Results from the Experimental Campaign with the H2 Oxyfuel Burner for Electric Arc Furnaces

DEVH2forEAF Project

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DevH2forEAF

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H2 FOR GREEN STEEL 3rd INTERNATIONAL CONFERENCE *meets* A CIRCULAR ECONOMY DRIVEN BY THE EUROPEAN STEEL

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PRIMETALS TECHNOLOGIES

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$DevH_2forEAF$

Developing and enabling H_2 burner utilization

to produce liquid steel in EAF

Eros Faraci (RINA-CSM)

Call: RFCS-2020
Instrument: RR
Start date: 01/07/2021
End date: 31/12/2024
Budget: 3.203.343 €

Outlook

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- Experimental campaign of the oxy-H2NG burner at RINA Combustion Station at Dalmine
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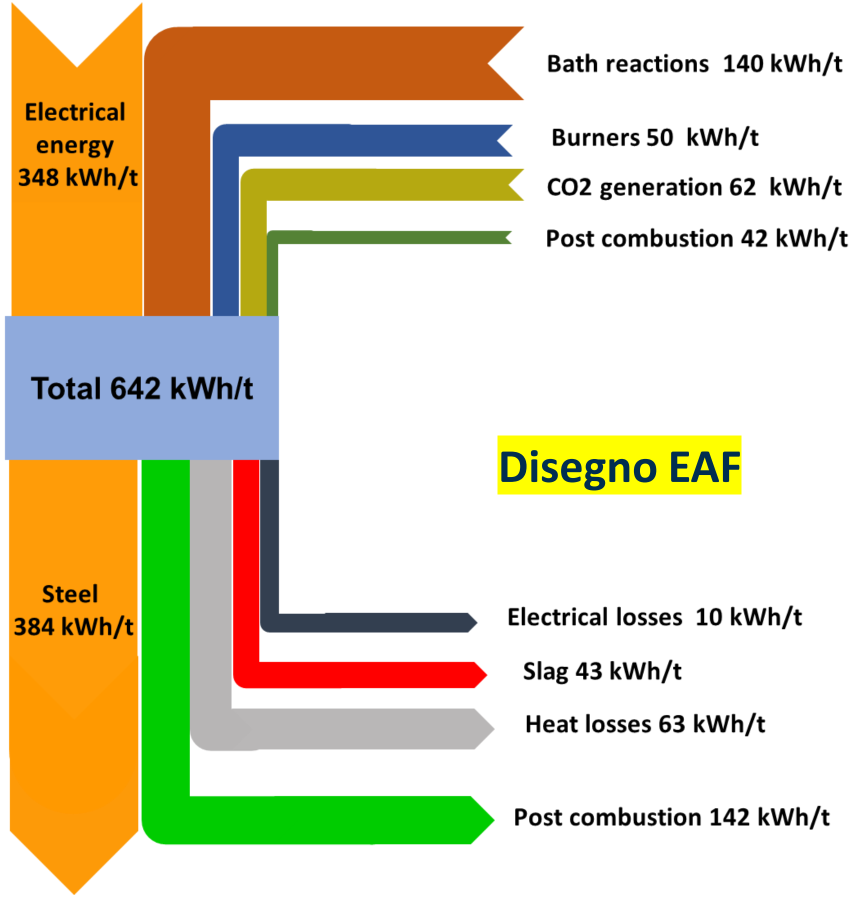
Introduction

DevH2forEAF

- EAF covers steel production in the EU-28 for 41.5 % (69 Mtons/year).
- Chemical energy for the scrap melting and refining is the range of 25-45% of the total energy required and Natural Gas (NG) burners provide in the range of 40-80 kWh/t of energy.
- 100 tons of steel requires 370-750 Nm^3 of NG with CO_2 emission of 0.75-1.5 tons.
- The substitution of NG with H_2 bring a remarkable reduction of CO_2 emission.



Disegno EAF

RFCS DevH2forEAF

Design and realization of burners, able to work with NG/H_2 mixture, up to 100% hydrogen in respect of EAF operative conditions (severe environment, mechanical and thermal resistance)

Project Overview DevH2forEAF – Key words

Main Issues

- **storage**,
- **transportation**,
- and **injection** of H_2 into the EAF
- **influence of the hydrogen** combustion in substitution of fossil fuels in **EAF process metallurgy.**

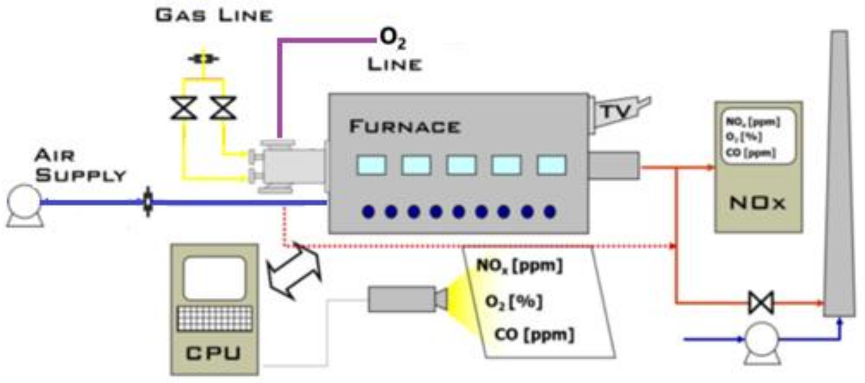
Project Overview DevH2forEAF – Main Objectives

Main objectives

- **Design and realization of burners**, able to work with NG/H2 mixture, **up to 100% hydrogen**. The burners is designed and manufactured by **SMS** to work in severe environment, thus ensuring mechanical and thermal resistance in respect of EAF operative conditions.
- **Risk analysis** for the definition of the correct actions and countermeasures **when hydrogen is used in EAF process**: safety issues related to **storage**, **transport** and **injection** must be identified and risks minimized.
- Analysis the **performance of hydrogen burner** in replacement of NG through experimental trials at two industrial sites (FeNO Celsa)

H2NG-Oxyfuel burner performance evaluation @RINA Combustion Station

Experimental campaign at RINA-CSM combustion laboratory in Dalmine from 100% NG to 100% Hydrogen, including mixed configuration of NG-H_2. The fuel mixing was performed by a dedicated mixing regulation system developed by Nippon Gases.

