ESTEP 2025 Annual Event
28-30 October 2025
Udine (ITALY)

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

HYBRID TECHNOLOGIES FOR SUSTAINABLE STEEL REHEATING: HyTecHeat project

Co-funded by the European Union

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INDEX

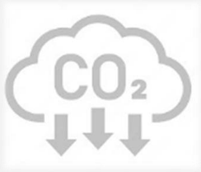
HyTecHeat

- Overview of the project
- Innovative multi fuel & Hydrogen ready burner
- Burner application in TRL7 democase
- Democases (2) & (3)
- Steel oxidation & descaling
- Conclusions

Project number:	101092087
Project name:	HYbrid TEChnologies for sustainable steel reHEATing
Project acronym:	HyTecHeat
Call:	HORIZON-CL4-2022-TWIN-TRANSITION-01
Topic:	HORIZON-CL4-2022-TWIN-TRANSITION-01-16
Type of action:	HORIZON-IA
Service:	HADEA/B/03
Project starting date:	fixed date: 1 December 2022
Project duration:	42 months

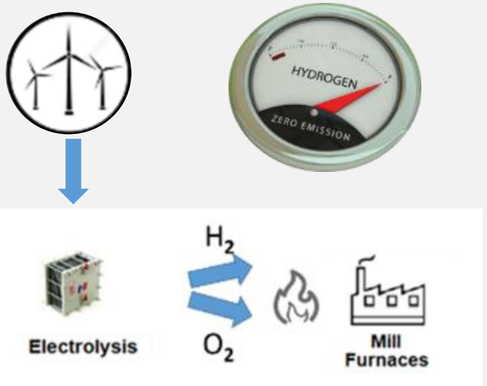
Project Overview

Project goal



Reduction of CO_2 emissions of industrial furnaces by mixing/replacing fossil fuels with **green H_2.**

Objectives



2 industrial size demonstrators of furnace fed by NG/H_2

1 demonstrators linking **PV, electrolyzes, storage** and **H_2 ready combustion system**

Guidelines on operation, maintenance, environmental footprint of steel production.

Guidelines on installation of electrolyzers on-site.

Digital tools for enhanced process monitoring.

Project partners

Rina-CSM (project coordinator): laboratory tests
- scale formation and descaling tests for H_2 combustion
- effect of H_2 atmosphere on furnaces refractories

SNAM / De Nora Upstream H_2 value chain:
Electroliser / H_2 storage

Tenova: technology provider furnaces and H_2 ready combustion systems
- modellig of burners and furnaces with different mix H_2/NG
- combustion test of innovative burners at TLAB in Castellanza

NUNKI STEEL SPA (NUNKI)
- steel samples
- applications of H_2 burners for Ladle pre-heating

TenarisDalmine: samples of steel grades for seamless pipe

SWERIM:
- Heating and descaling test on blooms with Oxy-fuel burner (Linde) and air burner (Tenova) with different mix H_2/NG

Linde: technology provider for oxy-fuel burners

SSAB:
- C steel sample for plates

Tata Steel:
- laboratory tests of existing burner fed with NG/H_2 mix
- C steel sample for plates

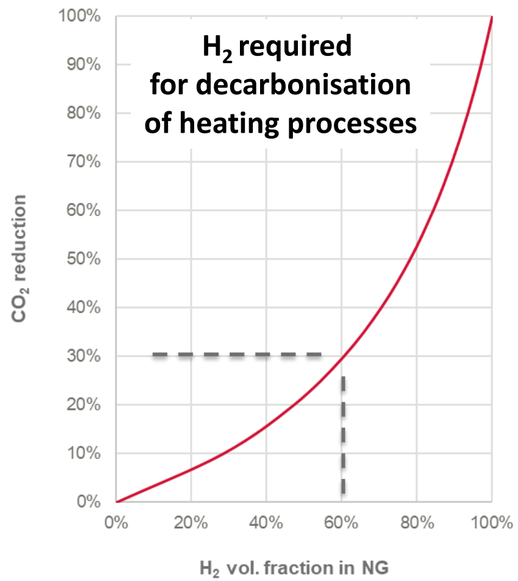
AM:
- Scale formation test
- C steel sample for plates

HyTecHeat

The challenge

H_2 allows a direct reduction of CO_2 emissions but require high % in volume:

