HYbrid TEChnologies for sustainable steel reheating – HyTecHeat

HORIZON-CL4-2022-TWIN-TRANSITION-01-16, Modular and hybrid heating technologies in steel production (Clean Steel Partnership)
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Deliverable 8.1: Exploitation Plan: first Draft
WP8 Exploitation & business plan

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Disclaimer

Executive Summary

These analysis will be also integrated by LCA analysis of the process. The trends of availability of green hydrogen will be taken into account. Also dissemination activities will be carried out according to a purposely prepared dissemination plan.

The purpose of Deliverable is to develop the first version of oriented exploitation plan and the management of relevant IPR that will allow the HyTecHeat project results as well as the technologies and model developed to penetrate the+ market in a cross-sectorial manner. This firs version of the exploitation plan gathers the initial ideas on possible exploitations. This document will be a living document, evolving throughout the project to keep track of potential opportunities for cross-sectorial application of the project results as they are identified.
In general, Exploitation indicates the utilization of project results outside the research consortium and for further research, commercial, societal, or political purposes. This is important because a project's ultimate success is defined by effective exploitation, involving also different industrial sectors.Based on results and data available from the market and literature an evaluation of cost benefit deriving from H_2 utilization will be carried out.

The measures to maximize the impact of HyTecHeat results will be based on the Communication, Dissemination and Exploitation (C&D&E) strategies focusing on the following main objectives:

- Promoting project outputs and successful results to the public audience,
- Describing the key results and making them visible and available to all key stakeholders to use them,
- Making concrete exploitation of results.

These strategies are outlined in the corresponding C&D&E plans, which will be living documents and will be constantly updated in agreement with the project results and community feedbacks. Three version of the three C&D&E plans are foreseen, namely by the first 6 months (first draft), at the middle of the project (mid-term draft) and at the end of the project (final draft).

To complete the scope of the deliverable 8.1. a summary of the most relevant points about IPR management has been included together with a summary of the background and foreground of all the HyTecHeat partners.

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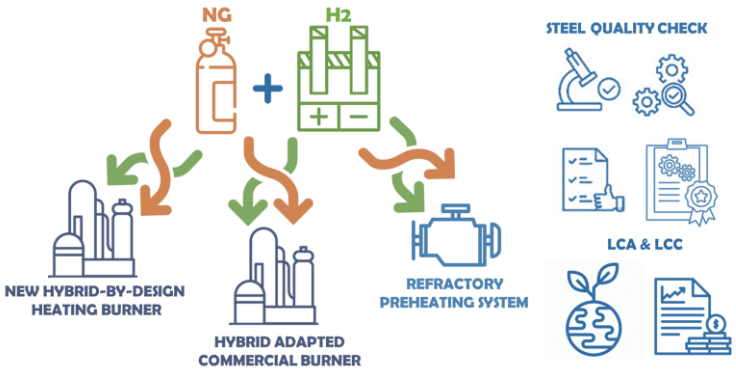
List of Acronyms

AMGA	Annotated Model Grant Agreement
CFS	Certificates on the Financial Statements
CP	Contingency plan
DLV	Deliverable
DoA	Description of Action
EC	European Commission
EU	European Union
GA	General Assembly
KoM	Kick of Meeting
MA	Mitigation action
OSH	Occupational Safety and Health
PC	Project Coordinator
PM	Person Month
SC	Steering Committee
TL	Task leader
WP	Work Package
WPL	Work Package Leader

1 INTRODUCTION

HyTecHeat aims at adopting hybrid heating technology (based on NG with progressive and increasing H2 utilization) in downstream processes so to path the way for the abatement of CO2 **for the whole downstream processes at EU level of 7.5 Mt (if conservatively 30% of H2 is considered) up to about 25 Mt (if 100% of H2 is used)**. Taking into account that the overall emission of CO2 in EU from all industrial sectors in 2018 (before the COVID pandemic) is estimated to be 2.9 Gt[1], the implementation of HyTecHeat technology in all EU downstream process (100% of H2) will lead to an abatement of 0.9% (25 Mt) of the EU CO2 emission. Thermal treatment and reheating processes, which are common to both BF and EAF route, in fact, have a significant NG demand (about 50 Nm3/t of produced steel). In order to allow the shift from NG to H_2 and consequently to reduce the environmental impact by using innovative hybrid combustion technologies, impacts on steel quality and furnace must be assessed also with the realization of Demo cases at high TRL (7).