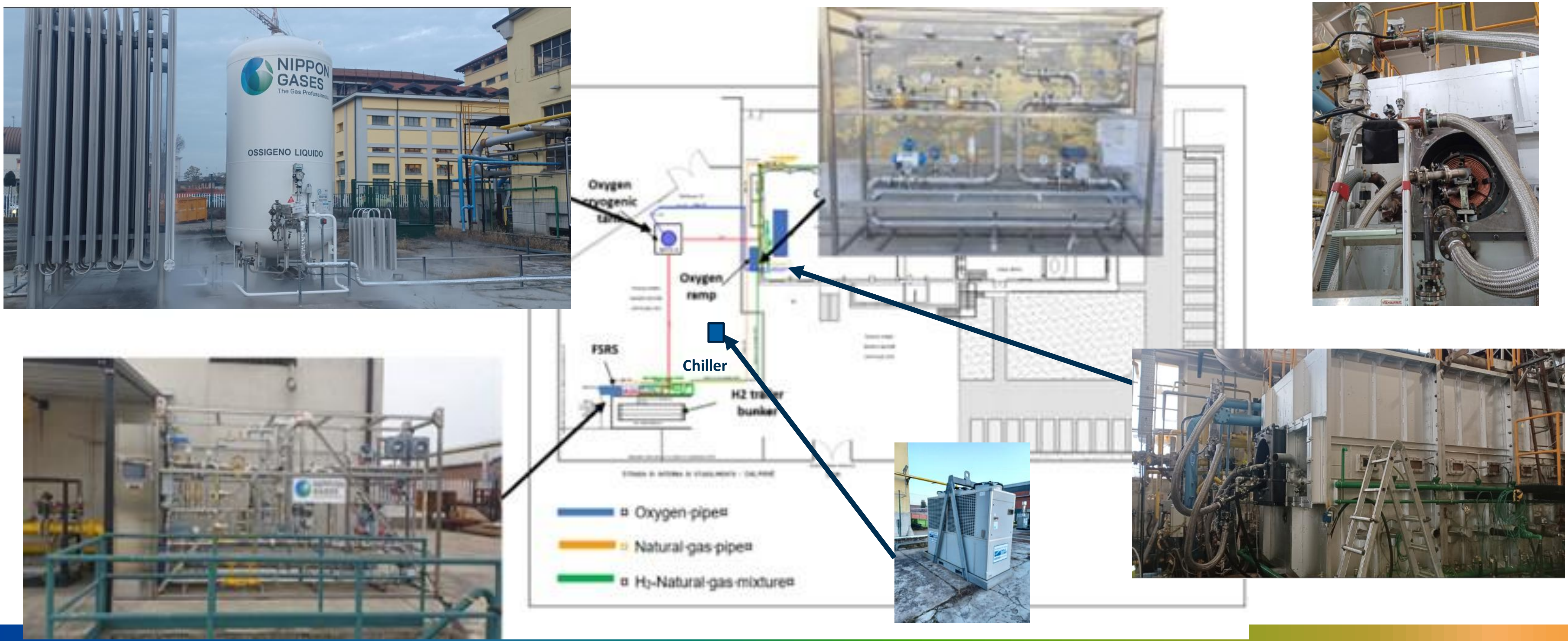


Analysis of the results and performance of H_2 burner to identify optimal operative conditions to be adopted at industrial scale in FeNo and Celsa

Length (internal)	[m]	3 – 7.5
Cross Section	[mm] x [mm]	2000 x 2000
Maximum Burner Capacity	[$MW_{gas\ based}$]	3
Maximum NG Flow Rate	[Nm^3/h]	300
Maximum Syngas Flow rate	[kg/h]	2000
Maximum Air Flow Rate	[Nm^3/h]	3500
Maximum Working Temperature	[°C]	1250
Thermocouples for measuring longitudinal temperature profile along burner axis;		
Pollutants Monitoring system for O_2, CO & NOx;		
Computer Controlled System		
Continuous Video Monitoring		

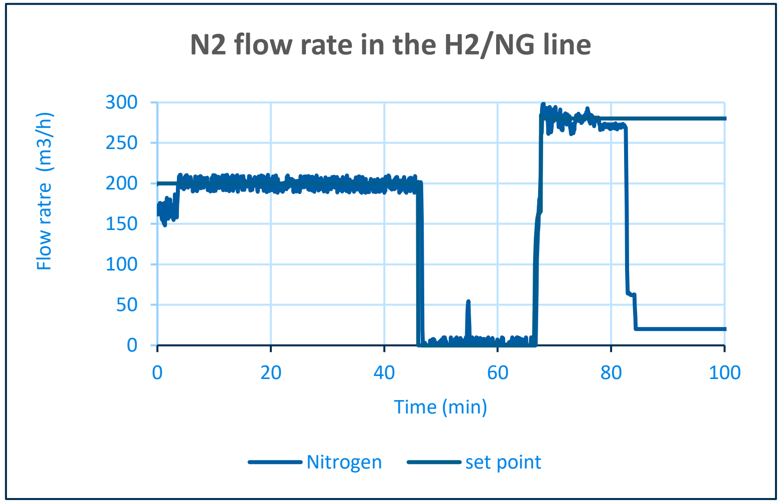
Preparation of the RINA-CSM Dalmine site for the experimental campaign

