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

DevH2forEAF

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European Academic Symposium on EAF Steelmaking

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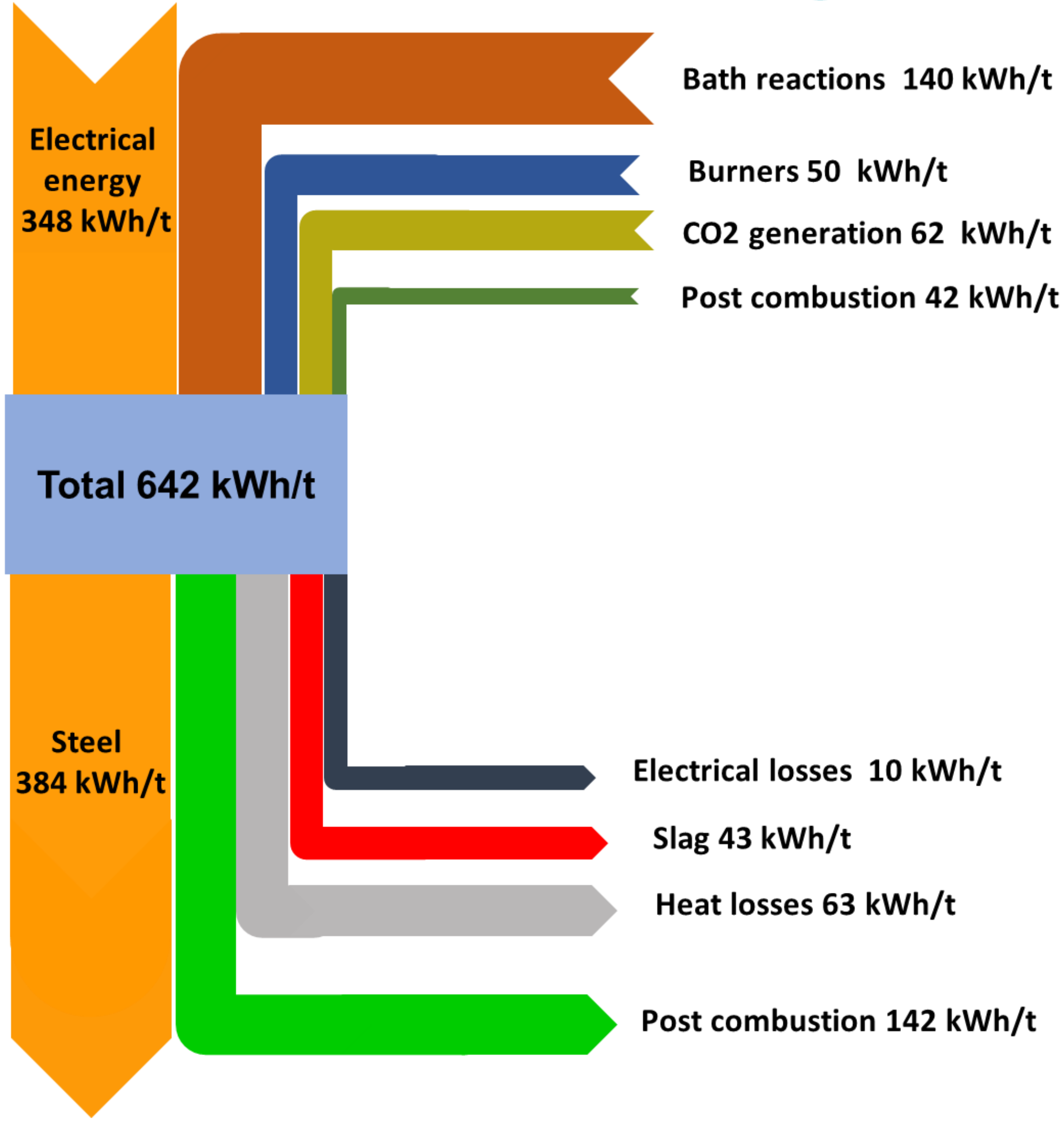
Introduction

- The steel production through EAF has an increasingly important role in modern steelworks concepts. Today the EAF steel of the overall steel production in the EU-28 is 41.5 % (69 Mtons/year) but in in Italy (81%) and in Spain (61%), the production of EAF steel is significantly higher than steel production via the blast furnace/basic oxygen furnace route.

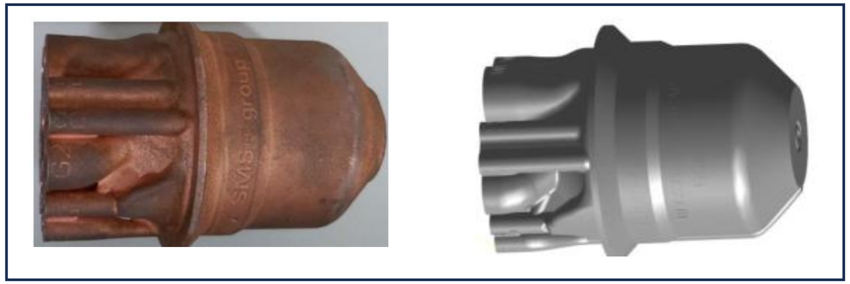
- In the modern EAF, the contribution of the chemical energy for the scrap melting and refining is the range of 25-45% of the total energy required. In EAF process the NG burners provide in the range of 40-80 kWh/t of energy. It means that the production of 100 tons of steel requires the combustion of 370-750 Nm^3 of NG with an emission of 0.7-1.5 tons of CO_2.