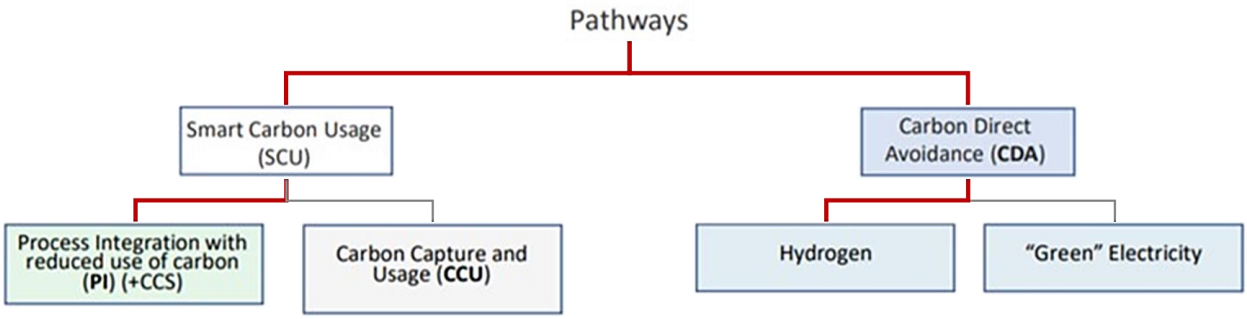
To have a complete picture of the possibility of **hybrid technology 3 different *democases* are envisioned**: first in TENOVA democase a **hybrid by-design burner will be designed and test in order to evaluate advantage and possible risk needed to be mitigated in this new systems**; in TATA democase, a burner **currently fully-NG will be adapted to evaluate the limit up to which the current systems can be pushed to work in hybrid heating gas atmospheres without reducing system performance.** Finally, in the Nunki democase the **effect of hybrid heating system will be evaluated on the quality of the refractory in pre-heating systems**. Moreover, lab test will be carried out in order to find the **optimal conditions to push the systems from TRL 7 (during the project) to TRL 8 (after the project)**. Thanks to HyTecHeat technology the effects and the limits of hybrid heating technology up to 100% of H2 will be evaluated on the entire chain of steel downstream process. The results are expected to have a wide impact on the entire steel sector due to the flexible approach of HyTecHeat, fully adaptable to both new-by-design and adapted burner systems.



[1] Global Carbon project https://ourworldindata.org/annual-co2-emissions

2 GENERAL SCENARIO DESCIPTION

The iron and steel industry is responsible for about 4 % of anthropogenic CO_2 emissions in Europe, and 9 % worldwide, due to the massive use of coal[2]. In order to contribute of the prevention of global warming, the reduction of CO_2 from the steel works becomes a major issue imposed on the steel industry. A variety of new CO_2 reduction technologies have been developed and can be adopted in the EAF steel production. In general, two main pathways for CO_2 mitigation in the steel industry are defined: Carbon direct avoidance (CDA) and smart carbon usage (SCU), while the latter consists of the two parts, i.e. 1) process integration with possible integration of carbon capture and storage (PI+CCS), and 2) carbon capture and usage (CCU) as illustrated in Figure below.



Scheme of technological pathways to reduce CO_2 emission in the steel industry.

CDA covers the development of new processes that would produce steel mainly from virgin iron ore using renewable electricity and/or hydrogen from renewable electricity to massively replace the current fossil fuels (coal and/or natural gas). PI refers to all process options to produce steel from fossil carbon-based fuels/reductants (e.g. coal, coke, oil, natural gas, etc.) which can reduce the fossil CO_2 emission compared to the state-of-the-art EU plants. PI is dedicated to the process improvements, modifications or fuel switching within existing steel plants (integrated and/or scrap-EAF), either to reduce fossil CO_2 emissions or capture CO_2 from the production processes.

Therefore, it can be combined with CCS (carbon capture and storage), which includes the CO_2 capture and separation from the large-scale emission sources, compression, and transportation to the suitable storage facilities and . Carbon Capture and Utilization (CCU) which includes CO_2 conversion into products like fuels, base chemicals or polymers. In EAF steel production, a large amount of the emitted CO_2 derives from burning of natural gas. Natural gas is used to support the melting process in EAF, to preheat ladle and tundish and in the reheating and thermal treatment furnaces.

Tables below report the annual natural gas consumption, the theoretical amount of H_2 (for 100% substitution) and the saved CO_2 (expressed in ton/y). data refers to a single steel plant equipped with EAF (bold character outline the data which are affected by HyTecHeat activities).
Larger NG consumption (and subsequent CO_2 emission) occurs in reheating and heat treatment furnaces.