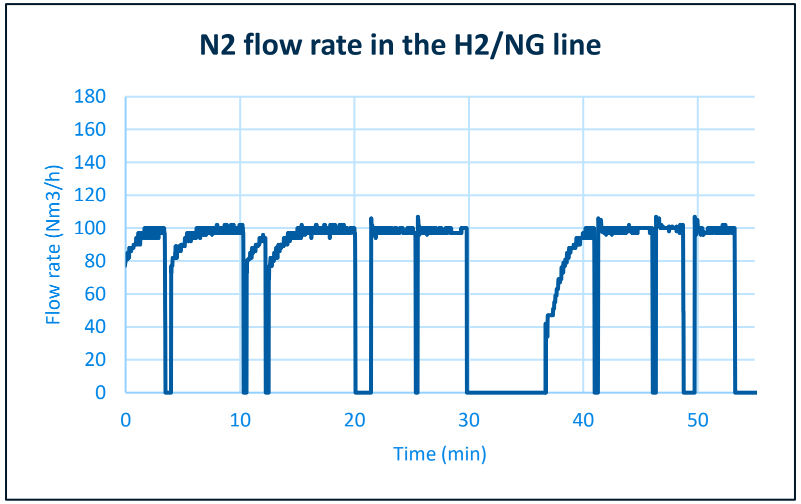
The **cryogenic oxygen tank of 10.000 L,** the **FSRS** and the **Oxygen ramp, H_2 burner and chiller** have been **installed** to RINA-CSM Dalmine.

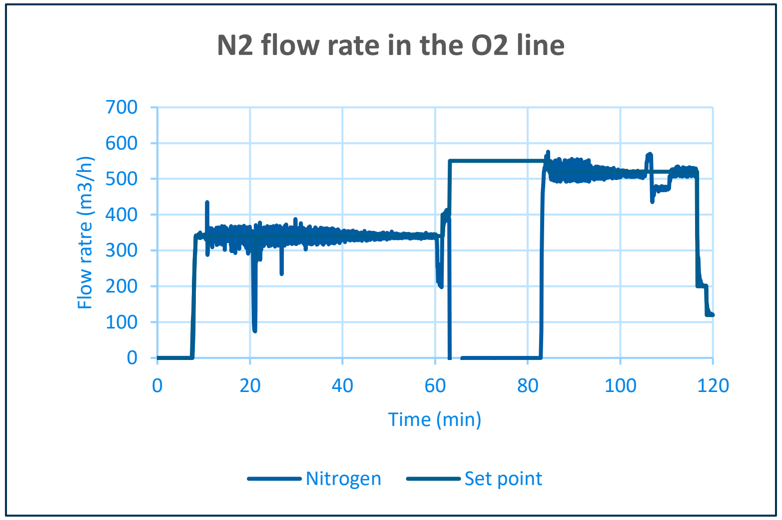


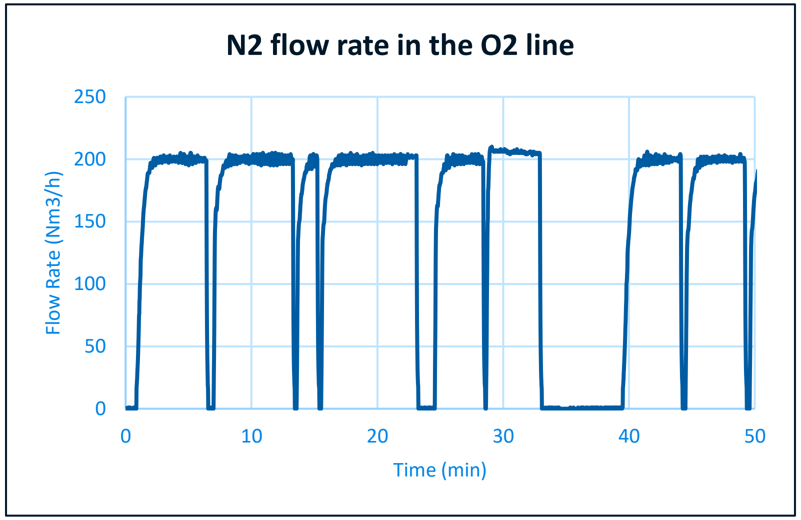
Experimental trials @ Combustion Station set up – Blank test with Nitrogen

Two experimental trials with N_2 to verify the whole equipment functionality **have been carried out**









Fuel Supply Regulation System developed by Nippon Gases works properly

Fine tuning of the vaporizers utilization especially at high flow rate

Freezing the modulating valves in the last opening position even during burner shutdown permits to reach very quickly the H2/NG and O2 flow rates required in the next phase.

Experimental trials @ Combustion Station RINA Dalmine - Set up

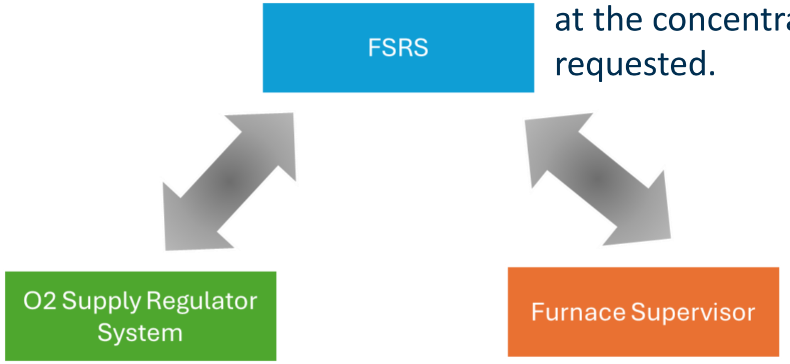
The furnace is preheated above the self-ignition temperature using two NG side burners:

- to preheat the combustion chamber above the autoignition temperature of the NG
- to inject air into the combustion chamber to simulate the air inlet through the slagging door of the EAF.