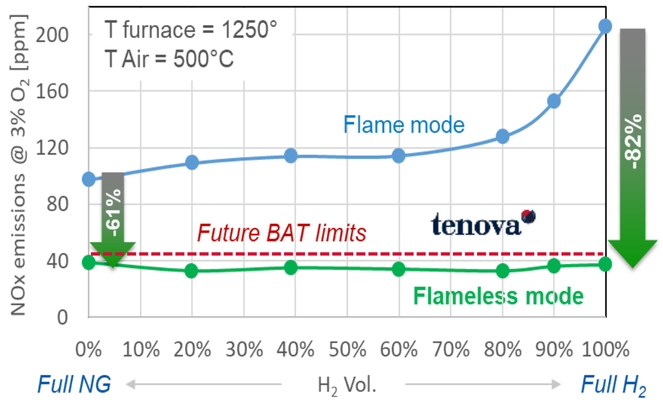
↑ **H_2 > 60%** ↓**CO_2 > 30%**



Flameless Combustion allows low NOx emission also with high % H_2

↑ **NOx flame burners**

↓**NOx flameless burners**



H_2 use in steel furnace poses some issues

Effect of H_2 atmosphere

Impact on product
(scale formation, yield)

Impact on insulation materials
(burner block, lining, gases duct)

Avoidance of undesired conditions (i.e. condensation)

Secure H_2 supply
(generation, transport & storage)

Long-term full-scale trials
- **system integration**
- **industrial demonstration**

HyTecHeat

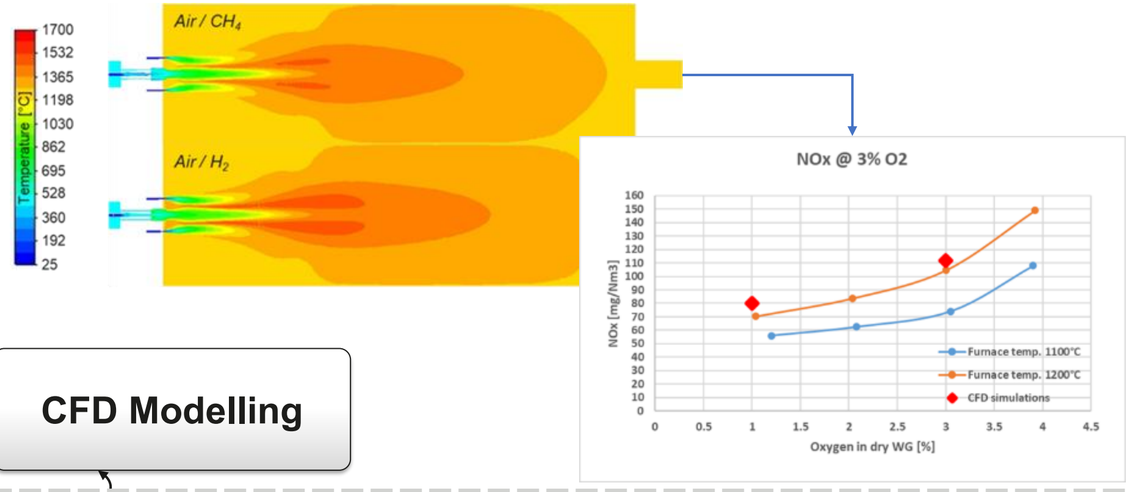
Innovative H_2 ready burner: Tenova TLX

Burner are designed and optimized by synergy between engineering, virtual prototyping, experiments

TLX burner for HyTecHeat(test at Tenova / SWERIM)	
Thermal power input	320 kW
Gas type	NG / Mix Gas (*)
Turnd-down	150-320 kW
Process Temperature	600-1250 °C
Combustion air temperature	450 °C / Ambient
Air pressure (at burner)	< 450 mm w.c.
NG pressure (at burner)	< 2000 mm w.c.
H2 pressure (at burner)	< 2000 mm w.c.

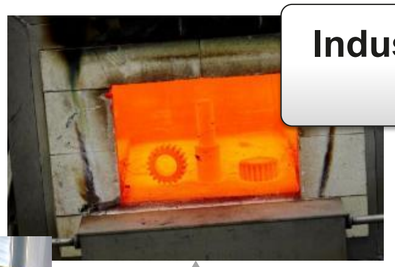
(*) 1/3 LPG and 2/3 H2 (in volume). LCV: 9143 kcal/Nm3, Density: 0,6813 kg/Nm3, Air and gas ratio: 9,527 Nm3/Nm3

