ESTEP SPRING DISSEMINATION EVENT

5-6 JUNE 2025 KRAKOW (POLAND)

Investigation of the use of hydrogen as reducing agent in the Direct Reduction of low-grade iron ore pellets

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ESTEP

HOTEL ★★★★ GALAXY JORDAN GROUP

Łukasiewicz GIT

Introduction: Hard-to-abate sectors

Sector	Annual production (Italy)	Specific CO_2 emissions kg/t product	Source
Steel (BF)	4Mt	1900	BCG, Steel's contribution to a low carbon Europe, 20
Steel EAF	16Mt	455	BCG, Steel's contribution to a low carbon Europe, 20
Glass	5Mt	330	Rapporto di sostenibilità di ASSOVETRO 2020
Cement	13.4Mt	800	Cembureau, 2019, Cementing the European Green Deal

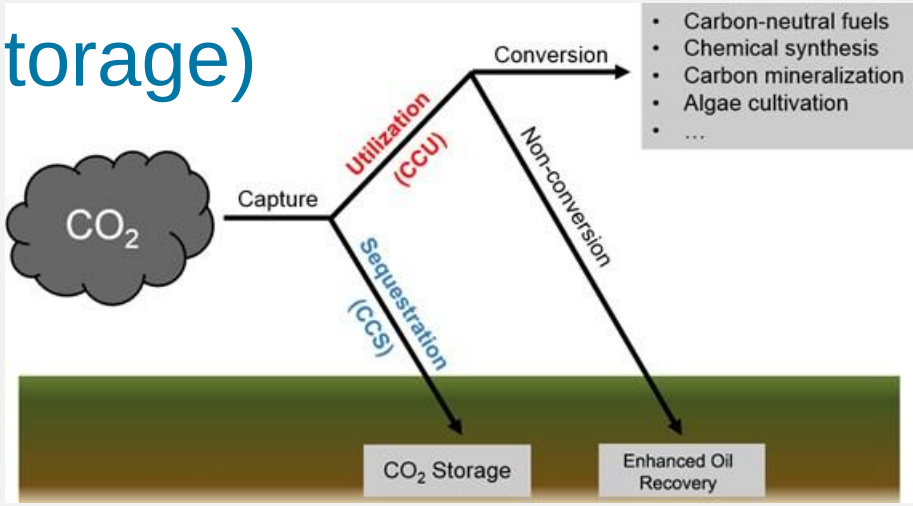
Blast Furnace (BF)

Electric Arc Furnace (EAF)

Introduction: Decarbonization strategies

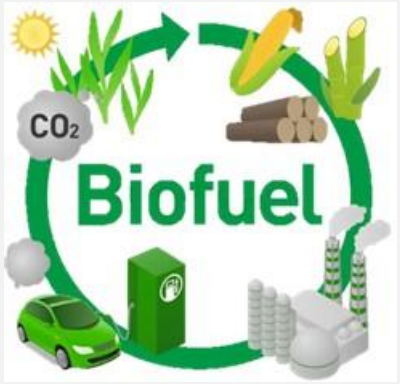
Every year 53 Mt of CO_2 are emitted by hard-to-abate sector in Italy and 80 % could be potentially removed by:

- **CCUS** (Carbon Capture, Utilization and Storage)