To guarantee the proper safety working conditions properly interlock signals have been defined with the aim to provide:

- information on the sequence status of each control system
- allow or stop the sequence after check the correct sequence status.

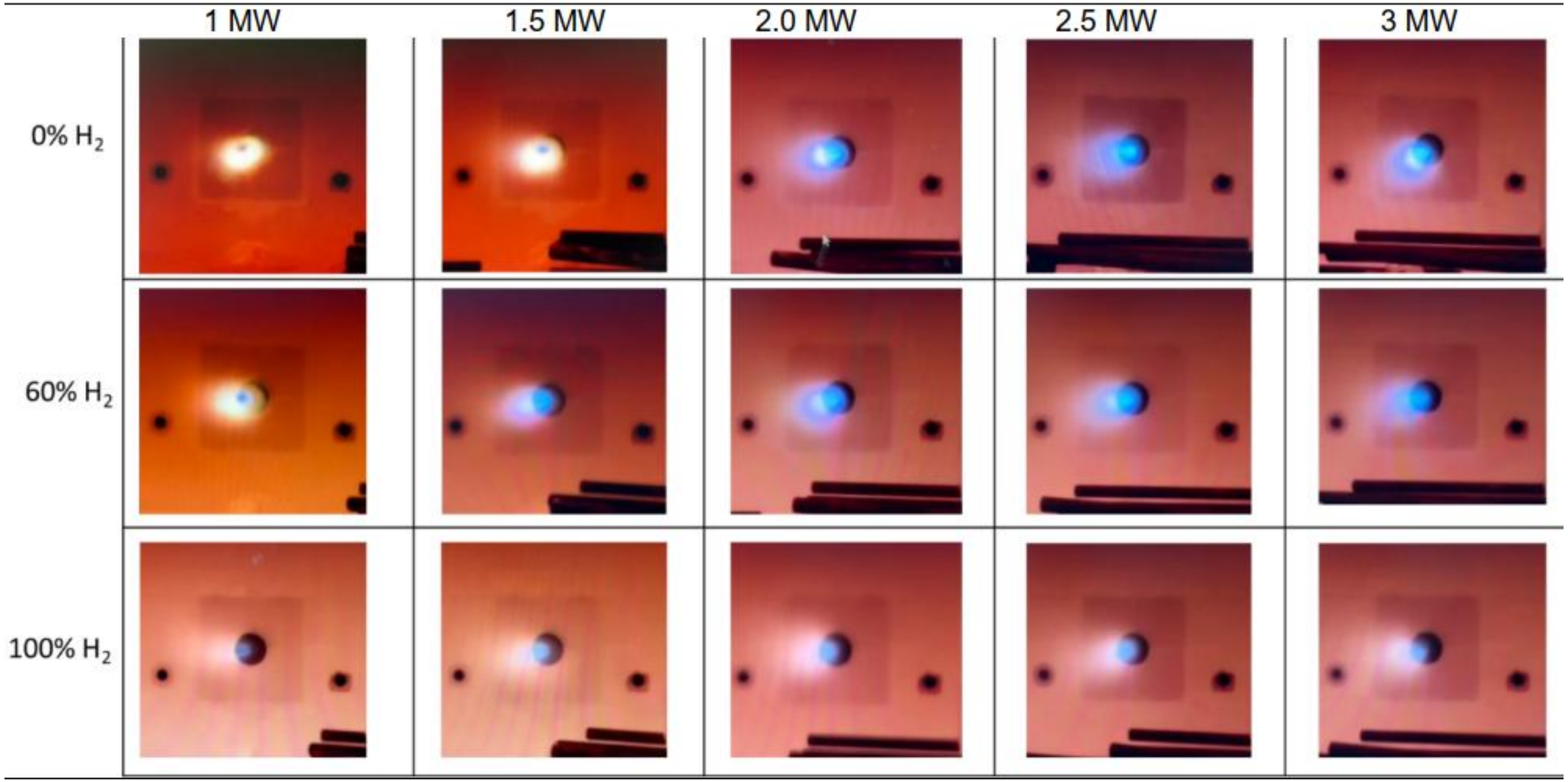
The FSRS to mix the fuels at the concentration requested.



The O2 supply regulator system to provide oxygen at the proper flow rate.

Experimental trials @ Combustion Station– Main Objectives

The experimental campaign has been carried out, with the objective to verify performance of the H_2 -burner in **preparation for the industrial trials**



These tests have permitted to evaluate:

1) The stability of the burner at high temperature with different level of the power and with different combustion ratio