TENOVA TLX for HyTecHeat



Design engineering ↔ **CFD Modelling**

Industrial scale Demo ↔ **LAB Tests**



DEMO 1 @Tenova
HYBRID HEATING
with H_2/NG

MILL TEST @ Swerim with LPG
STEEL QUALITY EVALUATION

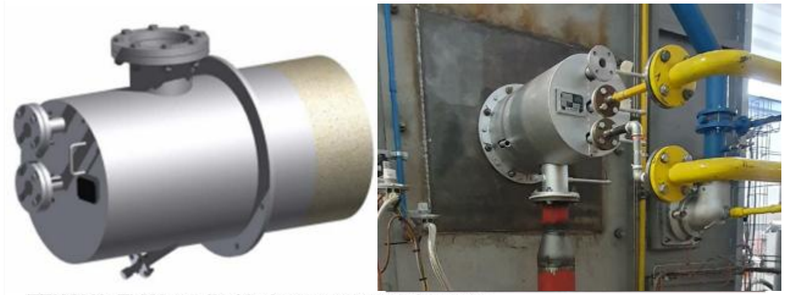
a) Flame during cold light up

c) flameless at 1200°C

Innovative H_2 ready burner: Main achievements

Lab tests

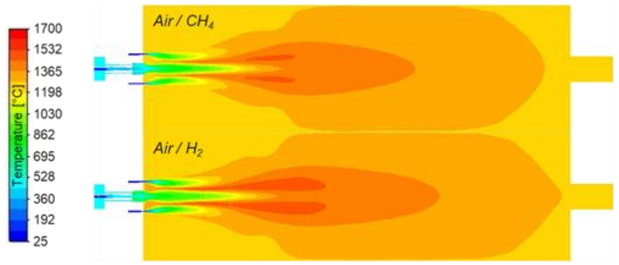
The experimental tests carried out with 100% NG (as H_2 is not yet available) confirm that Tenova TLX represents the baseline for the H2/NG/LPG multi-fuel burner prototype developed within the HyTecHeat project.

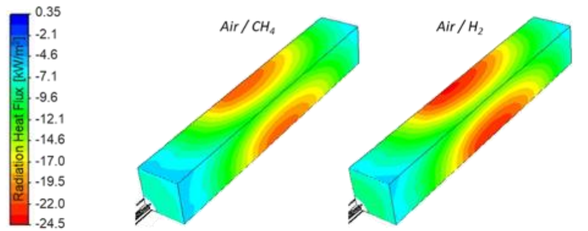


TENOVA TLX installed in heat treatment furnace

CFD modelling

- show good agreement with NOx emission trend registered during the test campaign with NG
- confirm that diffuse combustion allows lower peak temperature with respect to flame cases (Flameless Combustion) making possible the usage of high % of H_2 in industrial application with low NOx emissions, aligned with other Tenova NG and “Hydrogen Ready” combustion system family
- Indicate that different CO_2/H_2O ratio between NG and H_2 combustion lowers the absorption coefficient leading to higher heat flux for H_2 with the same energy input





Fume @ Furnace Exit	Air/CH_4	Air/H_2
Temperature [°C]	1269	1272
O_2 [% mol]	1.1	1.3
NOx [ppm 3% O_2]	33	16

Demo case (1) @ Tenova Campus in Castellanza

Demo owner: tenova

Demo location: Castellanza (Va), Italy

Technology providers: tenova, DE NORA, snam

Retrofit: on site green H_2 production

Capacity: 1 MW alkaline electrolyzer / 30 bar H_2 storage

Energy expected savings: Electrical energy from PV roof

CO_2 emissions potential[1] savings: 50/180 $kgCO_2/t_{CS}$

NO_x emission limit: 70-100 mg/Nm^3 (both for NG & H2)

TRL: 4 (current) → 7 (end of project)