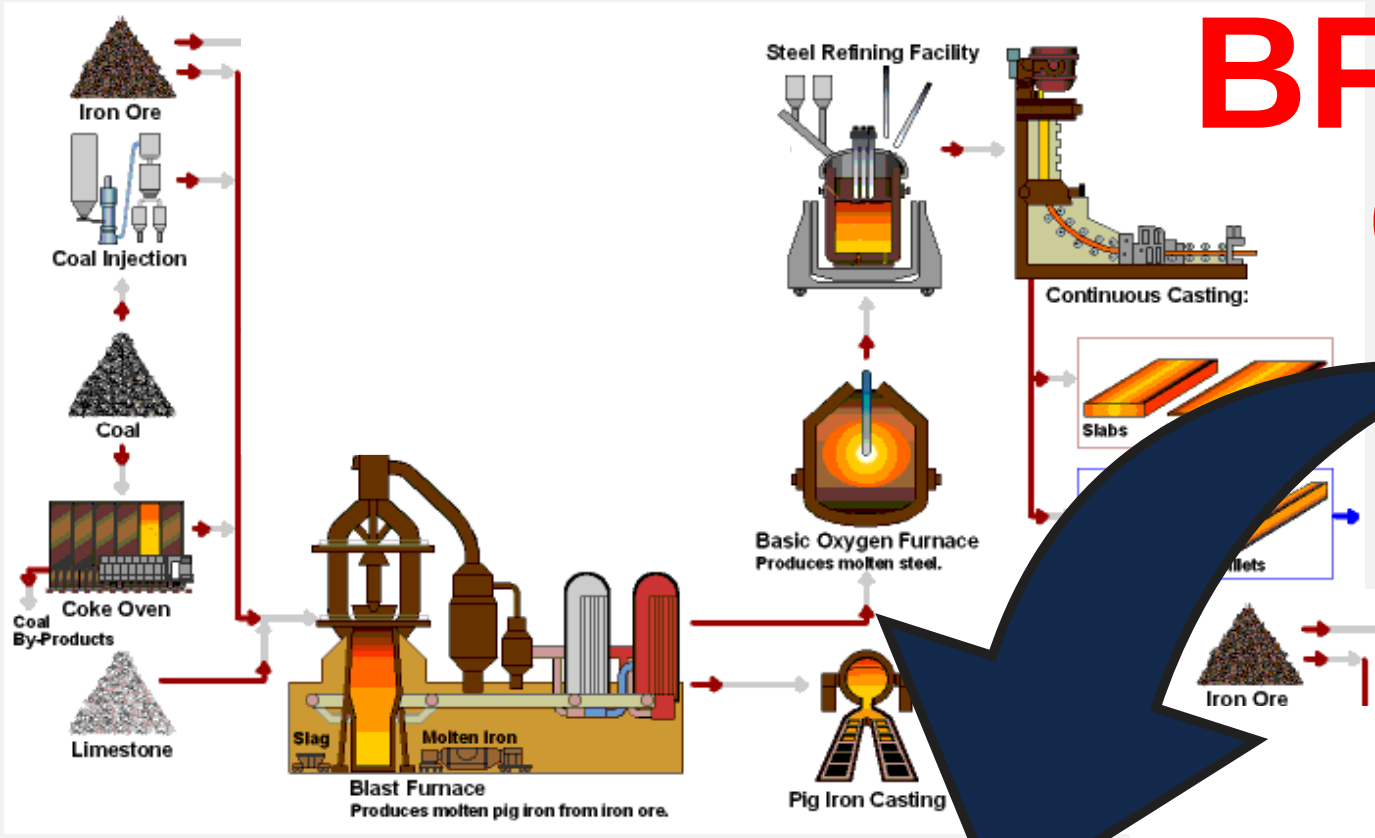


- **Electrification**

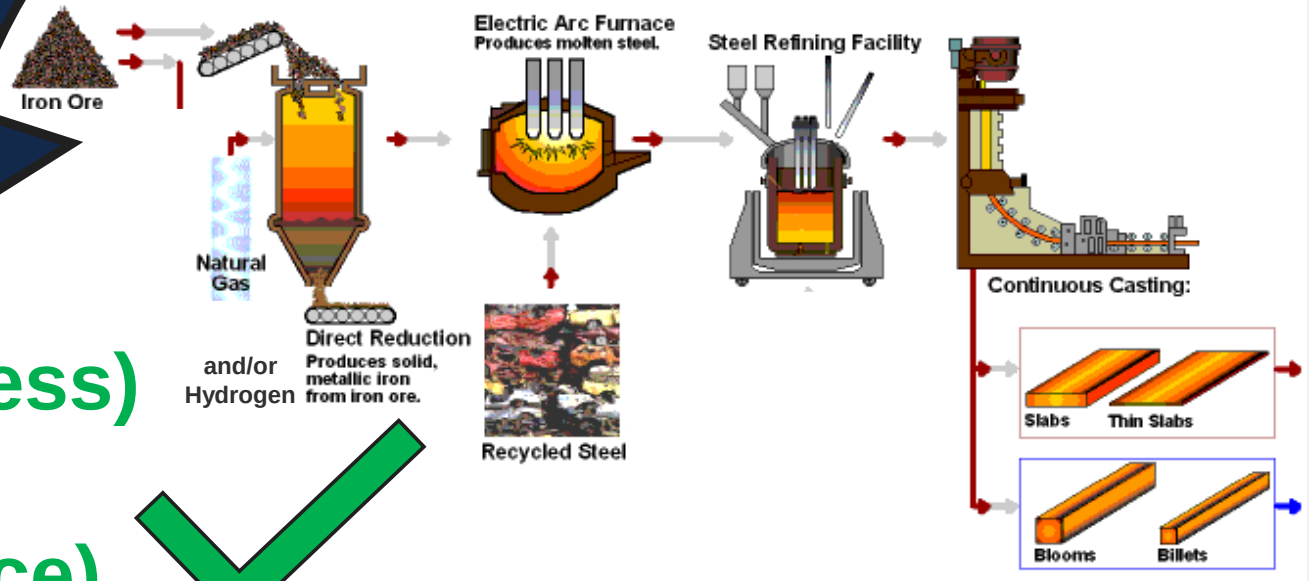
- **Green fuels**



Introduction: Hydrogen in the Steel Sector



BF (Blast Furnace) + BOF (Basic Oxygen Furnace)



DRP (Direct Reduction Process)

+ EAF (Electric Arc Furnace)

The HYDRA Project

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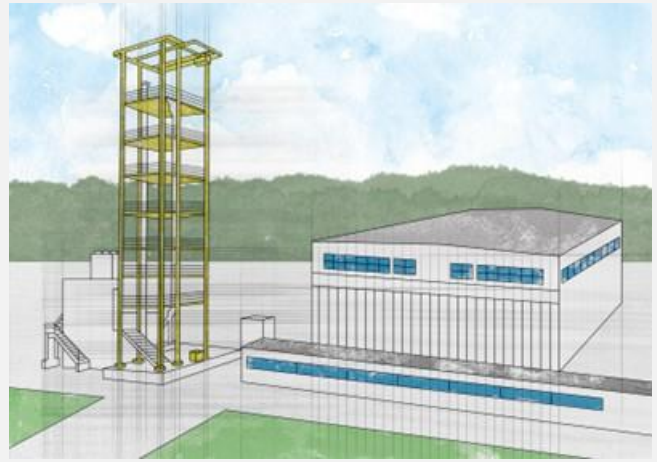
HYDRA is an “Important Projects of Common European Interest” (IPCEI) funded by the European Union in the framework of the NextGenerationEU, and is coordinated by **RINA** to decarbonize the steelmaking sector through **hydrogen**-related technologies.

HYDRA aims at developing an **industrial open platform** at Centro Sviluppo Materiali (CSM) headquarters in Castel Romano **with pilot plants and labs** to **develop, qualify and validate** the use of **hydrogen in** every phase of **steel industry.**

The platform will support the decarbonization in the steelmaking processes **replacing the traditional route based on Blast Furnace**.

The structure will consist of a direct iron ore reduction (DRI) plant using hydrogen as a reducing agent and an electric furnace.



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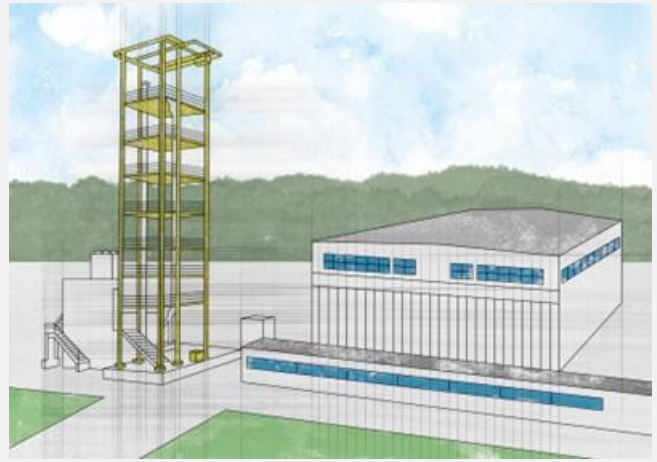
WP1: the study and development of methodologies for testing and qualification of materials and components to be used for the local transport of hydrogen;