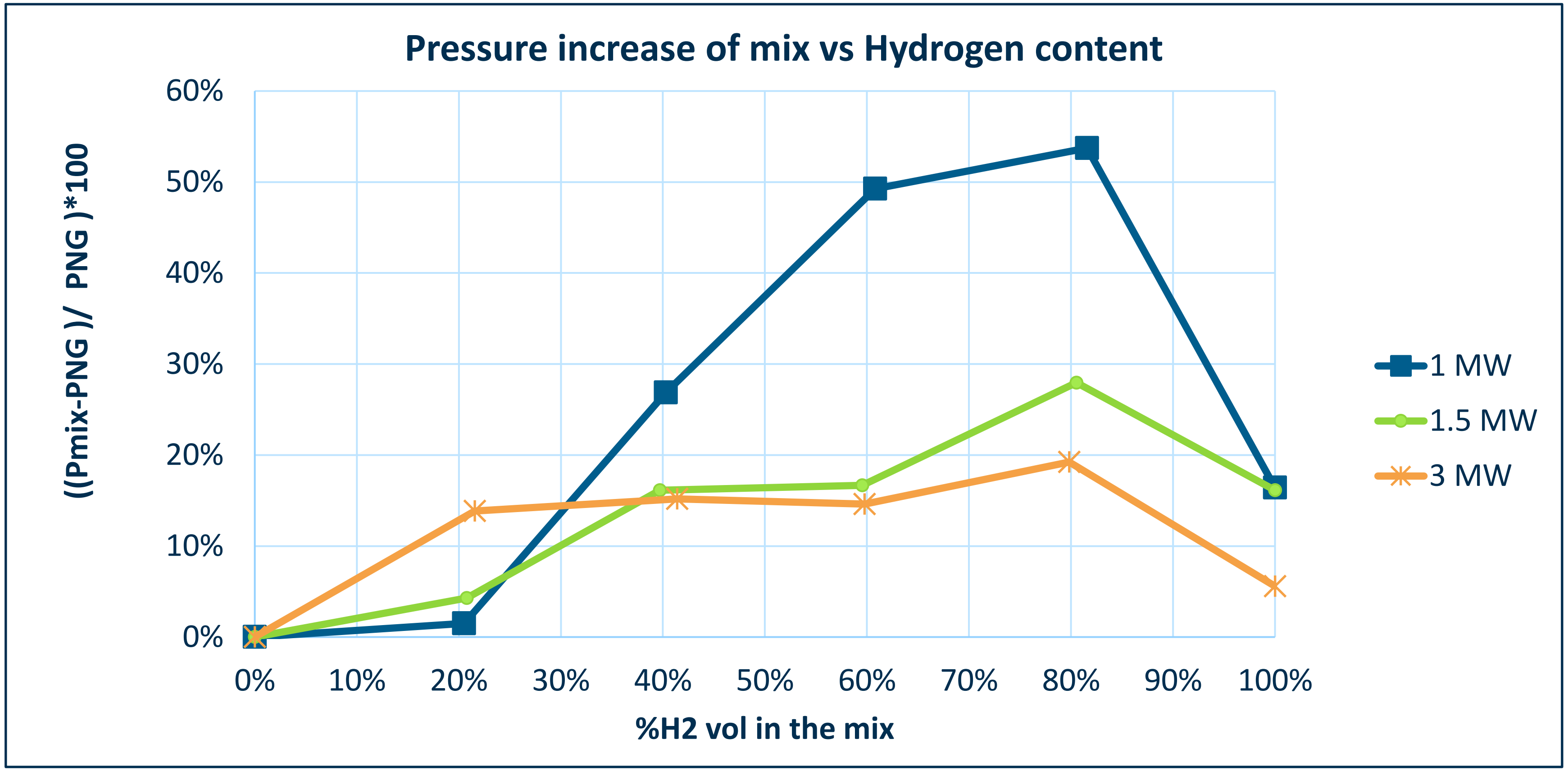
2) The thermal field and heat transfer in the furnace at different power input

3) Oxygen amount in flue gas

The increasing in the hydrogen content decreases the luminosity of the flame disappearing when $\%H_2$ is above 60%.