Experimental trials in pilot scale EAF (RWTH)

A downscaled version of the burner, used in the industrial trials, **was tested at the IOB**.

The burner has a **power of 50 kW** and is able to combust different fuel gases and their mixtures ranging from **100% natural gas (NG) to 100% hydrogen (H2)**.

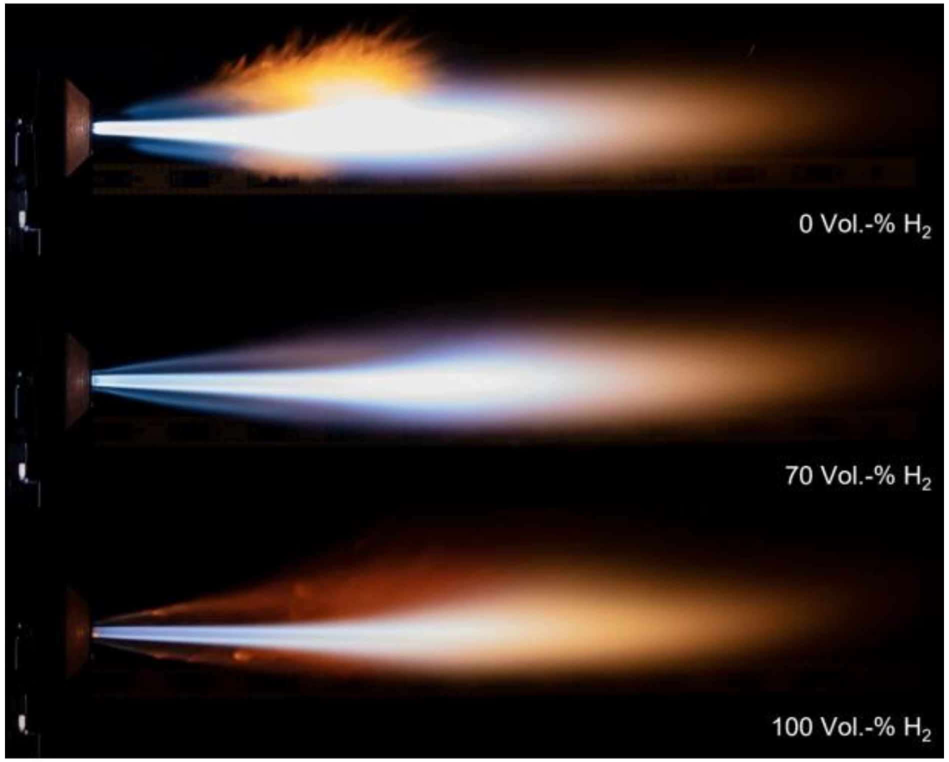


Small scale prototype – 50kW

Results

1) **The flame is stable** for all fuel gas composition and with **the increase of hydrogen concentration the flame is more stable**.

2) Even for the flame with **100% hydrogen in the fuel gas a flame is visible, due to particles present in the ambient** atmosphere which accumulate in the long exposure picture.

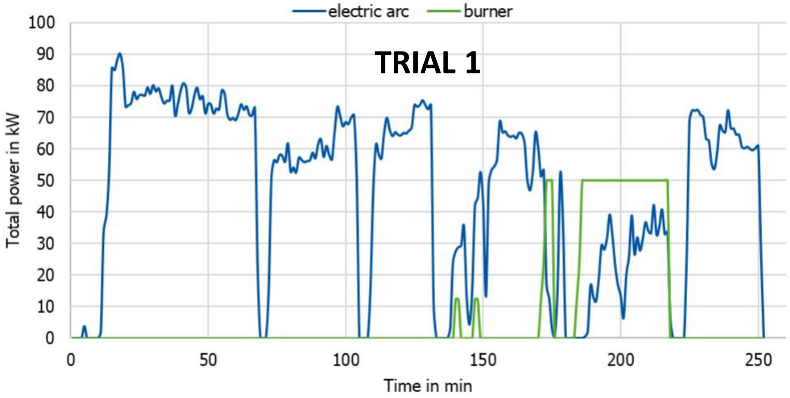


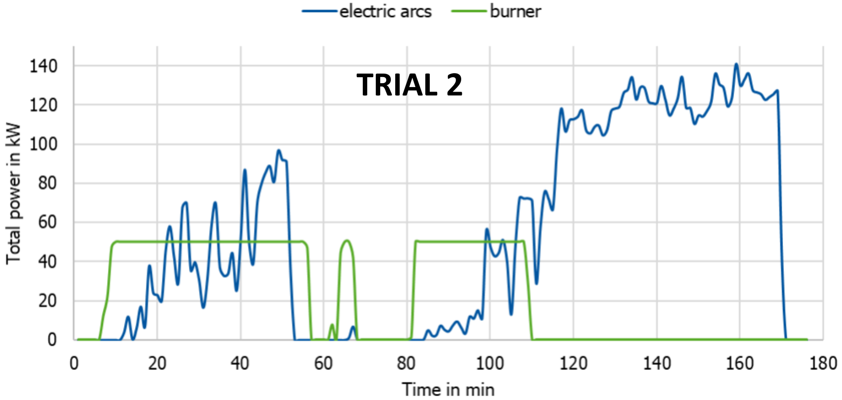
Experimental trials in pilot scale EAF (RWTH)

