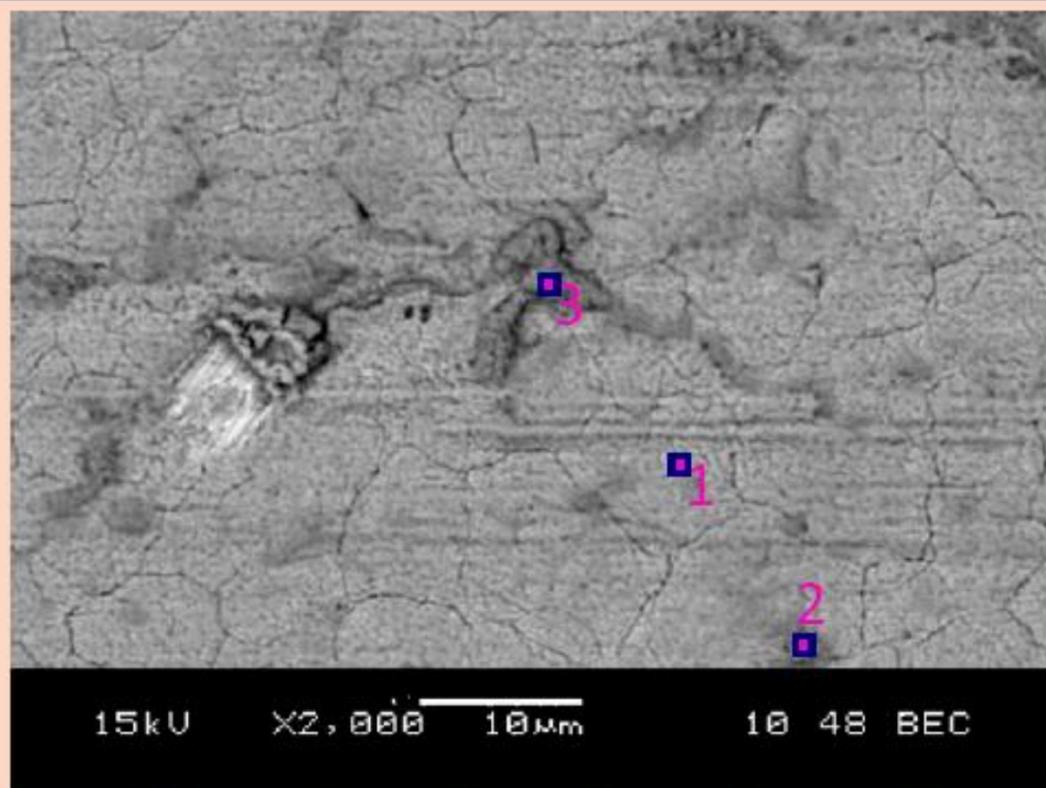


For 304DL and 316L, section SEM observation show that oxide thickness spans between 8 μm and 20 μm
During cooling a significant scale detachment took place only for H₂ flue gases annealing
The detached powder was analyzed by XRD revealing that it was mainly hematite and magnetite

No significant difference was found in terms of scale thickness for samples annealed in CH₄ fumes or H₂ fumes