Experimental results

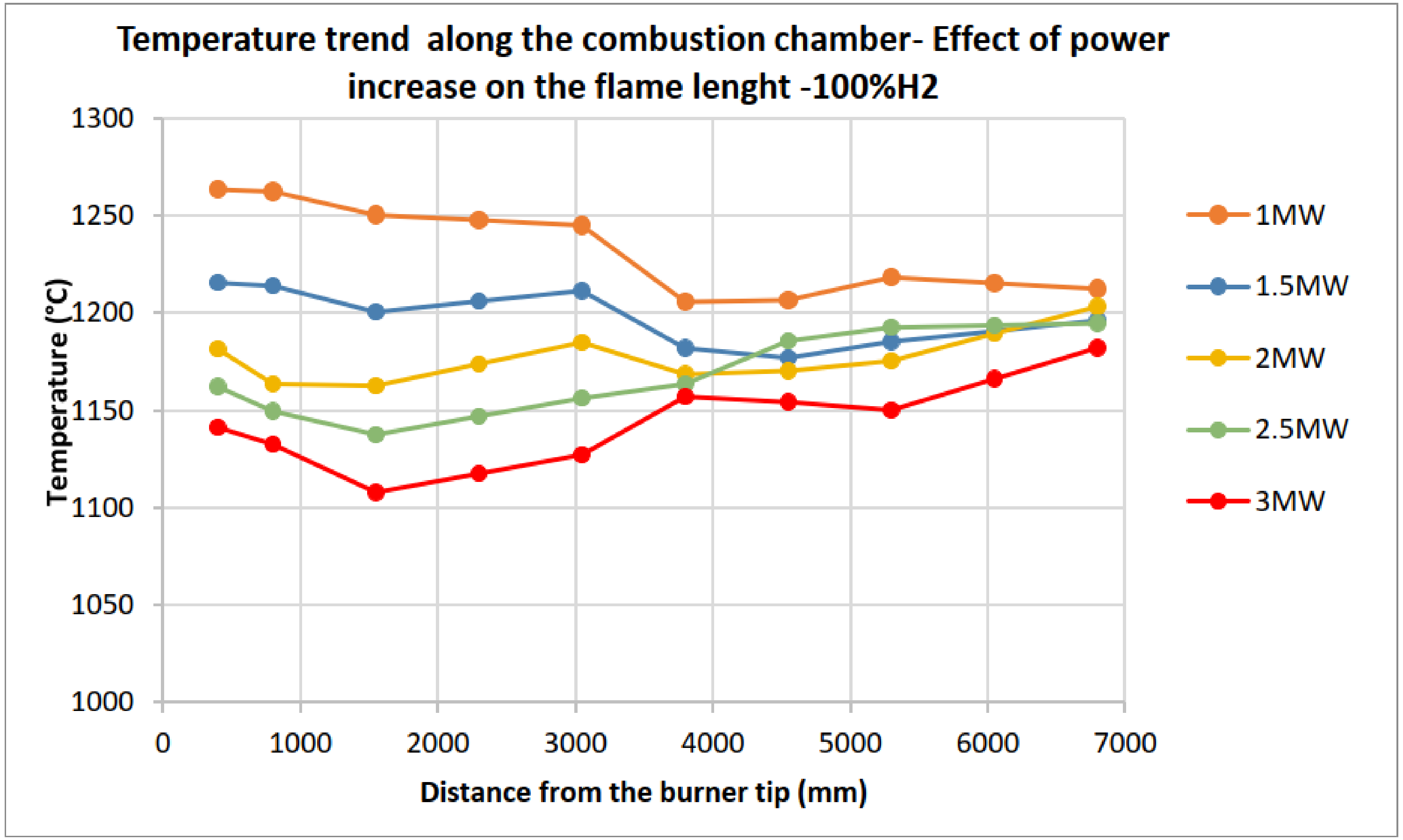
Pressure of mix Vs. H_2 Percentage



- Increase of **pressure fuel mixture** up to 80%vol of H_2 for all powers.
- Above 80%vol. of H_2 in the fuel mixture the fuel pressure decreases because the H_2 combustion mechanism becomes prevalent.
- This effect in percentage is higher at 1 MW.

Experimental results

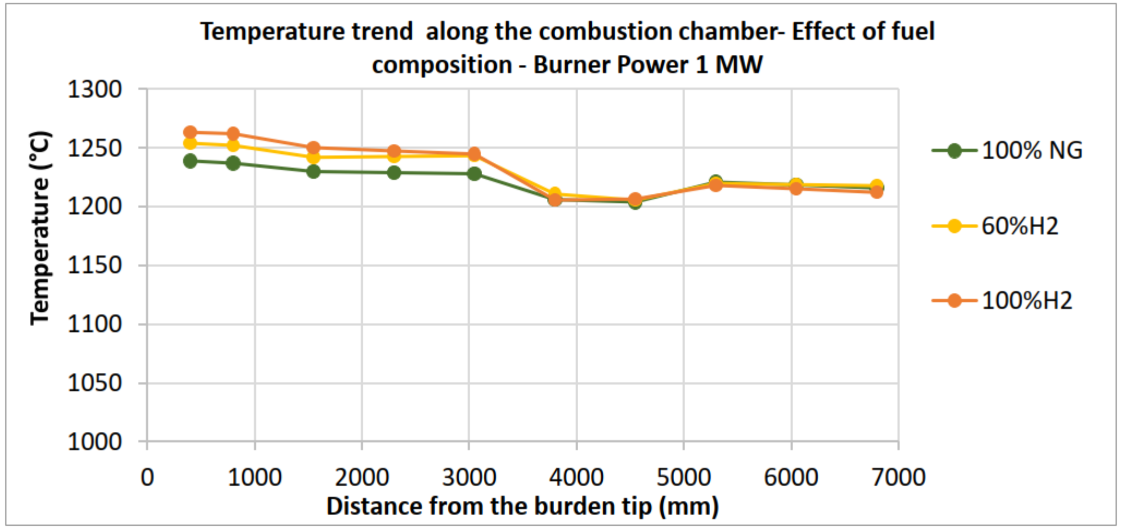
Effect of Power on the flame length



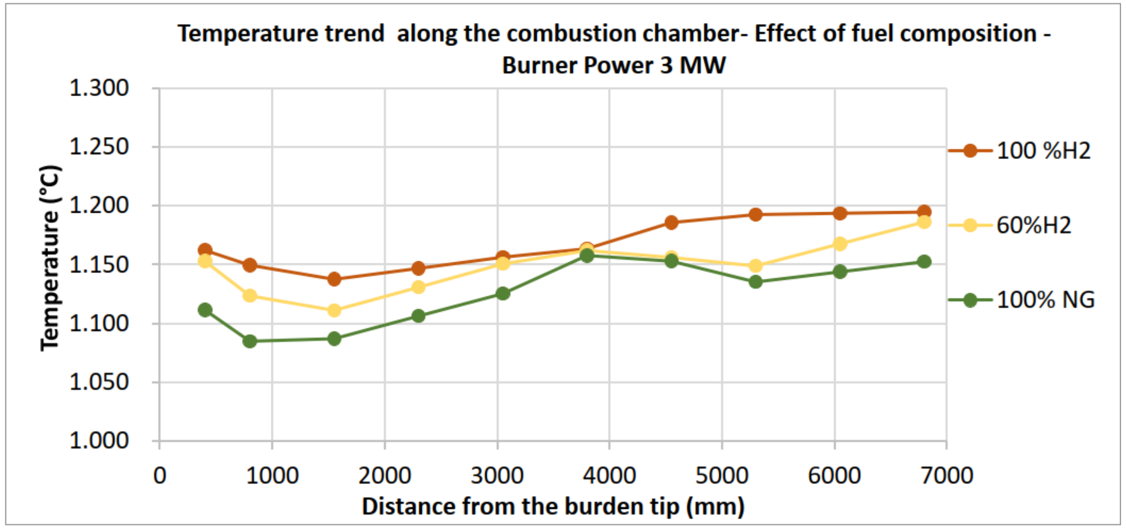
- 1) For **1 MW** of power the maximum temperature occurs with the first thermocouple. This indicates that combustion is completed in the first 800mm.
- 2) For powers **>2 MW** is evident that there is a temperature reduction for the first 1500mm and a subsequent increase. This indicates a lengthening of the flame and therefore the need for longer lengths to complete the combustion**.**