•**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

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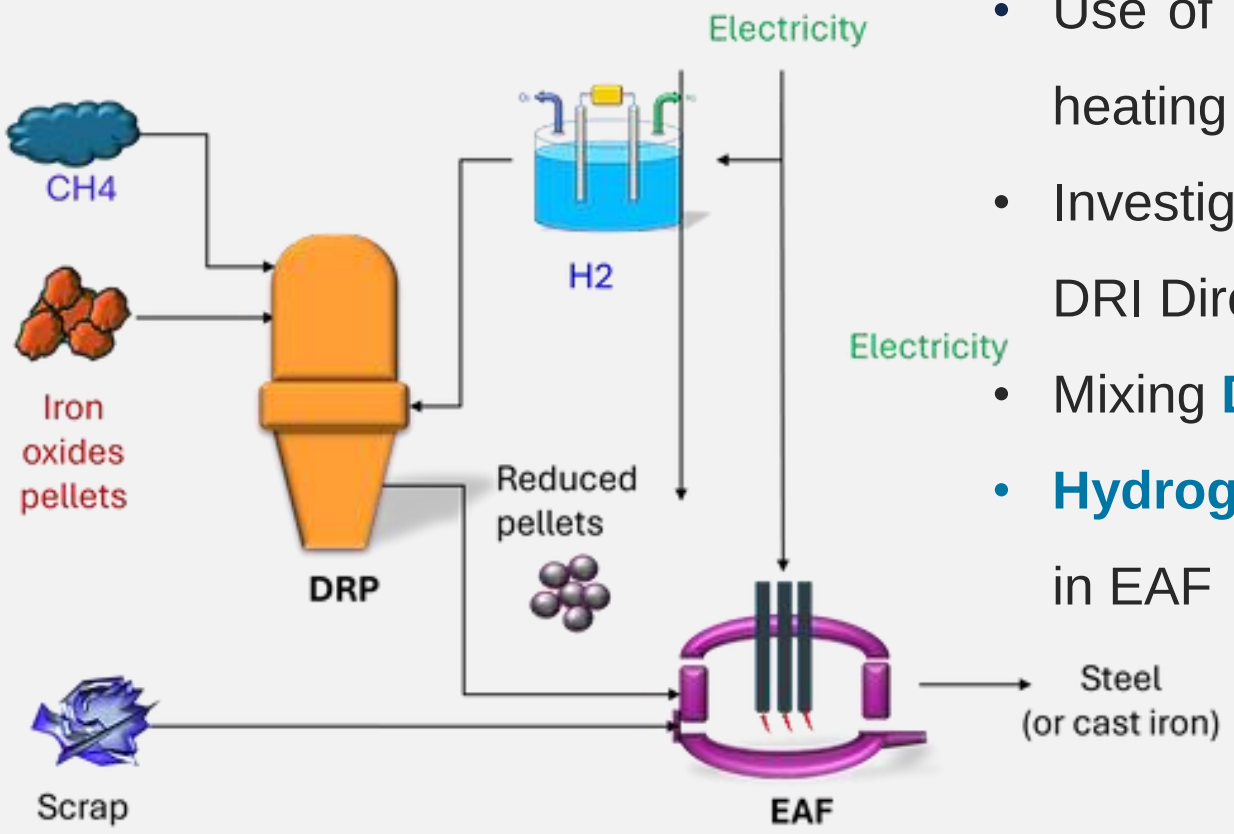
The transition toward a hydrogen-based **steelmaking** won't be short and many technological aspects are still under discussion, but the main aim of the HYDRA project is facilitating this transition.



Several solutions will be investigated and tested:

- Use of many **mix CH_4-H_2** in both Direct Reduction plant and heating burners
- Investigation on **different raw materials grades** to produce DRI Direct Reduced Iron
- Mixing **DRI** and **Scrap** in different ratios in the melting furnace
- **Hydrogen** burning and **Secondary Carbon Carriers** injection in EAF

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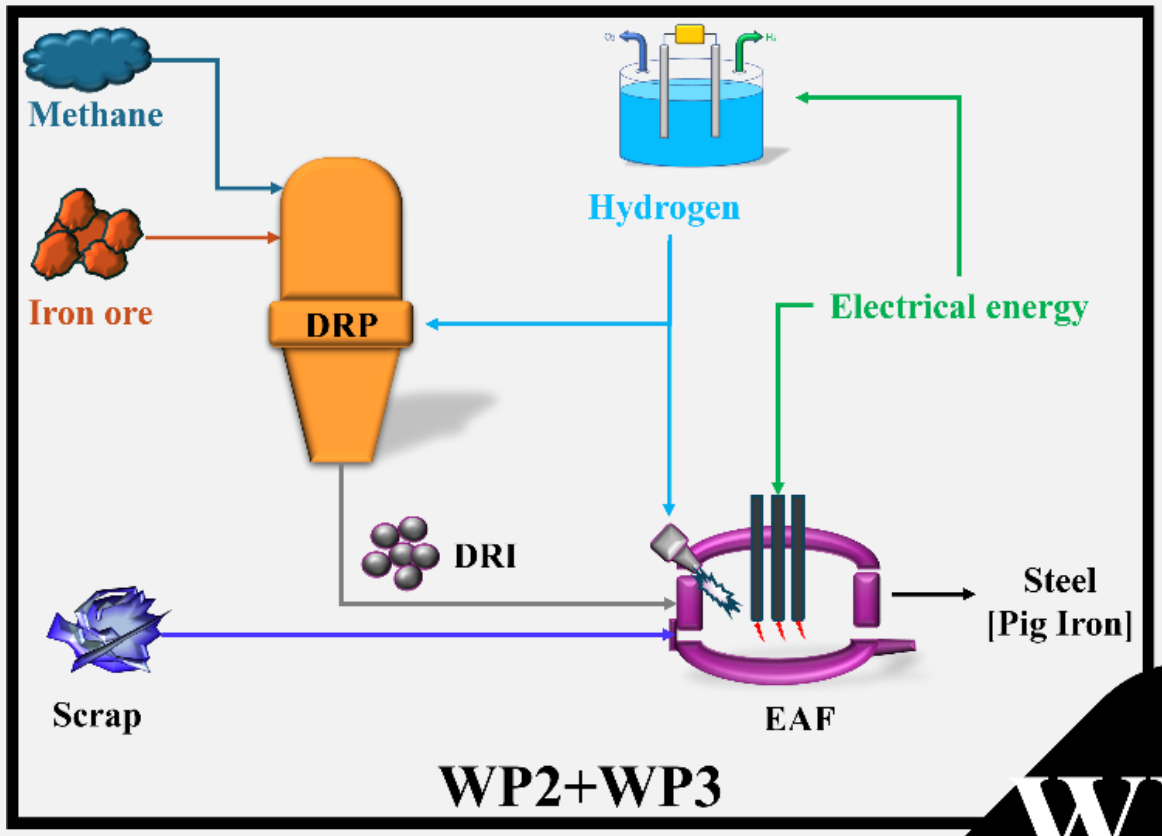
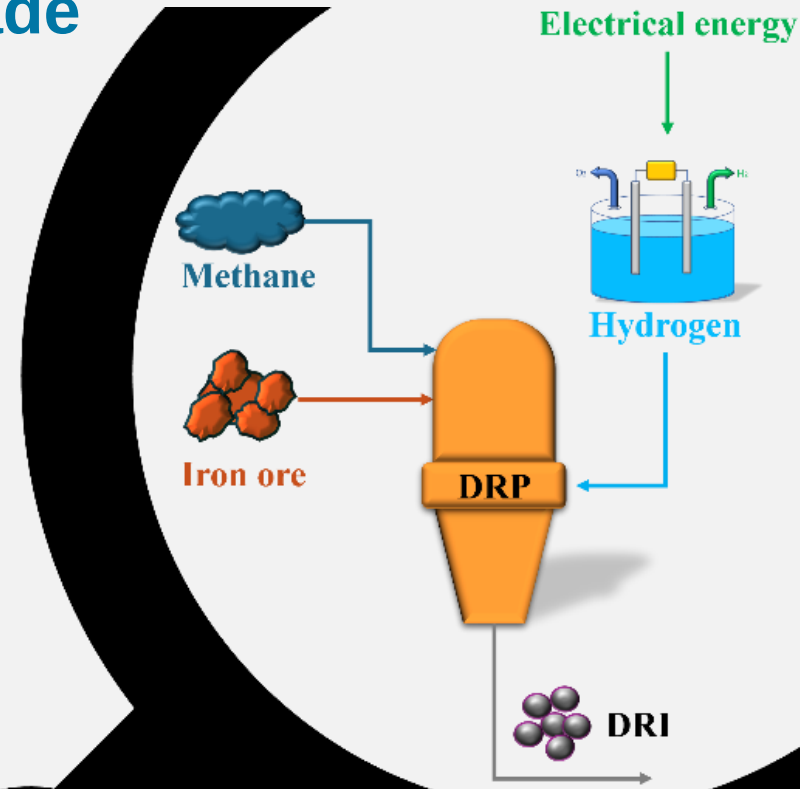
Preliminary **laboratory** results obtained by using **hydrogen** as reducing agent in the **Direct Reduction** of **low-grade iron ore** pellets