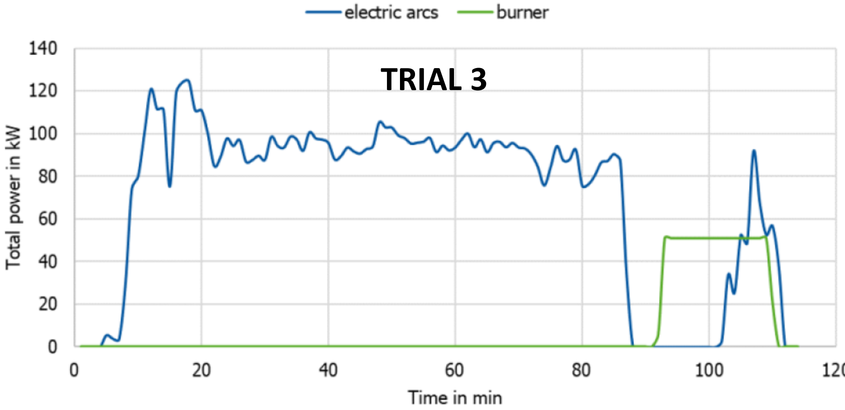
The 50kW burner has been installed in the pilot scale EAF with an active power of 600 kW and 2000 A of maximum arc current.

	Trial 1	Trial 2	Trial 3
Fuel gas	100%H_2	100% H_2	100% H_2
Operation mode	Flat bath, then burner	Burner during the melt down	Burner during the melt down
Problems	Start of the burner while the electric arcs are present	Burner ignition without ignition electrode	Water leakage at the electrodes in the last minutes

Material	Weight (kg)
Iron flakes	50
Anthracite coal	1.3
Dololime	3
Screws from railroad sleepers	67







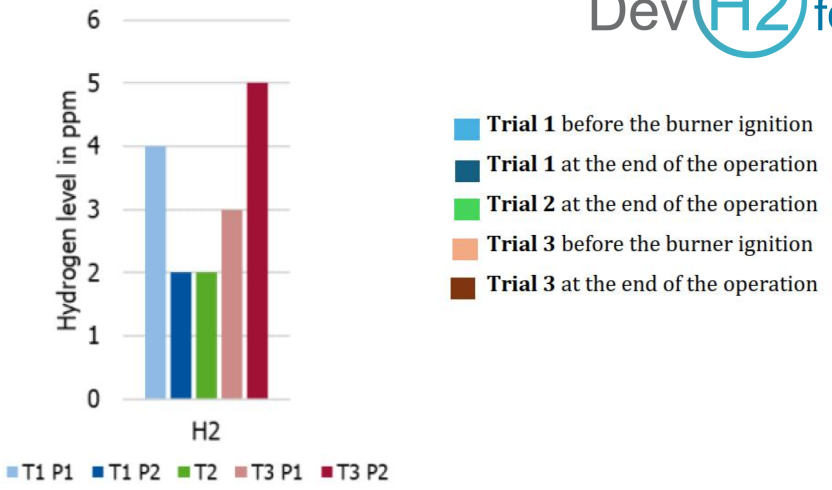
Experimental trials in pilot scale
EAF (RWTH)

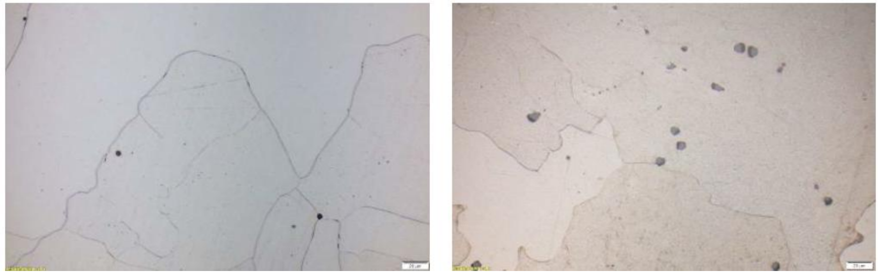
To assess the impact of the H_2 burner, **steel samples were analyzed during EAF trials.**

All samples showed **very low hydrogen content**.

1) **In the first and second trials**, **hydrogen levels remained low** or even decreased after burner use.

2) **In the third trial** was a **slight increase observed**, likely due to a water leak in the electrode cooling system.