Experimental results
Temperature and Composition Relationship

1MW



3MW

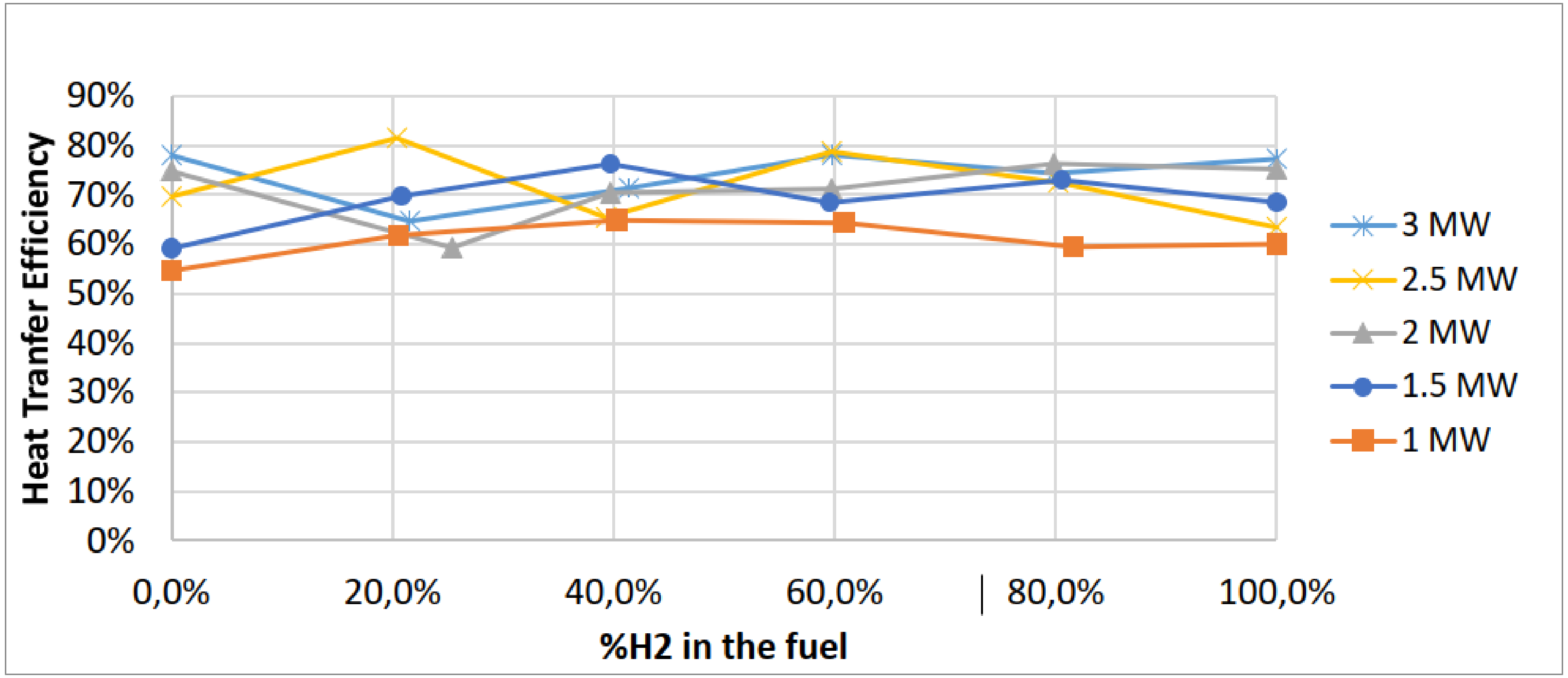


- **The increase of the %H_2** increases the temperature of the first thermocouple, it means that the H_2 is more reactive and start the ignition nearest the burner tip.
- The temperature reduction inside the combustion chamber, it is caused by the increase of **the heat extracted** by cooling circuit
- At 1 MW the **combustion** is completed in the first part of the combustion chamber; at 3 MW the **combustion** seems to evolve for the whole combustion chamber length.

Experimental results

Heat transfer Vs. fuel composition at the same Thermal Power

The heat transfer capability of the burner can be written as the ratio between the power transfer to the cooling water lances and power input of the burner.



$$Heat\ Tranfer\ Capability.\,(\%) = \frac{P^{H2O}_{cooloing\ lances}}{P_{burner}} \cdot 100$$

- The increase of the **$\%H_2$ in the fuel does not influence** the heat transferred.
- The heat transfer efficiency is **65-78% at 3 MW**
- The average heat transferred to the water of the cooling lances is 61% at 1 MW and 74% at 3 MW.