[2] EPRS | European Parliamentary Research Service, Author: Christian Kurrer, Scientific Foresight Unit (STOA); PE 641.552 – December 2020

NG utilization in EAF steel production	Continuous Charge CH_4Nm^3/tCS	Bucket Charge CH_4Nm^3/tCS (Nm3/y)	Continuous Charge H_2 (Nm^3/y)	Bucket Charge H_2 (Nm^3/y)
liquid steel (EAF)	5-6.5	11-15	15-19.5	33-45
EAF	1-1.5	7-10	3-4.5	21-30
refractory heating	**4-5**	**4-5**	**12-15**	**12-15**
Reheating furnace	**40-60**		**120-180**	

Potential CO_2 saving	Continuous Charge CO_2 kg/tCS	Bucket Charge CO_2 kg/tCS
liquid steel (EAF)	10-12	21-30
EAF	2-3	14-20
refractory heating	**8-10**	**8-10**
Reheating furnace	**110-160**	

(*) I. Matino et all Green Hydrogen for decreasing the fossil fuels exploitation in electric steelmaking route: one of the identified priority intervention areas of the ESTEP roadmap for an improved EAF scrap route, paper presented at the workshop Hydrogen route for a green steel making process, online workshop, 7 th , 21 th , 28 th MAY 11 th JUNE 2021, organized by ESTEP Focus Group Circular Economy

(**) N. Schmitz, L. Sankowski, F. Kaiser, C. Schwotzer, T. Echterhof, and H. Pfeifer, "Towards CO2-neutral process heat generation for continuous reheating furnaces in steel hot rolling mills – A case study," Energy, vol. 224, p. 120155, Jun. 2021, doi: 10.1016/j.energy.2021.120155.

Five European steel manufacturers (Arcelor, Tenaris, Nunki, SSAB, Tata) will participate in HyTecHeat. This important industrial presence in the project covers a very broad range of the European steel manufacturers with different types of steel grades (carbon steel, micro alloyed steel up to stainless steels) and product forms (strip, tube, long product / profiles and wire) and also with different raw material formats (billet to slab) and consequently different treatment temperatures (reheating furnaces, tunnel furnace, heat treatment). In addition, a supplier of burners and furnace components (Tenova) and technology providers (Linde Snam and Denora) are involved in strong cooperation with the steel manufacturers. The participating research institutes (RINA-CSM S.p.A, SWERIM) will support the steel and burner suppliers in this project with technical up-scaling up to expertise -the industrial tests validation and implementation.

According to table above, the maximum expected CO_2 saving is in the range 110/160 $kgCO_2/t$ produced steel.
In the European Union the annual crude steel production is about 158Mt; EAF production is 65 million tCS/y (Eurofer Steel Figure 2020, available at https://www.eurofer.eu/assets/Uploads/European-Steel-in-Figures-2020.pdf). Therefore, **HyTecHeat technology will lead to a CO2 reduction for the whole downstream processes at EU level of 7.5Mt (with conservative H_2 utilization of 30%) and up to about 25Mt CO2 (if 100% H_2 utilization is targeted).**

The Benchmark for Hot Strip Mills assumes a specific energy consumption of 1.4 GJ/t[3] rolled steel in gaseous fuels. The application regenerative and oxyfuel combustion technologies (both applied in this project) can decreases the process hydrogen demand at least of 30-50 Nm3/t of steel, favoring the hydrogen transition of the downstream processes. In addition to the climate targets, the participating mills will also benefit from the fact that:

(i) some customers are already demanding the "green steel",

(ii) they are prepared for the regulations that will be enacted in the future,

(iii) they gain early experience in dealing with H_2-additions and the solutions how to control the changing influences on product quality – and this will give them a strategic competitive advantage. Steel production is a strategic factor for European economy.

According to EUROFER data, (2020 European Steel in Figures, https://www.eurofer.eu/assets/publications/brochures-booklets-and-factsheets/european-steel-in-figures-2022/European-Steel-in-Figures-2022-v2.pdf) the Gross Value Added (GVA) of the European steel industry is also upwards of €134.5 billion (accounting direct, indirect and induced effects). It directly employs 310,000 highly skilled people; globally taking into account induced and indirect job positions, about 2.5 million of jobs are related to steel production. World leading technology providers are European companies too.