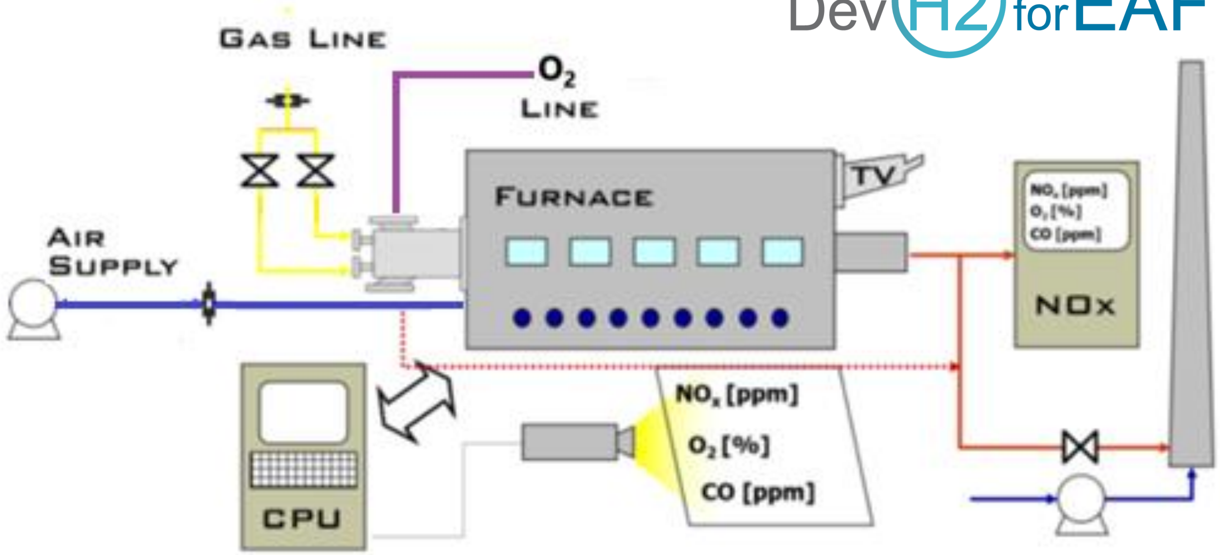
Steel microstructure was also examined. This analysis showed that none of the samples had **any pores that could have been caused by hydrogen pick-up**.

The low hydrogen levels detected in the samples as well as the microscopic analysis indicate that the use of a hydrogen-fired burner does not affect the hydrogen pick-up of the produced steel

Preliminary experimental campaign with Oxyfuel burner (RINA-CSM)

Experimental campaign at RINA-CSM combustion laboratory in Dalmine from **100% NG to 100% Hydrogen**, **including mixed configuration of NG-H2**.

The fuel mixing was performed by a dedicated mixing regulation system developed by Nippon Gases.



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		

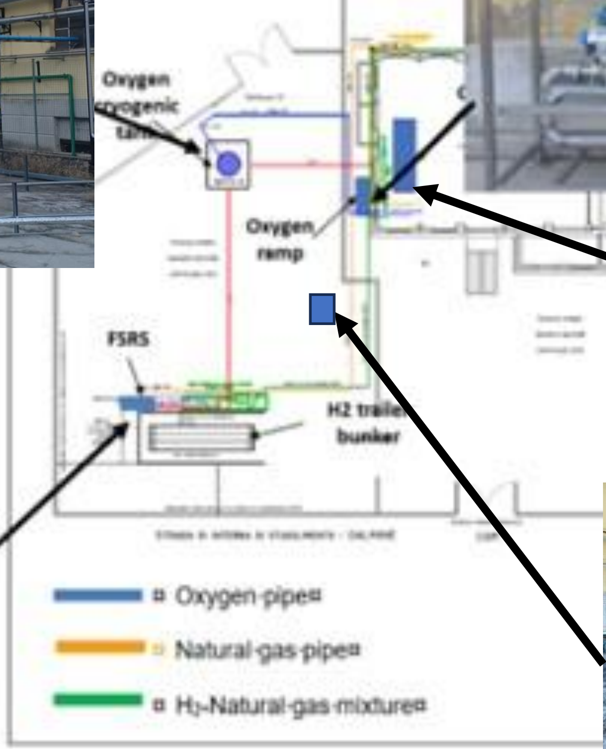
Preliminary experimental campaign with Oxyfuel burner (RINA-CSM)

The cryogenic **oxygen tank of 10.000 L**, the **FSRS** and the **Oxygen ramp**, **H2 burner** and **chiller** have been installed to RINA-CSM Dalmine.

Oxygen tank

Oxygen ramp

H2-burner



Fuel Supply and Regulation system

Chiller

Combustion chamber

Preliminary experimental campaign with Oxyfuel burner (RINA-CSM)