WP2

Materials and Methods

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Low Grade Pellets (LG)

Chemical Component	
Fe_{tot}	64.3
Fe_{met}	<0.5
Fe^{+2}	<0.5
Fe^{+3}	~63.0

Chemical Component (%)	
C	<0.1
S	<0.05
N	0
O	13.2
P_2O_5	<0.05
SiO_2	4.97
Al_2O_3	0.64
CaO	0.77
MnO	0.08
MgO	1.04
Na_2O	0.4
K_2O	0.06

H_2 Flow rate (Nl/h) / Time (min)	50	120	200
20	800/1000 °C	800/1000 °C	800/1000 °C
40	800/1000 °C	800/1000 °C	800/1000 °C
60	800/1000 °C	800/1000 °C	800/1000 °C
90	800/1000 °C	800/1000 °C	800/1000 °C

Results: Mass Loss

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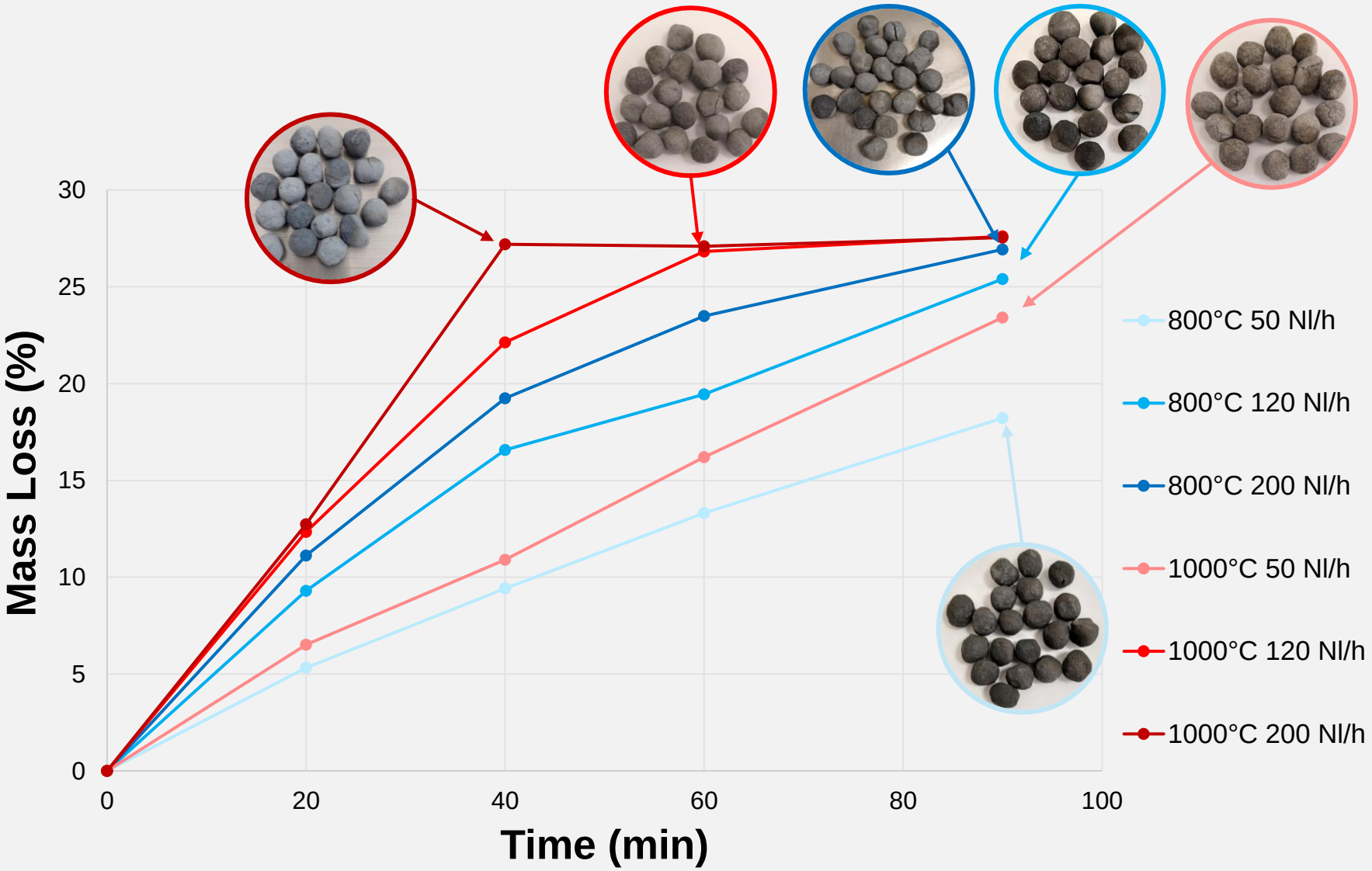

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Statistical Analysis (ANOVA)

Strong dependency of reduction kinetic on all operating parameters with hydrogen flow rate and residence time playing the most significant role.

This outcome is extremely interesting from the pilot scale perspective. Indeed, HYDRA shaft furnace is designed to work with an almost fixed operating temperature, but the results allow to infer that iron ore pellets reduction can be optimized and tailored just modifying residence time and hydrogen flowrate.

Results: Iron Speciation

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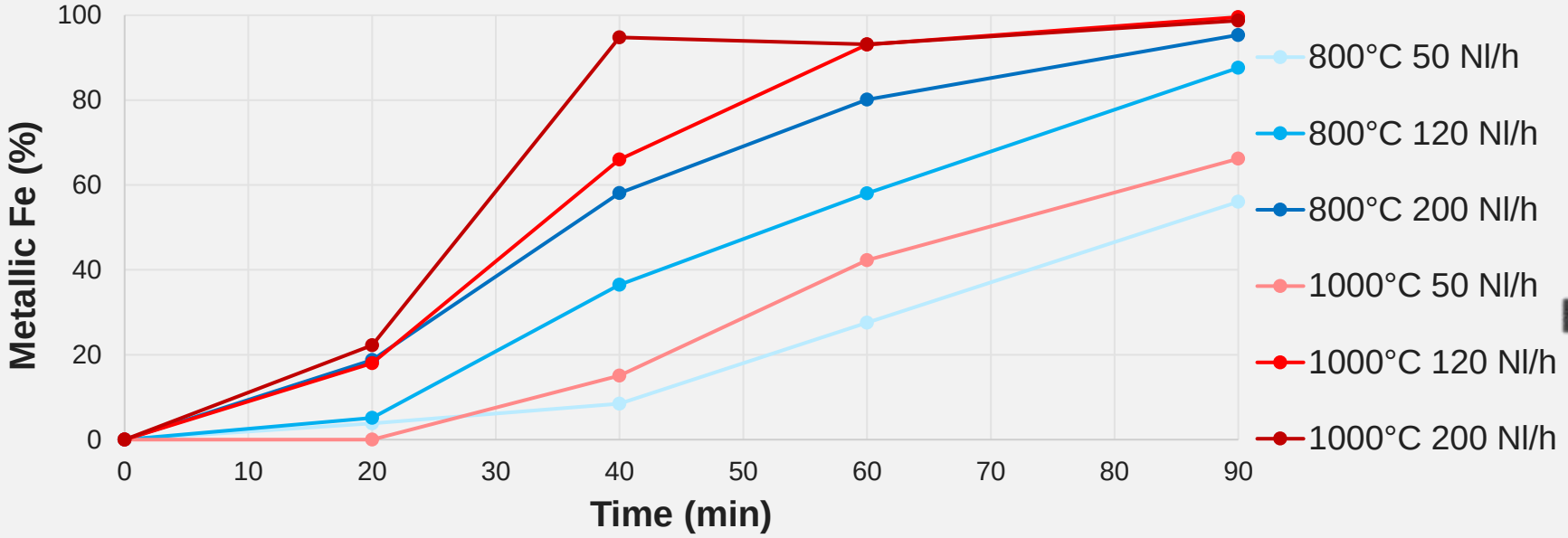