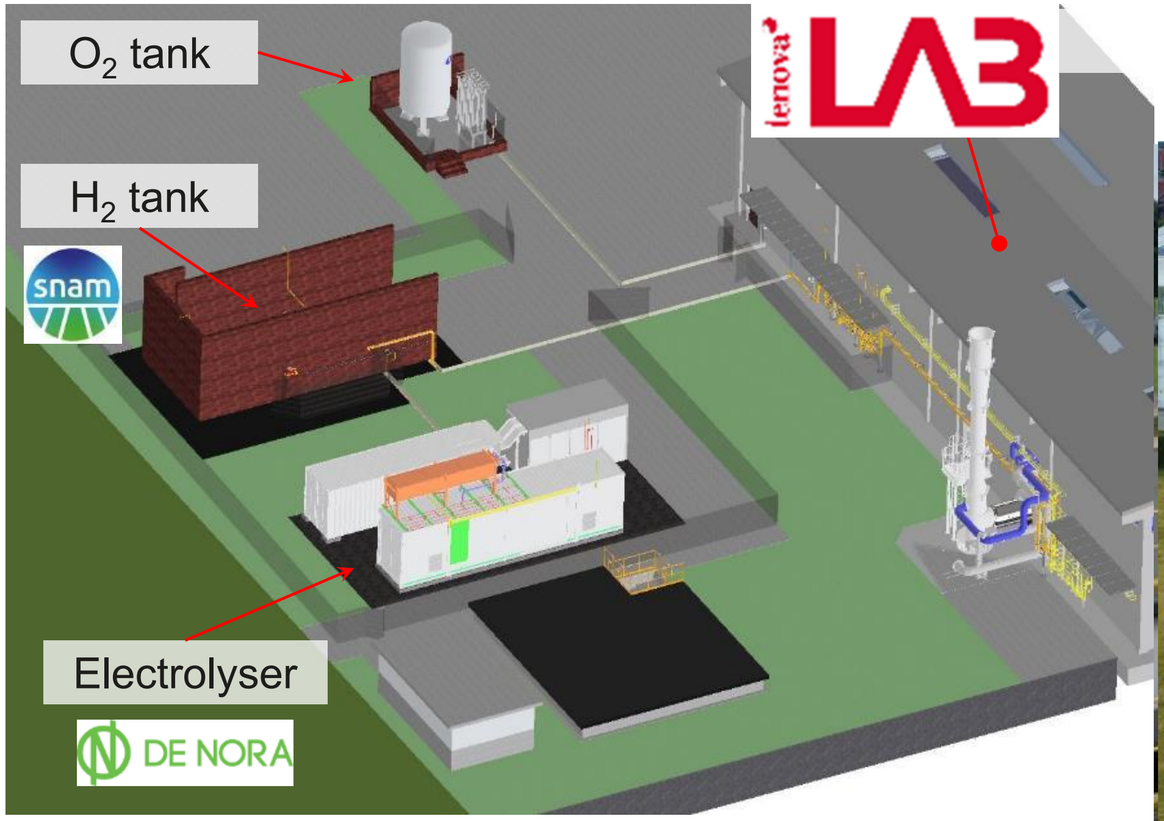
Further characteristics: High-efficiency "H_2 ready" Tenova TLX 320KWth lateral burner for re-heating and treatment furnaces

Tenova TLX burner

HyTecHeat installation

Installation and Testing of H_2 production

The expansion of the TenovaLAB has been completed with the 1MW new generation alkaline electrolyzer (De Nora DragonFly® system) for producing up to 240 Nm^3/h of H_2, and 30 bar H_2 storage.



Storage: technical solution

The tank has a volume of 30 m^3 and can store up to 900 Nm^3 of H_2 at a pressure of 30 barg.

Box of reinforced concrete walls

Safety devices to prevent the pressure from exceeding the design value.

Cooling system with water spray, triggered by a fire detection device.

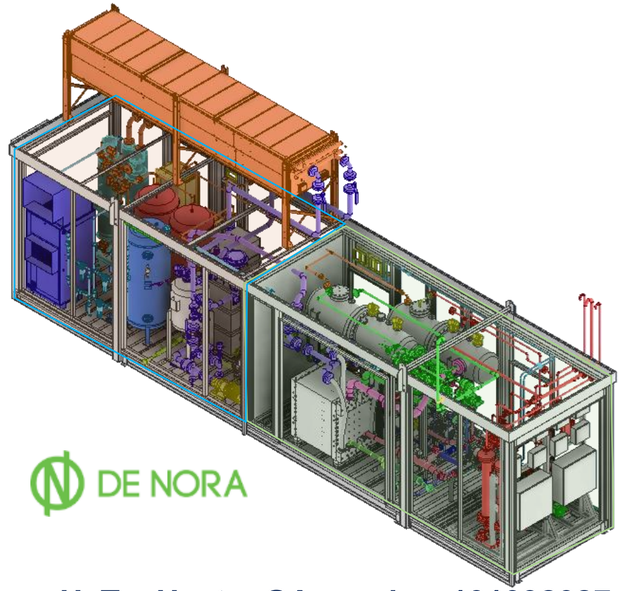
Alkaline electrolyser: challenge and technical solution

Pertaining technical challenges handled by DragonFly® solution, main items are:

High Productivity Stack

The stack installed is based on De Nora know-how in electrode technologies, allowing for continuous and

Specific Stack productivity can be as high as 3x vs traditional AWE stacks



Innovative cooling system

Strong reduction in circulating electrolyte solution by means of an alternative service fluid, utilizing the stack as an heat exchanger

HyTecHeat project: democases (2) and (3)

Democase (2): limit of current combustion system

Tata democase is devoted to test limits of current combustion systems; revamping the existing pilot furnace (Rondeoven) in Tata Steel Nederland

Furnace upgrade is ongoing up to a 700 kW capacity and a maximum operating temperature of 1350 °C.

The combustion air can be preheated by a gas powered 210 kW pre combustor and oxygen can be added to the combustion air to compensate for the used oxygen by the burner.

The revamped furnace is representative of the working condition of the majority (more than 60%) of the burners used in reheating processes by Tata.