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 in flue gas**

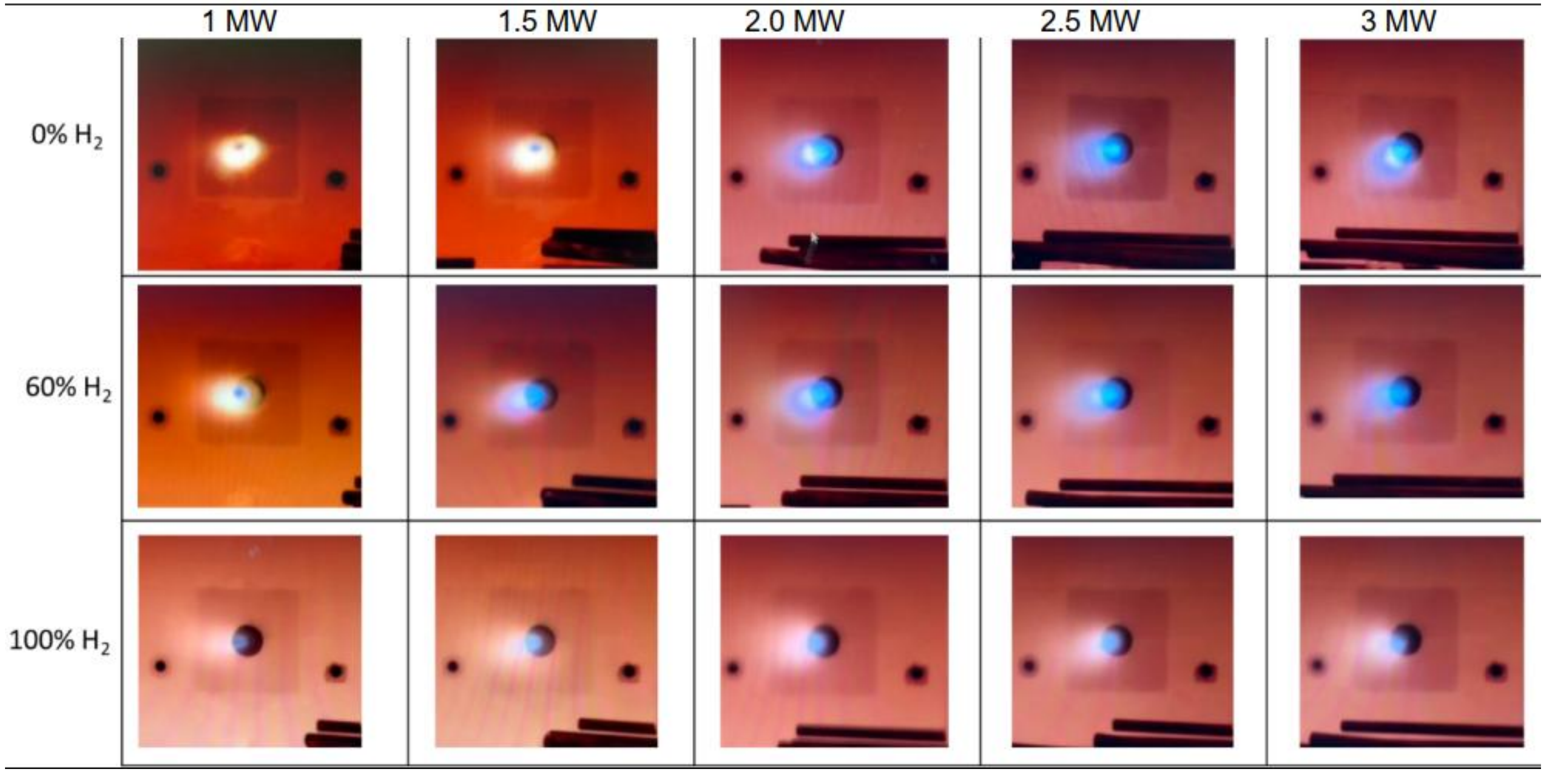
The H_2 burner has been tested at various power (**from 1 to 3 MW**) and various percentage of NG and H2 (**up to 100% of H_2**) and with different **combustion ratio** (1.05 and 1.2) at 1250 °C.

Power	Combustion ratio	%H_2
1	1.05 and 1.2	0%- 20%- 40%-60%-80%-100%
2	1.05 and 1.2	0%- 20%- 40%-60%-80%-100%
3	1.05 and 1.2	0%- 20%- 40%-60%-80%-100%
4	1.05 and 1.2	0%- 20%- 40%-60%-80%-100%
5	1.05 and 1.2	0%- 20%- 40%-60%-80%-100%

Preliminary experimental campaign with Oxyfuel burner (RINA-CSM)

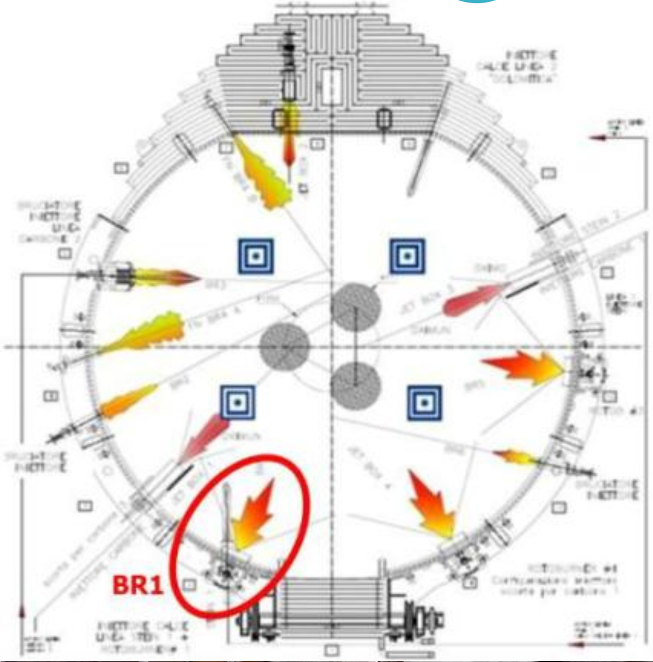
These tests have permitted to evaluate:

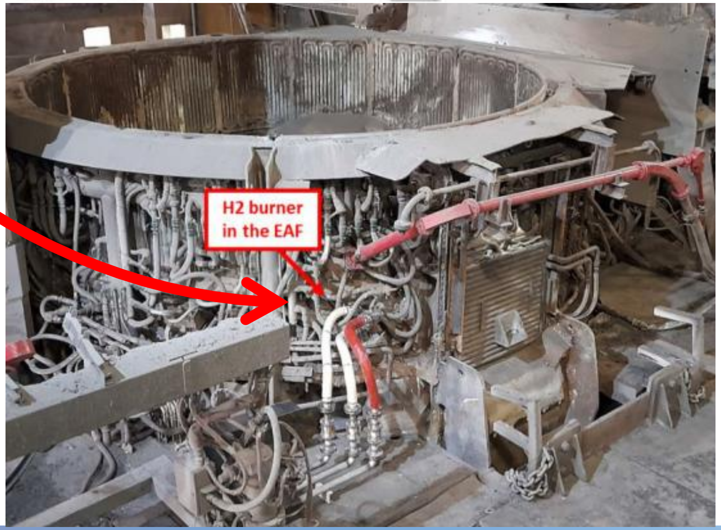
1) **The H2/NG flow rate remained stable**, even at 3 MW and high hydrogen concentrations.
2) The increase in hydrogen content led to a rise in temperature at the first thermocouple, indicating that **hydrogen is more reactive** and initiates ignition closer to the burner tip.
3) The average heat transferred **was 61% at 1 MW** and **74% at 3 MW**, attributed to the longer cooling lances necessary to maintain furnace temperatures below 1250°C.



Industrial experimental trials with Oxyfuel burner (FeNo)

Process Data	FENO
Capacity (t)	147 t liquid
N° of burners	8 NG burners+3 sidewall lances (in the first stage burners - in the last lances)
Max burner power (MW)	4
N° of Tuyeres	3 (bottom)
Max tuyere power (MW)	1
N° of Jet burners	4
Max Jet burner power (MW)	3
N°of C injectors	3
N°of polymers injectors	1
N° lime injectors	2
N° white slag injectors	2





The operating mode are reported below

- **Active Burner Mode**: Power set point received remotely, leakage check, calculation of required oxygen flow rate, and stoichiometric ratio monitoring.
- **Anti-Splash Mode**: Set points for oxygen and NG, stoichiometric ratio monitoring.
- **Purging Mode**: Nitrogen used to flush out residual gases.
- **Anti-Clogging Mode**: Nitrogen used to prevent blockage of burner channels.

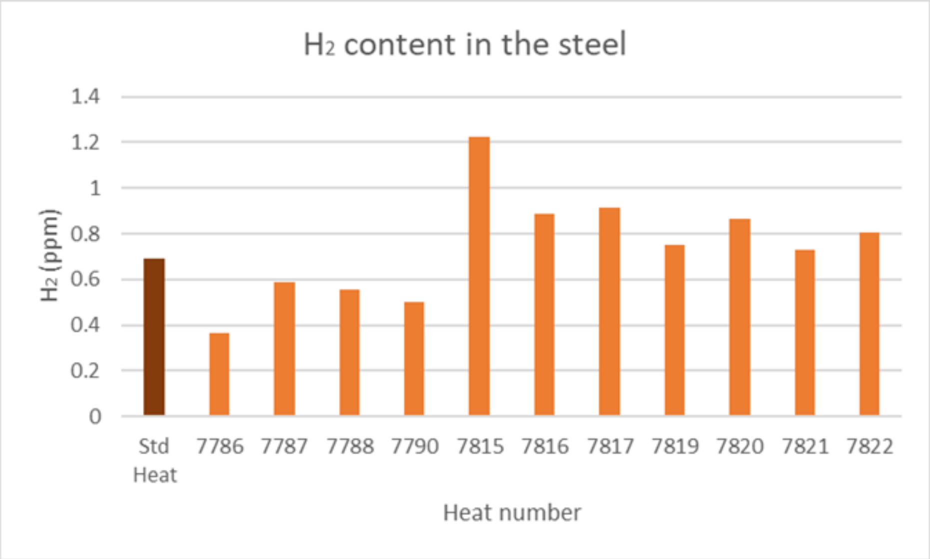
Industrial experimental trials with Oxyfuel burner (FeNo)

Approximately **3,800 Nm^3 of hydrogen used**. The H_2 burner was tested at its maximum power (**4 MW**) and with a **100% H_2 flow rate**.

Number of H2 Test	N° Heat	Steel Grade	N° Basket	% H2	Max Deliv. Power
1	7786	FE34+B	1	50	3.0 MW
			2	50	
2	7787	FE34+B	1	75	3.0 MW
			2	75	
3	7788	FE34+B	1	100	3.0 MW
			2	100	
-	7789	FE34+B	1	0	3.0 MW
			2	0	
4	7790	FE34+B	1	100	3.0 MW
			2	100	
5	7791	FE37+B	1	100	3.8 MW
			2	100	
6	7792	FE37+B	1	100	4.0 MW
			2	100	
7	7793	FE37+B	1	100	4.0 MW
			2	100	
8	7794	FE37+B	1	100	3.8 MW
			2	0	
9	7795	FE37+B	1	100	3.1 MW
			2	100	
10	7796	FE37+B	1	100	3.0 MW
			2	100	