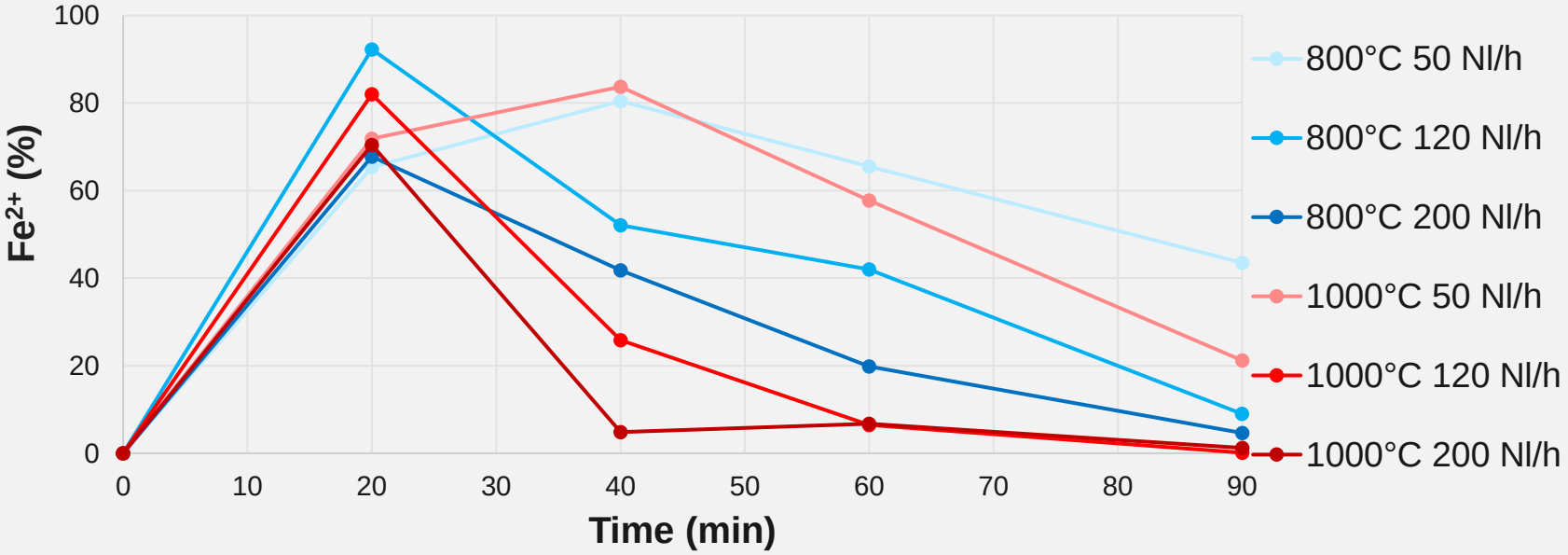

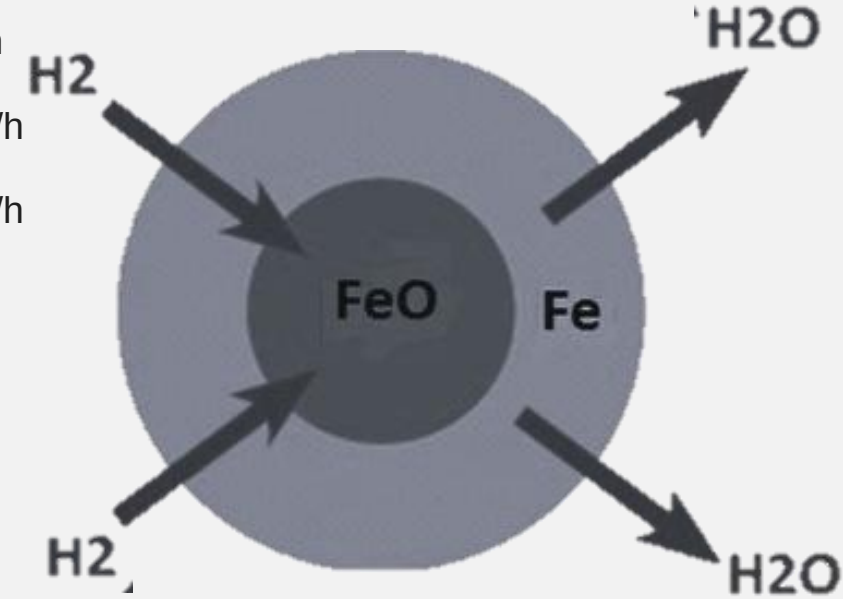

Results: Porosity

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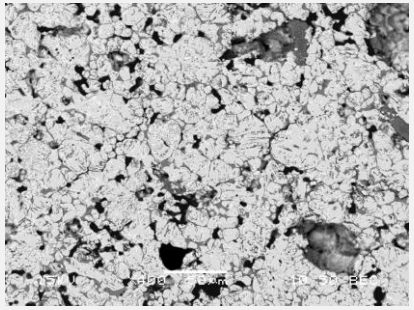
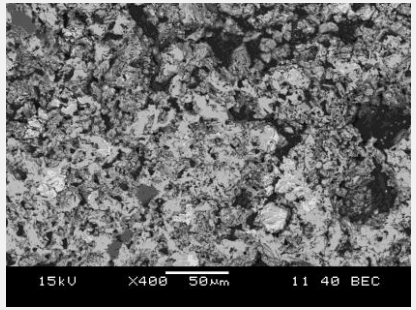
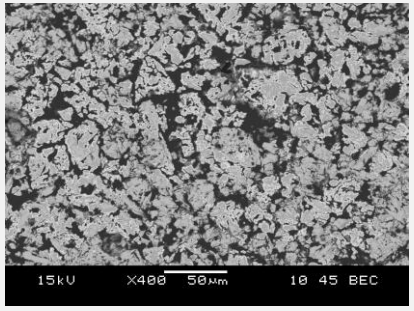
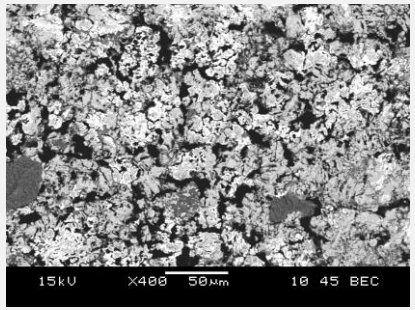
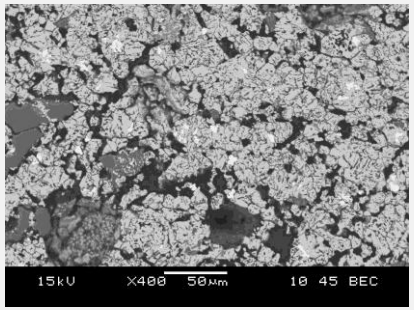
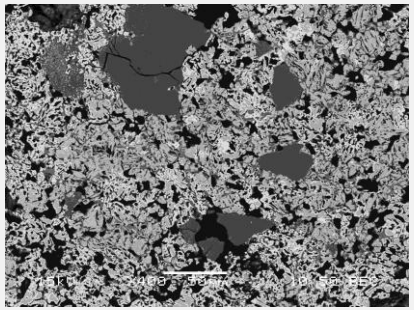
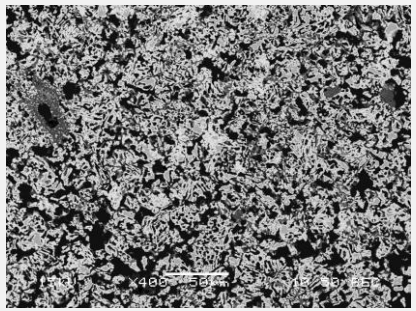
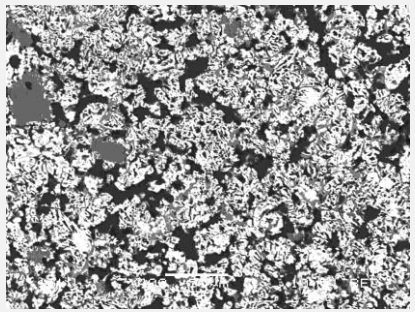