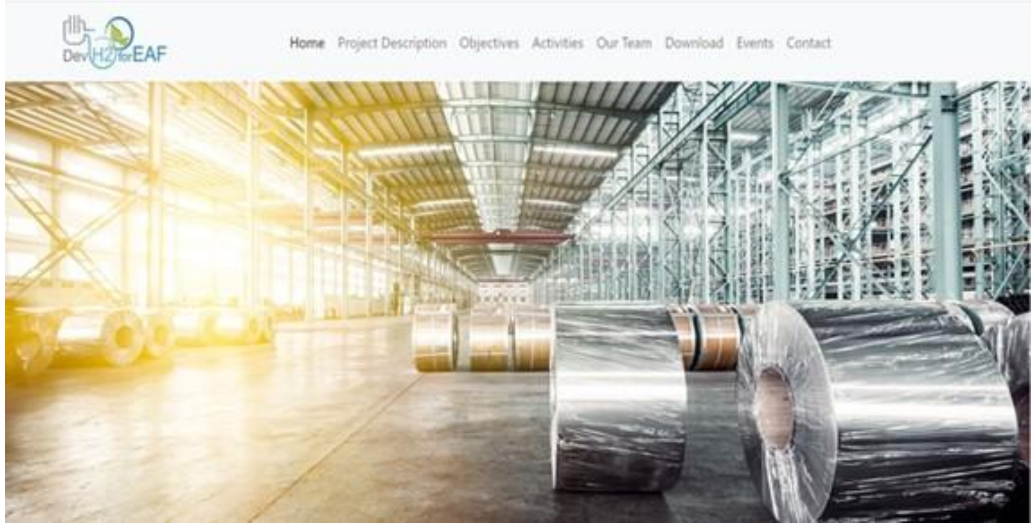
Conclusions

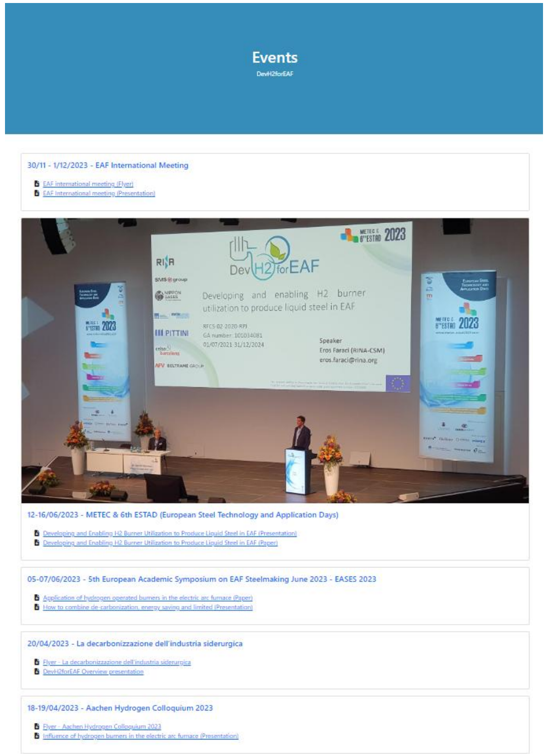
The experimental campaign was successfully carried out:

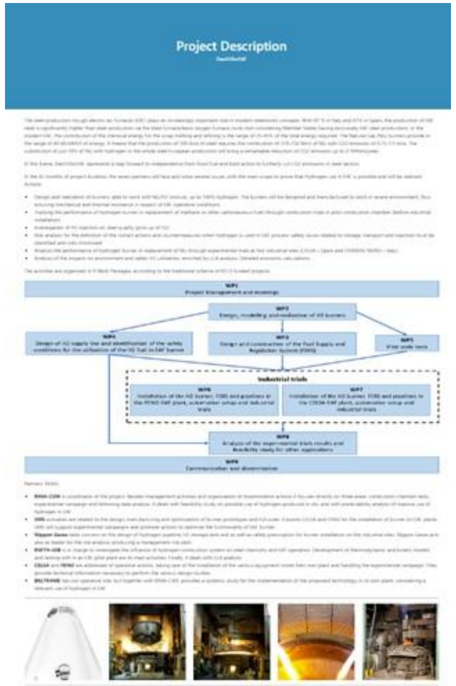
- FSRS (Fuel Supply and Regulation System) to provide NG and H_2 mixture at proper flow rate composition and pressure.
- The burner is stable and works correctly up to 3 MW with from 100%NG to 100%H_2 for all the working conditions tested. The effect of the hydrogen in the case of use of the H_2-NGH_2 blends is visible on:
  - Luminosity of the flame that disappears when %H_2 is above 60% vol.
  - Using pure hydrogen (100%) in the furnace, the flame begins closer to the burner tip (as detected by the first thermocouple). This suggests that hydrogen, due to its high reactivity, initiates combustion nearest the burner tip.

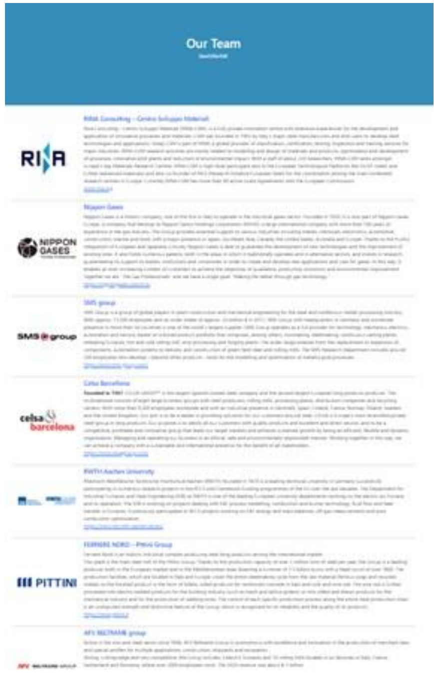
DEVH2ForEAF website homepage

The DevH2forEAF web site has been realized at the following address: **https://www.devh2eaf.eu/**. The website page is periodically updated in accordance with the progress of the project and the dissemination activities.









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https://www.devh2eaf.eu/

This work was carried out with support from the European Union's Research Fund for Coal and Steel (RFCS) research program under the ongoing project: *Development and enabling of the use of the H2 burner to produce liquid steel in EAF – DevH2forEAF*- GA number: 101034081.

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