Setup under conclusions and tests in November 2025.

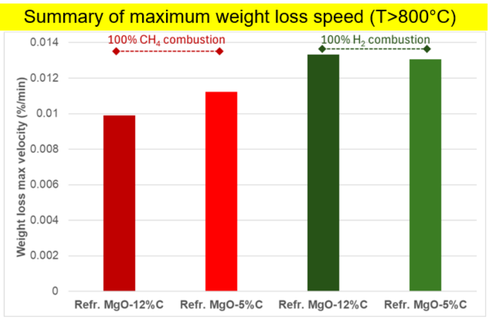
Democase (3): ladle refractory preheating

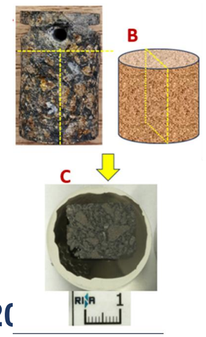
Democase (3) is devoted to hybrid ladle refractory preheating

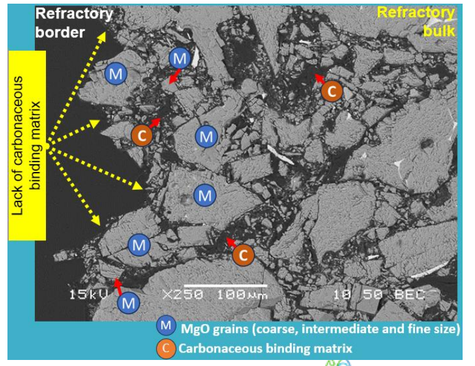
The burner has 2 MW maximum power, (the working range is between 0.2MW-2MW), with NG max flow rate of 240Nm3/h

Thermogravimetric tests simulating the hydrogen combustion atmosphere have been performed at 900°C on the two MgO/C type (C respectively at 5% and 12% in the refractory mix),

Tests revealed an increase of reactivity of binding carbonaceous phase, with H20 (parallel reactions also with CO2 and O2), but the increasing of thickness of decarburised layer was not significant







Steel oxidation rates under different conditions

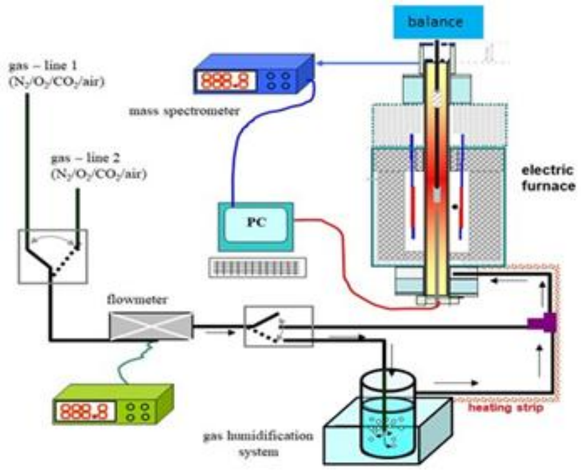
AIM

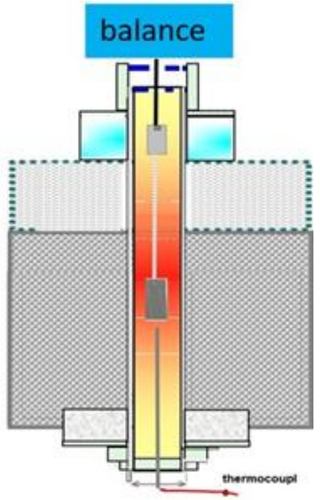
To define differences in the oxidation kinetics of a variety of steel grades with increasing %H_2O in the furnace atmosphere resulting from H_2 combustion in air instead of NG

To outline variations of oxide scale features that can have a potential effect on the descalability.

ACTIVITIES

TGA tests & Post-test SEM/EDS analysis on steel samples supplied by partners





Substitution of NG with H_2			
	NG/air combustion		O_2 enriched air combustion
Gas mixture	0% H2	100% H2	100% H2
	composition (%)		
O_2	2	2	2
CO_2	9	0	0
N_2	remaining		
H_2O	18	32	48

Temperature		
1200°C	1050°C	900°C

Time	Gas flow rate
120 min	250Nl/h

Isothermal TGA tests at 1200°C, 1050°C, 900°C in atmospheres:

- NG/air combustion;
- 100% replacement of NG with H2,
- 100% replacement of NG with H_2 in O_2 enriched air combustion