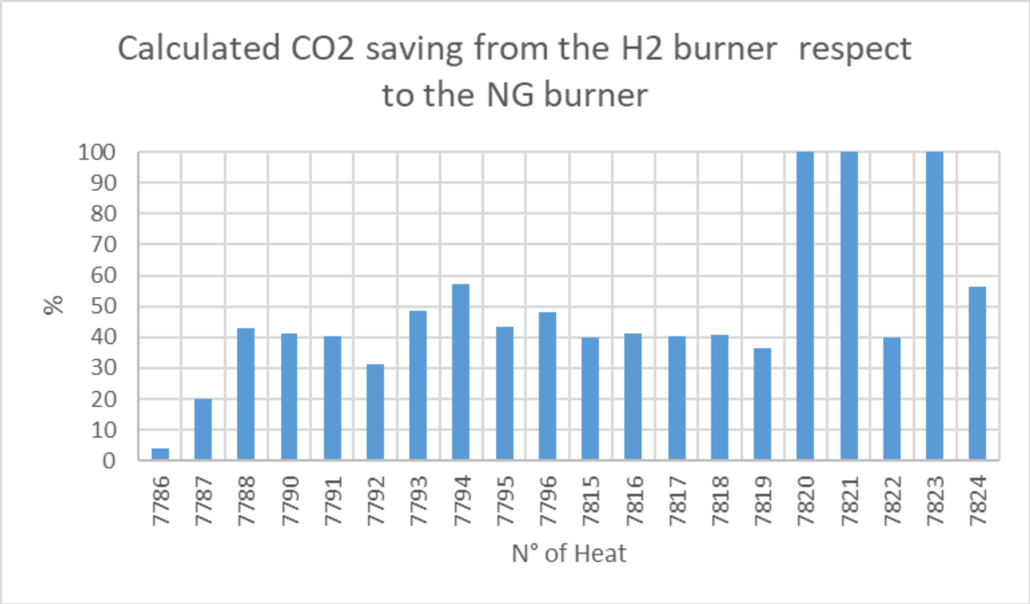
Number of H2 Test	N° Heat	Steel Grade	N° Basket	% H2	Max Deliv. Power
11	7815	FE50	1	100	2.9 MW
			2	100	
12	7816	FE50	1	100	3.0 MW
			2	100	
13	7817	FE50	1	100	3.0 MW
			2	100	
14	7818	FE50	1	100	3.1 MW
			2	100	
15	7819	FE50	1	100	3.5 MW
			2	100	
16	7820	FE50	1	100	3.7 MW
			2	100	
17	7821	FE50	1	100	3.6 MW
			2	100	
18	7822	FE50	1	100	3.1 MW
			2	100	
19	7823	FE50	1	100	2.9 MW
			2	100	
20	7824	FE50	1	100	3.1 MW
			2	100	

For **15 heats, the H_2 burner was operated with 100% hydrogen**, while the other burners were supplied with natural gas. For **3 heats all the NG burners have been shout down.**



There is a certain variability on the results, but **the hydrogen concentration is always lower than 2 ppm** which is safe enough against any type of defects.

Industrial experimental trials with Oxyfuel burner (FeNo)



1) Average CO_2 reduction achieved by the H_2 burner is **approximately 48%**, due to NG has been used during the anti-splash phase.

2) For three heats, however, a **100% CO_2** reduction was achieved, **as the other burners were turned off** and **hydrogen** was also used during the **anti-splash phase**.

Conclusions

The experimental campaigns demonstrated the feasibility of using hydrogen (H_2) burners in Electric Arc Furnaces (EAF) without impairing steel quality and ensuring the highest level of safety. Here are the detailed conclusions:

1) **EAF Pilot scale trials**: H_2 content in the steel after using the H_2-burner is only a few ppm for all samples, This confirms that hydrogen burners do not compromise the structural integrity of the steel.

2) **Preliminary experimental campaign with oxyfuel burner**: The hydrogen burners demonstrated good operational stability even at high power levels (up to 3 MW) and with high hydrogen concentrations.

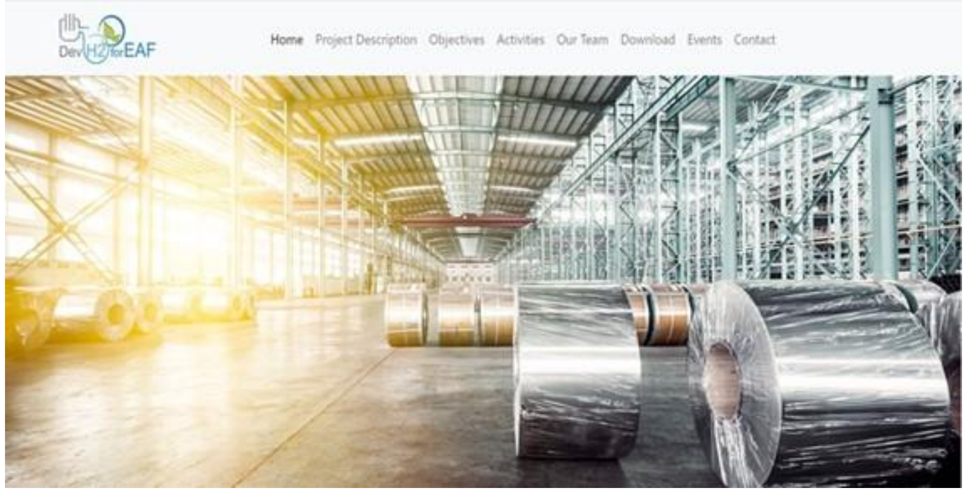
3) **Industrial experimental trials**:
   3.1) Experimental trials with the hydrogen (H_2) burner steel samples in LF remained below 2.0 ppm, which is considered safe and does not lead to any defects.
   3.2) The H_2 burner achieved an average CO_2 reduction of 48% due to NG use during the anti-splash phase, while 100% reduction was reached in three heats where only hydrogen was used throughout.