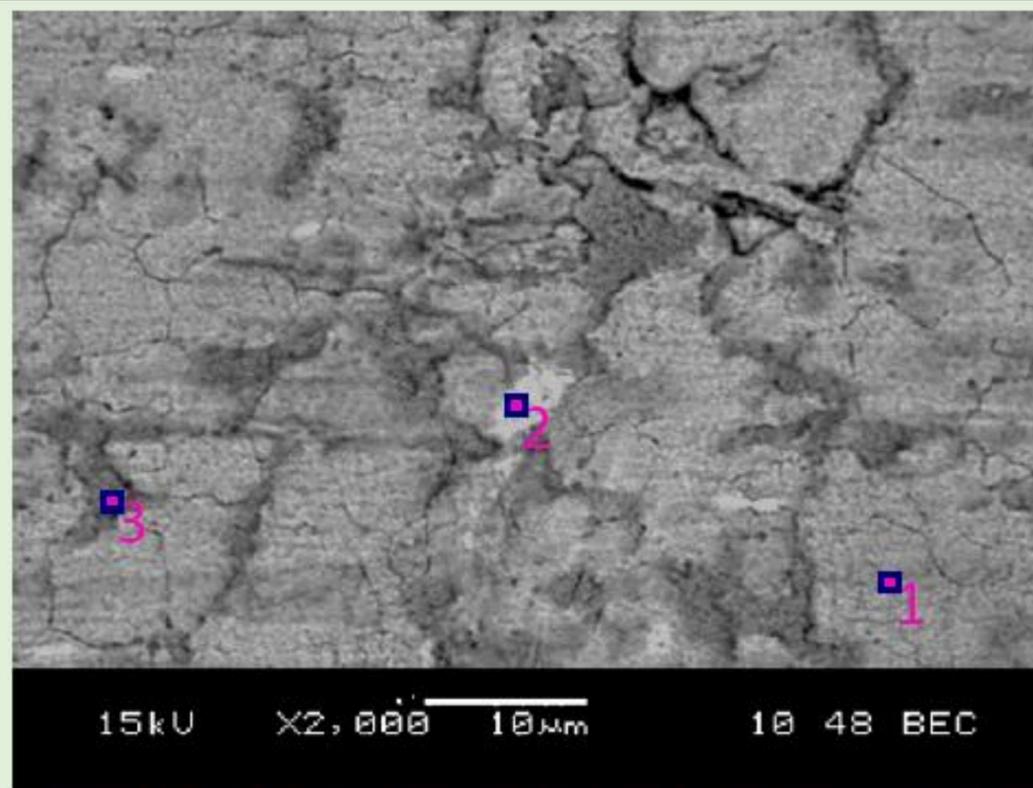
First results: (WP4) Impact of hydrogen combustion atmosphere on steel oxidation. descaling and annealing: experimental conditions

304DL– 1150°C - CH₄ fumes



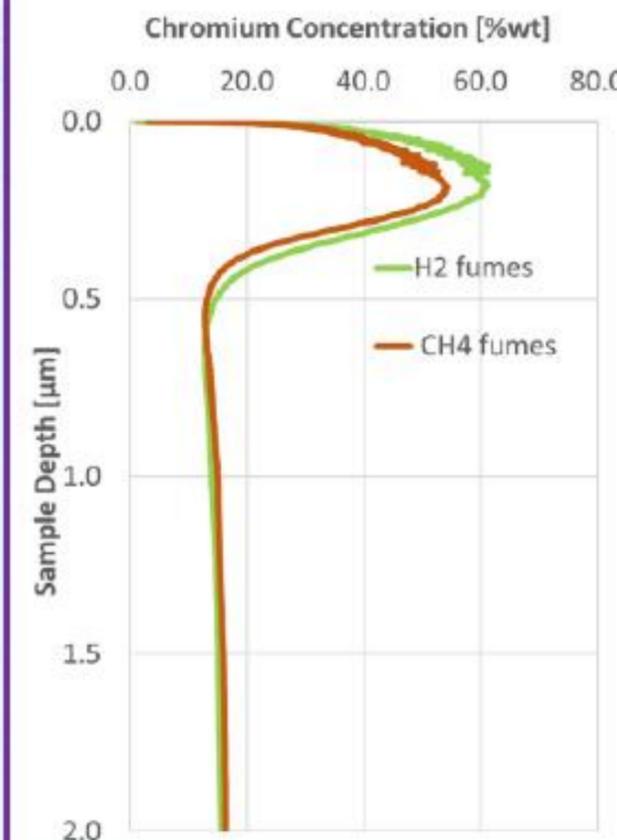
| (%wt) | O | Si | Cr | Fe | Ni | Mo |
|-------|----|------|----|----|----|----|
| Sp. 1 | 6 | 0.46 | 24 | 62 | 7 | |
| Sp. 2 | 16 | | 39 | 43 | 2 | |
| Sp. 3 | 18 | | 10 | 73 | | |