List of tested steel grades

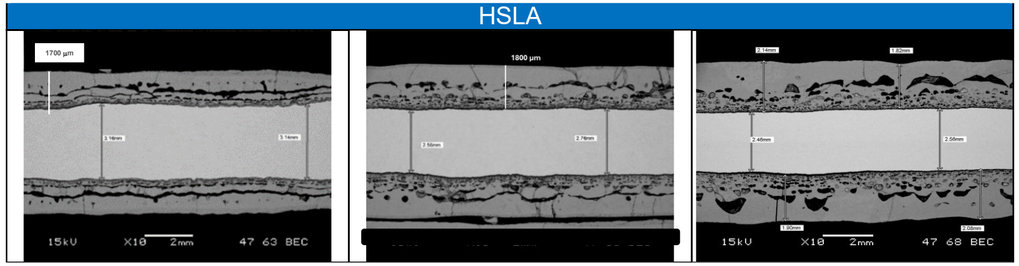
Steel	C	Si	Mn	Cr	Mo	Ni	P	S	V	Al	Cu
HSL	0,045	0,02	0,976	0,036	-	0,049	-	-	-	-	0,138
DD11	0,052	0,028	0,154	0,054	-	0,062	-	-	-	-	0,163
ST52	0,177	0,212	1,16	0,022	-	0,040	-	-	-	-	0,085
DP600	0,07	0,224	0,842	0,695	-	0,022	-	-	-	-	0,017
S420MC	0,067	0,011	0,704	0,014	-	0,022	-	-	-	-	0,008
ULC	0,013	0,093	0,993	0,433	-	0,142	-	-	-	-	0,214
1,9Mn0,8Si	0,23	0,79	1,9	0,1	-	-	-	-	-	-	-
X22CrMoV	0,18-0,24	<0,05	0,4-0,9	11,0-12,5	0,8-1,2	0,3-1,5	<0,015	<0,015	0,25	-	-
AISI316	<0,07	<1.0	<2.0	16,5-18,5	2,0-2,5	10-13	<0,05	<0,02	-	-	-
13Cr	<0,05	<1	0,25-1,0	11,5-13,5		<0,5	<0,02	<0,01	-	-	-
P91	0,08-0,12	0,2-0,5	0,3-0,6	8-9,5	0,85-1,05	<0,12	<0,02	<0,01	0,19-0,25	<0,01	-
N80Q	0,23-0,26	0,15-0,30	1,25-1,4	0,4-0,5	0,08-0,1	-	<0,02	<0,01	-	0,02-0,035	-
X60	0,08-0,19	0,2-0,35	0,1-1,4	<0,06	<0,07	<0,15	<0,015	<0,03	0,04-0,1	-	-
HSLA	0,05	-	1,3	-	-	-	-	-	-	-	-
DP800HpF	0,2	0,4	2	-	-	-	-	-	-	0,7	-

Results of oxidation tests

All steel grades tested as well as the post-test scale characterisation completed (by Rina CSM and AMMR)

Samples analyzed by LM and/or SEM with EDS analysis (scale thickness, morphology, level of porosity, and oxide/steel interface with increasing H_2O content 18% → 32% → 48%. **Tests with 48% water non foreseen in the original technical annex**

Oxidation rate increase with the water vapour content, however, large differences between the steel grades were observed.