At the present, **the transition from natural gas to hydrogen in electric arc furnaces (EAFs) is currently hindered by**
1) the **lack of adequate infrastructure** for hydrogen transportation
2) **high production cost of green hydrogen**,

However, considering that **green hydrogen production costs will decreases** by around 50% by 2030 due to falling renewable energy prices and that the **price of CO2 will increase** due to stricter EU climate targets, the use of H2 in EAF could become economically viable very quickly.

DevH2forEAF web site

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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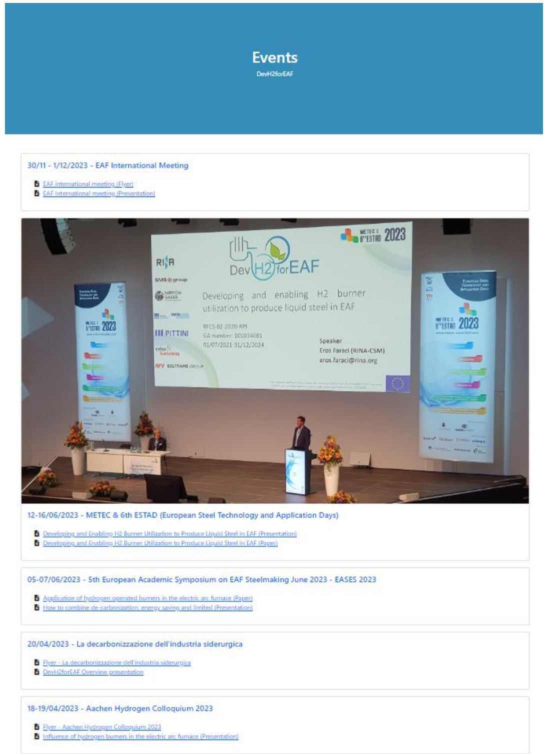

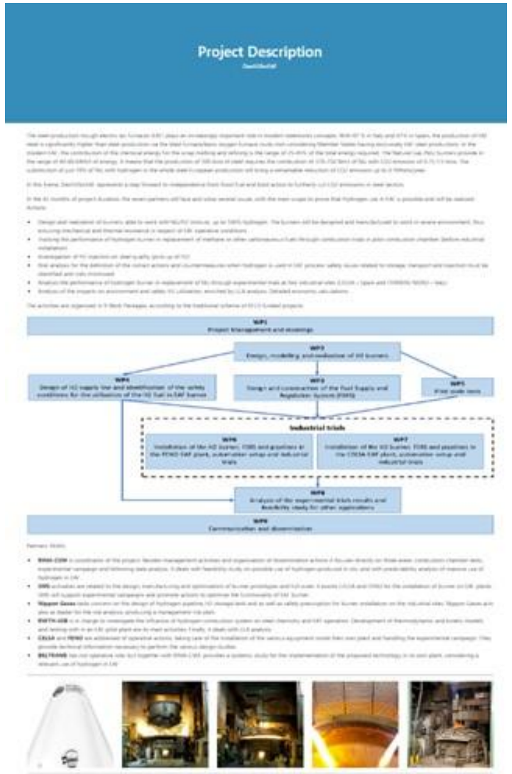

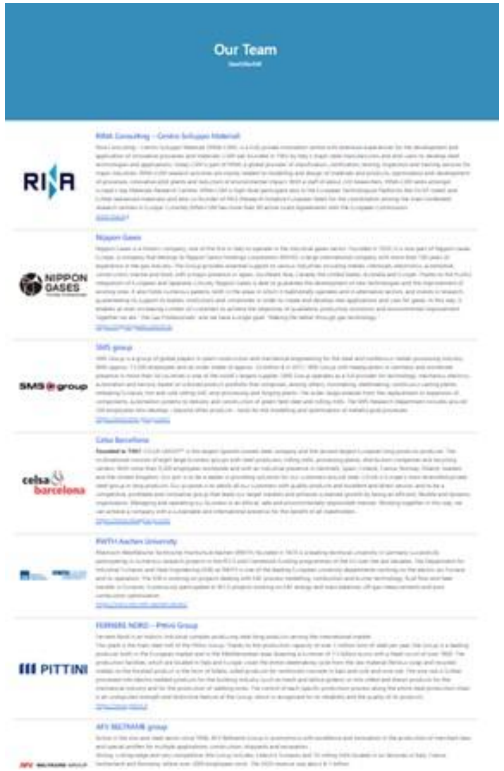

ACKNOWLEDGMENTS

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DevH2forEAF

Thank you for your attention

For further information visit the website
https://www.devh2eaf.eu/

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