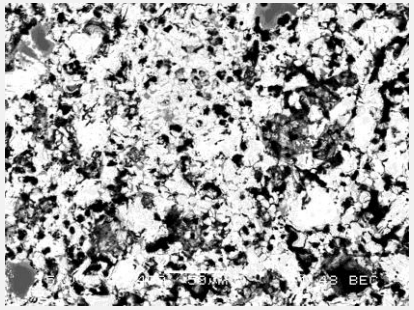
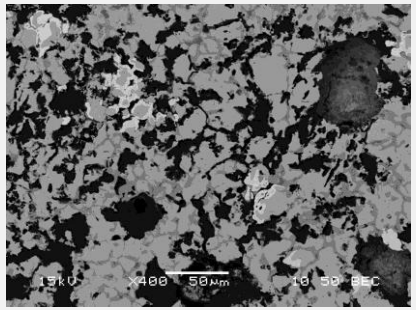
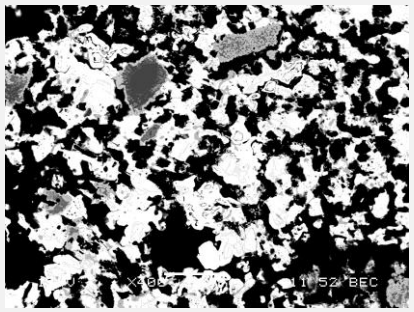
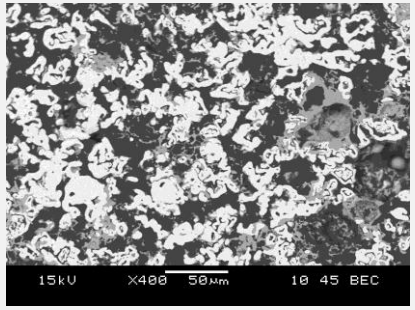
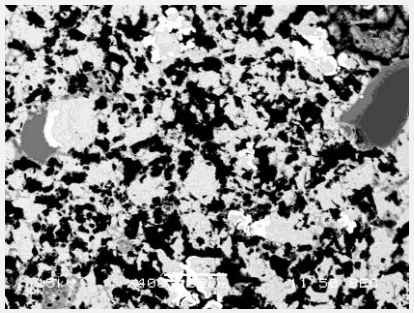
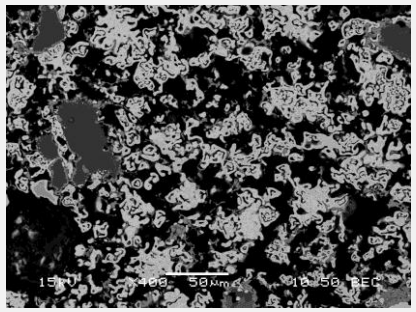
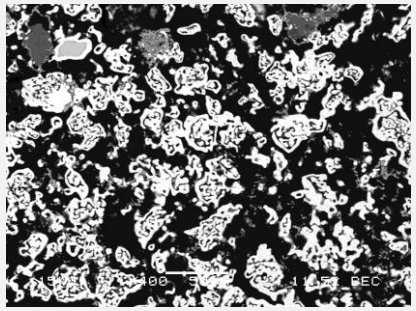
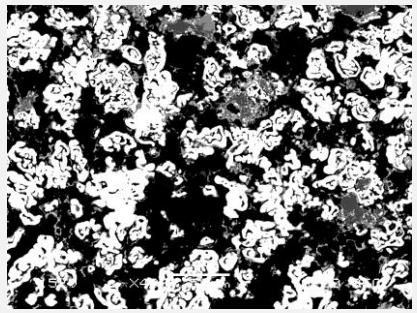
Boundary Region

	20 min	40 min	60 min	90 min
800 °C- 50Nl/h				
800 °C- 200 Nl/h				
1000 °C- 50Nl/h				
1000 °C- 200Nl/h				