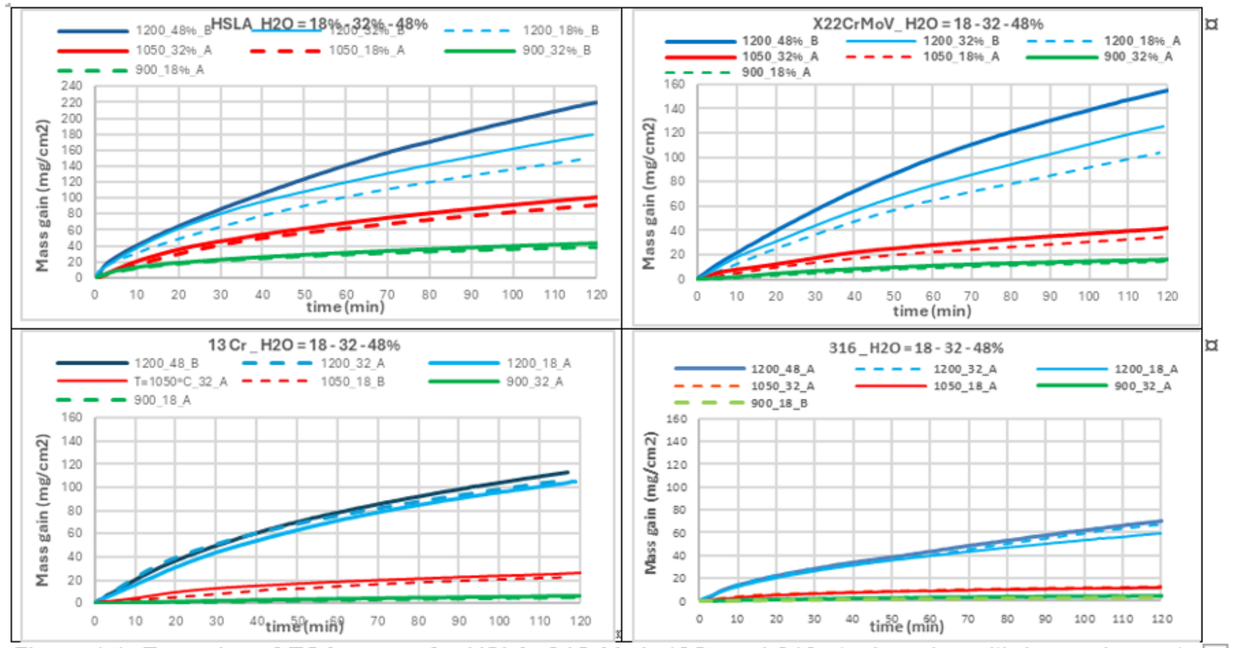
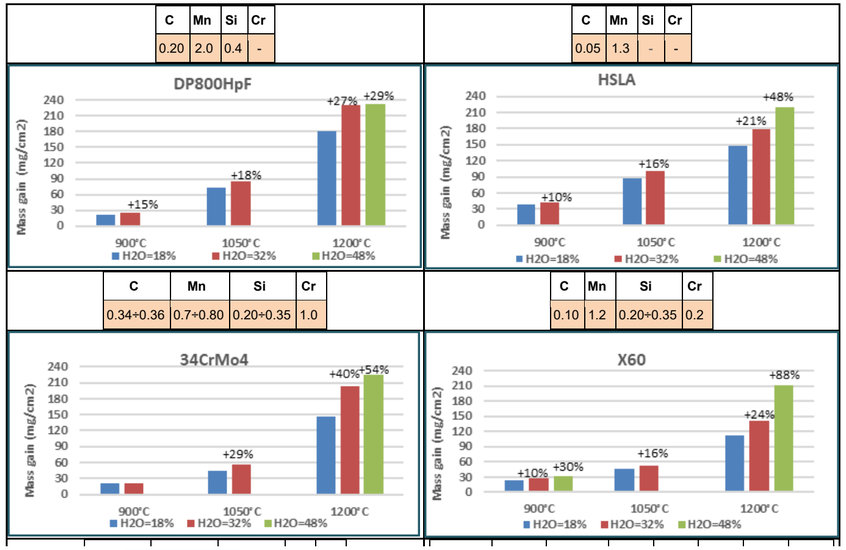


Figure 1.1: Examples of TGA curves for HSLA, 34CrMo4, 13Cr and 316 steel grades with increasing water vapor content 18% → 32% → 48%



Calculation of the kinetic constants Kp for steel grades: From TG tests carried out at the different temperatures and atmospheres, ln Kp in $(mg/cm^2)^2/s$) was plotted as a function of the inverse of the absolute temperatures 1/T obtaining a straight line

$k_p = A \cdot e^{(-E/RT)}$

$\ln K_p = \ln A - E/RT$

Results of descaling tests

The descaling conditions used for these trials represent an efficient furnace descaling configuration, including high-pressure water jets and optimized nozzle arrangements.