304DL – 1150°C – H₂ fumes



| (%wt) | O | Si | Cr | Mn | Fe | Ni | Mo |
|-------|----|-----|----|----|----|----|-----|
| Sp. 1 | 2 | 0.8 | 18 | 2 | 69 | 8 | |
| Sp. 2 | 1 | 0.1 | 13 | 1 | 75 | 9 | 0.4 |
| Sp. 3 | 13 | 0.5 | 27 | 4 | 49 | 5 | 0.4 |

GDOES

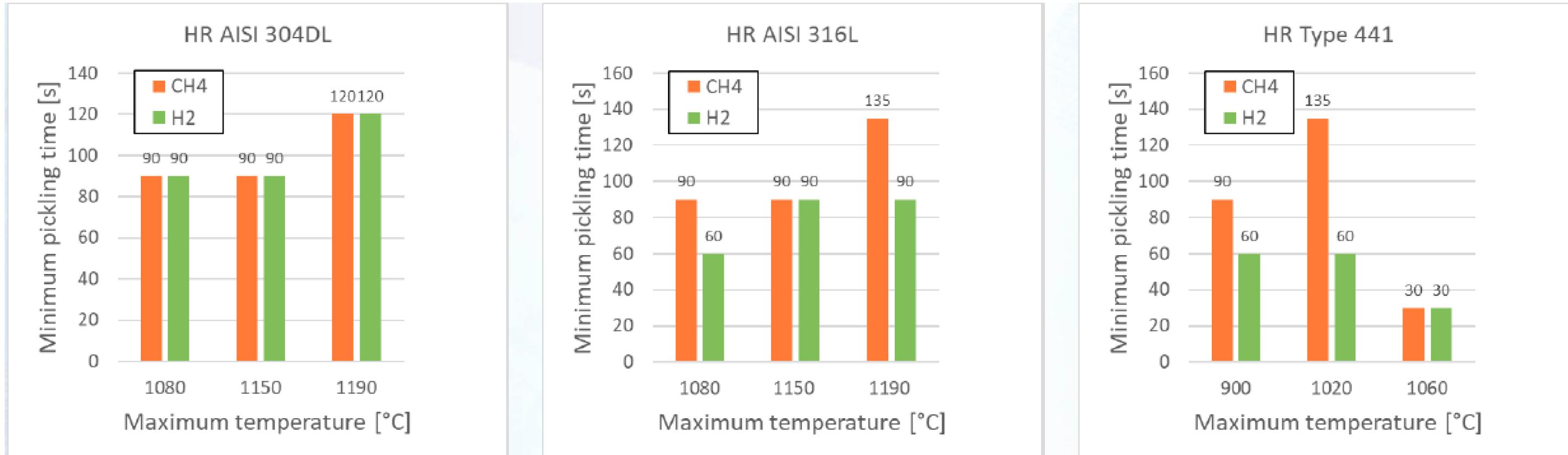


- Scale is very thin and constituted mainly by Chromium oxides
- Some dark smudges made of Iron oxides are found. On H₂ samples the number of smudges is greater
- No significant difference in Cr-depletion was observed

First results: (WP4) Impact of hydrogen combustion atmosphere on steel oxidation, descaling and annealing: experimental conditions



Pickling in sulfuric and H₂SO₄/HF acid to assess the minimum pickling time and the surface quality for hot rolled samples