Results: Porosity

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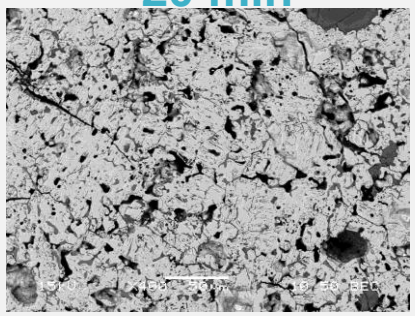
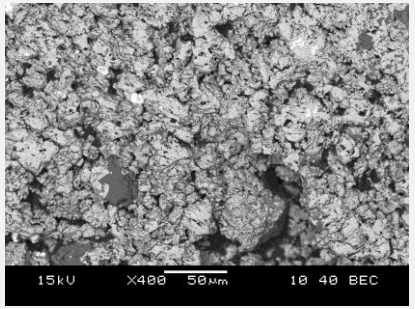
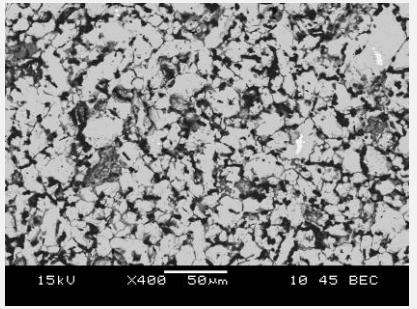
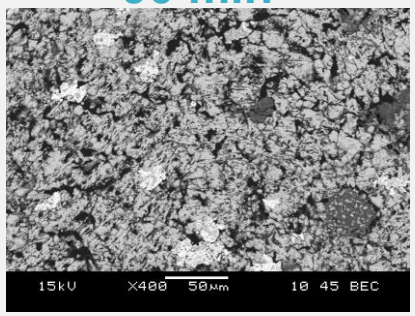
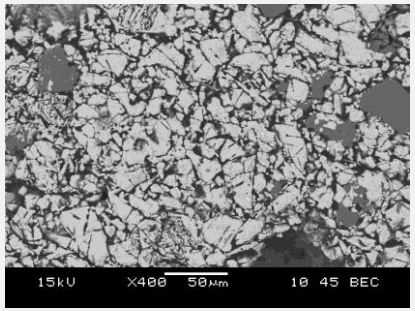
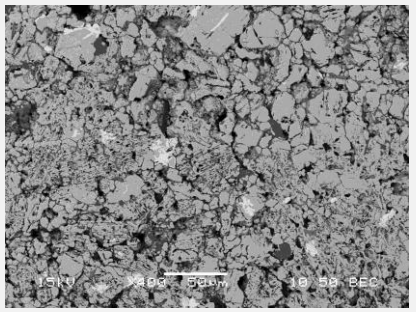
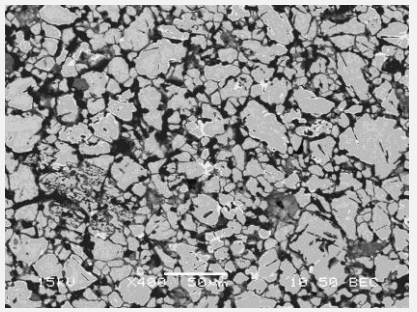
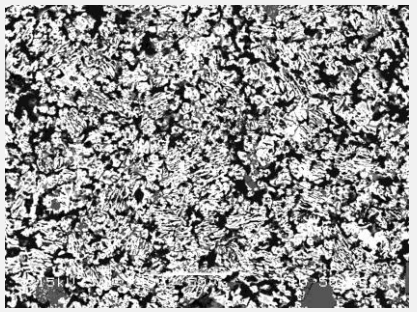
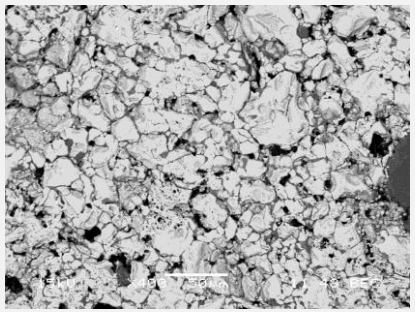
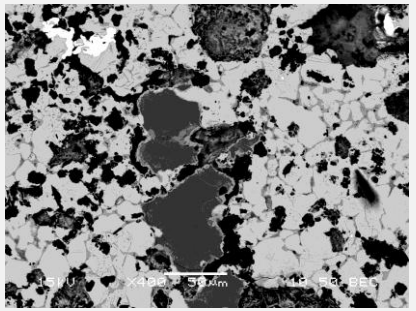
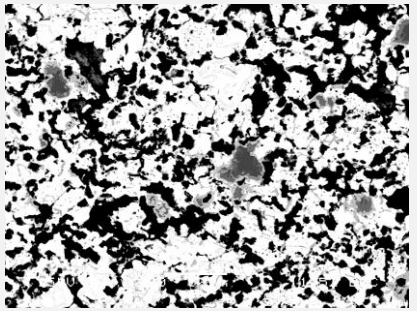
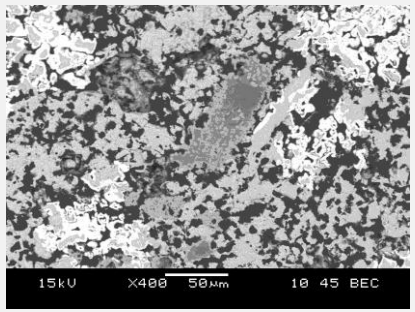
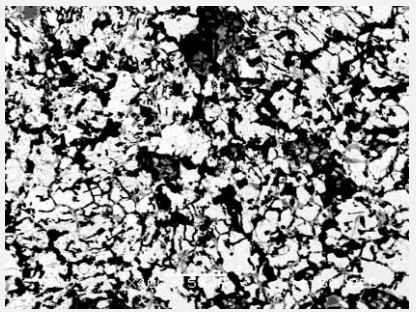
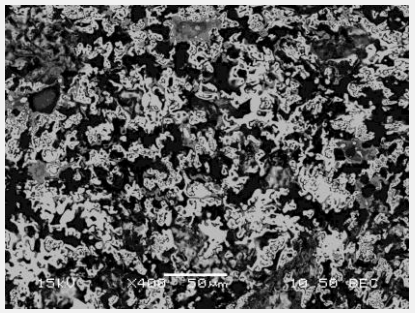
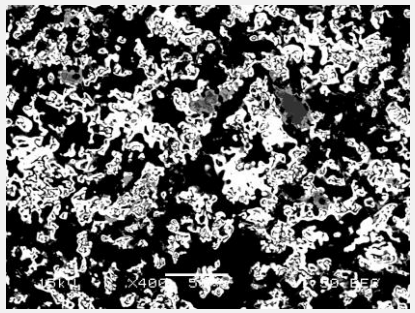
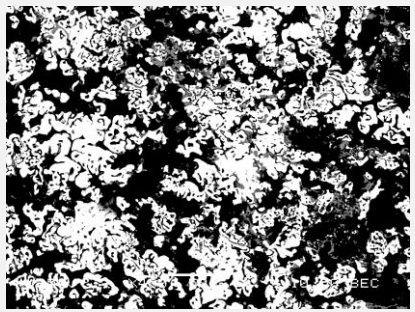
Central Region

	20 min	40 min	60 min	90 min
800 °C- 50Nl/h				
800 °C- 200 Nl/h				
1000 °C- 50Nl/h				
1000 °C- 200Nl/h				