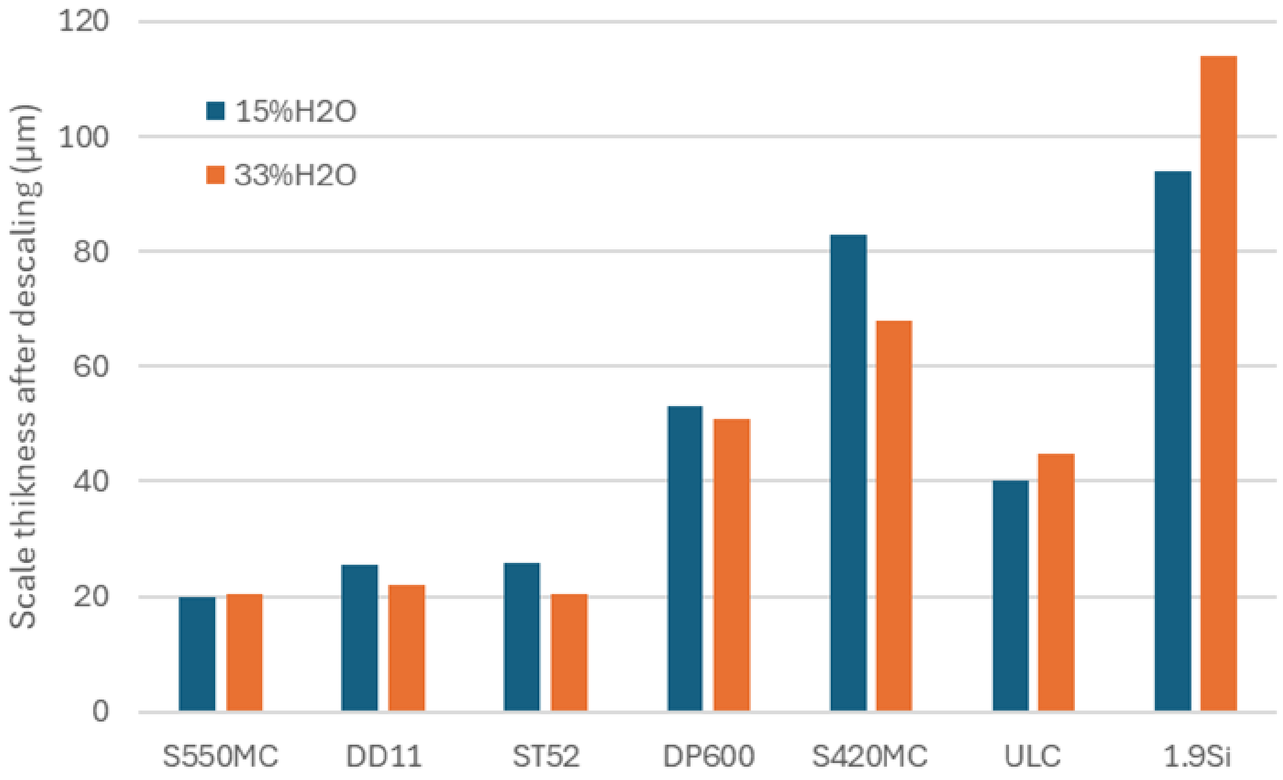
All descaling trials were performed under the following parameters:

- Descaling speed: 0.8 m/s; Supply Pressure: 160 bars
- Flow Rate per Nozzle: 83 l/min

No surface or descaling issues are observed with the usual atmosphere corresponding to natural gas combustion with an excess air leading to 2-3% of O2, a vapor amount of 15%.

Heating conditions differ based on the type of production facility: CSP plants use rapid heating conditions (980°C to 1160°C in less than 40 minutes), HSM facilities employ gradual heating conditions (20°C to 1230°C over 3 hours and 30 minutes), and plate mills utilize tailored heating conditions specific to their thicker products.

The specific heating conditions were used depending on the industrial conditions in the furnaces.



Results by AMMR tests simulating industrial conditions

HyTecHeat project: 1st reporting period conclusions

- ✓ Tenova adapted the TLX burner to be used in hybrid and flexible conditions to burn NG/LPG/H_2 with air and O_2
- ✓ TLX burner has been connected to a 1MW electrolyser (Democase 1) to be fed by green hydrogen simulating industrial environment
- ✓ Simulation and testing of Tenova TSX burner with NG provided reliable results; demo case operation with H_2 foreseen by end of 2025

- ✓ Thermogravimetry oxidation tests and the scale characterization by LM and/or SEM with EDS analysis completed. TG tests were performed on all the selected carbon and stainless-steel grades at 1200°C for 120 min in an atmosphere composition corresponding to the total substitution of NG with H_2 in O_2-enriched air combustion, characterized by a water vapour content of 48% with 2%O_2 in N_2.
- ✓ The oxide scale features were then compared to previously oxidized samples to identify any variations in thickness, morphology, level of porosity, and oxide/steel interface with the increasing H_2O content (18% → 32% → 48%). **Results indicate that all the steel grades show an oxidation rate increase with H_2O content, but large differences amongst the steel grades were observed: for some steel grades** the increase ranges between 20 and 30%, except for stainless steels
- ✓ Scale thickness after a descaling with an effective configuration: The scale thickness after descaling was not significantly affected by the higher vapor content during heating (32% of H_2O vs 15% of H_2O)

Future outlook

Condition for a successful transition of hard to abate industry to H_2 …

Availability of green H_2 in high quantity at affordable cost

Energy infrastructure

Timely permitting

Agreements with customers & green premium

.. while key risk and opportunities need to be managed

- Competitive sourcing of H_2
- Operational integration of plant assets with diversified sources of H_2 production, transport and supply
- Project execution in green and brownfield environments
- EU and National policy development and regulatory uniformity

QUESTIONS & ANSWERS

Co-funded by the European Union

Hybrid **TeC**hnologies for sustainable steel re**heat**ing - **HORIZON-CL4-2022-TWIN-TRANSITION-01-16, Modular and hybrid heating technologies in steel production (Clean Steel Partnership) - GA number:101092087**