Samples annealed in atmosphere simulating H₂ combustion:

require **shorter** or same pickling time

no effect on the total weight loss for **austenitic** steel grades

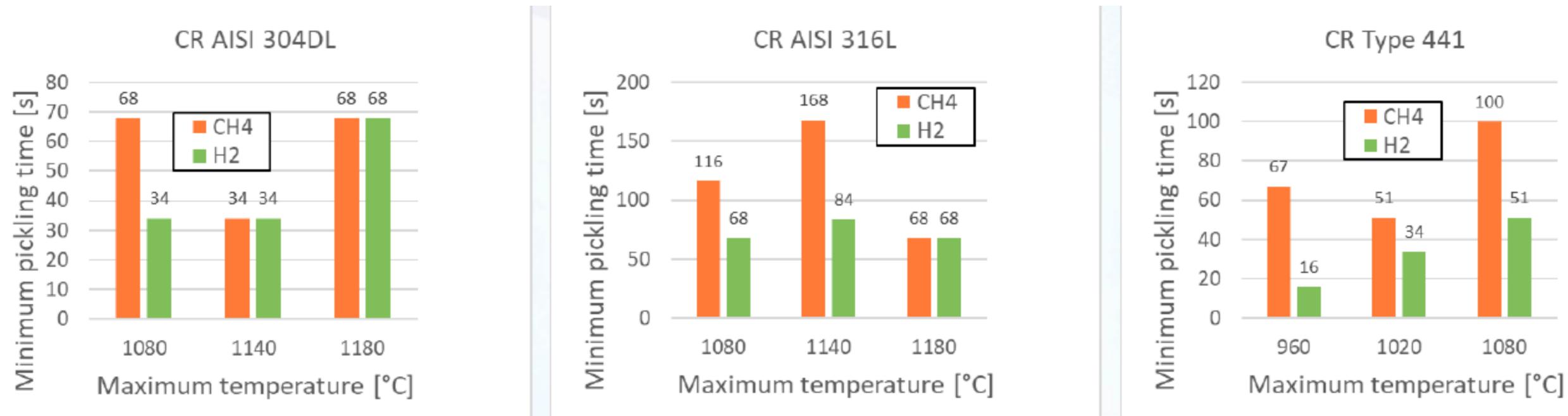
reduced descaling weight loss (due to spallation during annealing) for 441

In general chemical pickling weight loss was never significantly affected by the change of atmosphere

First results: (WP4) Impact of hydrogen combustion atmosphere on steel oxidation.
descaling and annealing: experimental conditions



Pickling in sulfuric and H₂SO₄/HF acid to assess the minimum pickling time and the surface quality for cold rolled samples



Samples annealed in atmosphere simulating H₂ combustion:
shorter or same pickling time as samples annealed in CH₄fumes.

slight increase in weight loss for **austenitic** steel grades

- For 441 annealing in H₂ fumes **reduced** pickling weight loss
- For austenitic grades weight loss increased with annealing temperature

First results: (WP4) Impact of hydrogen combustion atmosphere on steel oxidation.
descaling and annealing: experimental conditions



Conclusion

- HR samples showed minor differences in oxidation or chromium depletion due to the preexisting, thick, tertiary rolling scale
- CR samples showed the formation of iron oxide clusters when annealing at intermediate or high temperature, testifying the more oxidizing nature of Hydrogen fumes
- Pickling time remained roughly the same for both HR and CR when switching from CH₄ to H₂
- Chemical pickling weight losses did not change for HR samples and only slightly increased for CR samples
- Scale spalling during cooling was detected for samples annealed in H₂ fumes

General conclusions

- The HYDRA project is aimed to support steel decarbonization with integrated approach
- The experimental facilities will be in operation end of 2025-beginning of 2026
- iron ore reduction kinetic tests performed and hydrogen combustion impact on scale formation (reheating and annealing) carried out
- Tailored activity to support downstream decarbonization started
- Degree thesis ongoing (this amount expected to grow in 2026)
- Experimental campaigns at pilot facilities will start in spring 2026

QUESTIONS & ANSWERS

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**THANK YOU
FOR YOUR
ATTENTION**



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