Results: Porosity

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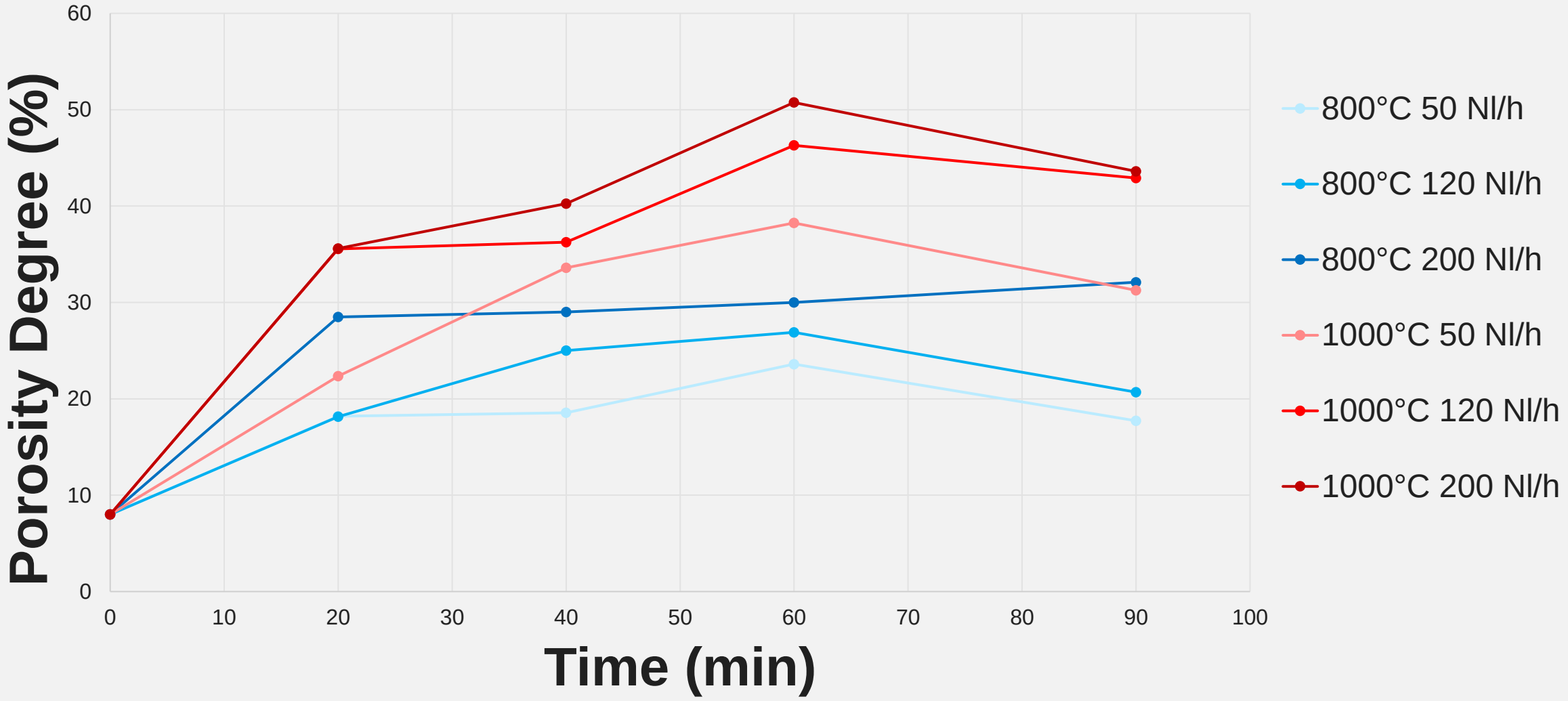

Future Developments

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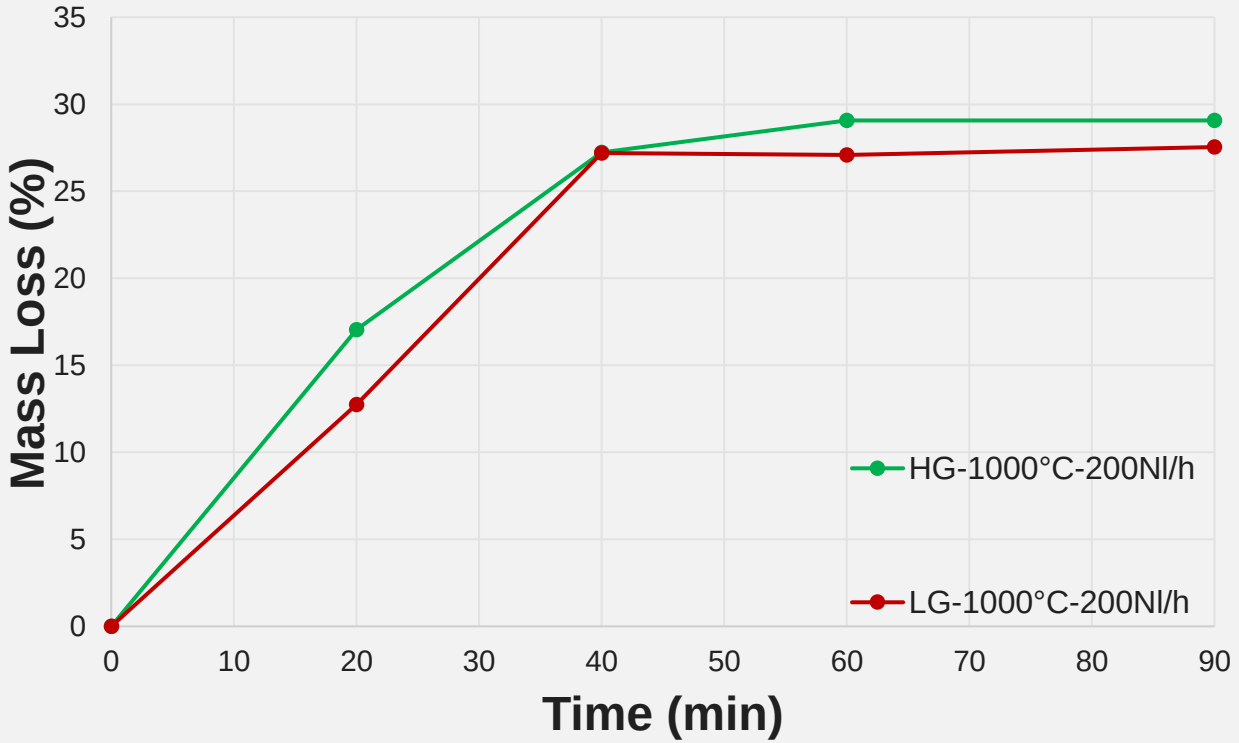
High Grade Pellets (HG)

Chemical Component	
Fe_{tot}	67
Fe_{met}	-
Fe^{+2}	0.1
Fe^{+3}	66.9

Chemical Component (%)	
P_2O_5	0.15
SiO_2	1.71
Al_2O_3	0.5
CaO	1.14
MnO	0.1
MgO	0.42
Na_2O	<0.1
TiO_2	0.05



Conclusions

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- The IPCEI **HYDRA** project aims at decarbonizing the steelmaking sector through **hydrogen**-related technologies by developing an **industrial open platform with pilot plants and labs** to **develop, qualify and validate** the use of **hydrogen in** every phase of **steel industry.**
- The main idea behind the project is to **replace the traditional route based on Blast Furnace** with a structure consisting of a direct iron ore reduction (DRI) plant using hydrogen as a reducing agent and an electric furnace.
- The preliminary experimental results highlight a strong dependency of reduction kinetic on all operating parameters with hydrogen flow rate and residence time playing a significant role. This is advantageous from the pilot scale perspective allowing to optimize iron ore pellets by modifying residence time and hydrogen flowrate.

Thank you for your attention

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