The European steel industry is a world leader in innovation and environmental sustainability and HyTecHeat proposal can contribute to *the top level* position of the European steel production in the competition of process decarbonization**.**

[3] according to *N. Schmitz, L. Sankowski, F. Kaiser, C. Schwotzer, T. Echterhof, and H. Pfeifer, "Towards CO_2-neutral process heat generation for continuous reheating furnaces in steel hot rolling mills – A case study," Energy, vol. 224, p. 120155, Jun. 2021*

EXPLOITATION ACTIONS

The measures to maximize the impact of HyTecHeat results will be based on the Communication, Dissemination and Exploitation (C&D&E) strategies focusing on the following main objectives:

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These strategies are outlined in the corresponding C&D&E plans, which will be living documents. These deliverables will be constantly updated in agreement with the project results and community feedbacks. Three version of the three C&D&E plans will be delivered, namely by the first 6 months (first draft), at the middle of the project (mid-term draft) and at the end of the project (final draft). Finally, a C&D Manager and an Exploitation Manager will be appointed by the Steering committee by the first 6 months who will oversee all dissemination, communication and exploitation activities. The C&D&E activities will be carried out in parallel during the lifetime of the project and will be on a two-way exchange basis to either:

- Obtain stakeholders' needs and expertise to be considered in project activities
- Disseminate achievements to the relevant stakeholders thus facilitating the evolution of the project solutions to further maturity levels.

The aim of the HyTecHeat exploitation strategy is to maximize the impact of the project key exploitable results (KER) and to bring the relevant results commercially fruitable, while granting to the HyTecHeat partners access to the rights of ownership to a full set of instruments to maximize the opportunities to create profitable results.

The following topics are also considered:

- hydrogen availability or in situ generation will be taken into account and estimated
- the total number of potential units will be estimated (reheating furnaces and heat treatment units) at European level
- a survey of 3-5 industrials plant facilities in Europe will be organised to explore user needs and their existing alternatives; this survey will be carried out by preparation of a questionnaire
- the minutes of every interview will be validated by the interviewees and their consent for using these minutes in a report will be requested formally, in accordance with EU data privacy rules.

Project outcomes will allow to associate to each steel grade the maximum amount of H_2 which can be used in reheating and thermal treatment furnaces without affecting scale formation and surface quality. An ideal prosecution of the achievements of this project is the H_2 utilization in real industrial furnaces, in blend with natural gas, using current combustion systems, up to 100% hydrogen utilization with installation of new burners. **Direct involvement of industrial partners in the project, represented by engineering companies and steelmakers, guarantees results transferability at European level beyond the lifetime of the project**. The large variety of steel grades investigated in this proposal and the large participation of industrial partners ensures applicability to integral and EAF steel production. In the following table the relevant assets developed within the project, are highlighted and their relevant impacts towards the market briefly described.

Project expected Exploitable result	Partner	Relevant Background - Foreground	Main exploitable responsible and routes for the market
Frontline in international research on the topic and validated pilots for H_2 (also in blends) will engage industry and lead to IA & RIA projects, and publications on the topic. Innovations in measurement technology can be tested and validated in our demonstrator. Swerim has developed a furnace control system software which simulate heat-transfer in a large number of operations for stock temperature control, ®STEELTEMP, that is used for research, and as a licenced software to many steelworks. It is also the core in the FOCS commercial on-line system for furnace control. ®STEELTEMP	Swerim, SSAB, Linde	Swerim is well renowned applied research institute well-known for large scale pilot demonstrators and close collaboration with the Nordic and European steel industry and research institutions. Work in heating technologies on the reheating side spans over many decades and has focused on NOx, CO2, energy efficiency, material quality, combustion, electrical heating etc.	Conferences, publications, LinkedIN and Webpage, the results will target EU industry, suppliers , SMEs, policymakers and stakeholders that are engaged in the steel market and its development, especially todays focus on decarb..
As research and consultancy company RINA-CSM will support steel companies in hydrogen transition using current system and integrating new technologies. As part of Rina Group RINA-CSM can support also energy audit, certified GHG emissions and lCA analysis	RINA-CSM	RINA-CSM is strongly involved at international and national level in research project and proposal preparation for green hydrogen utilization in different industrial sectors	Specialised congress and fares, social media, webpage and dedicated workshops
Tenova Demo case will define the industrial guidelines for integrating an electrolyzer in existing industrial combustion systems. This will demonstrate the feasibility of reducing CO2 emissions from any heating equipment in hot rolling area. Modification of the furnace control logic, relevant operating parameters and definition of proper furnace control strategies will be carried out given the presence of an electrolyzer stack fully representative of industrial green hydrogen production units.	Tenova	Tenova is a worldwide leader in reheating and heat treatment furnaces for the steel industry, combining long experience and innovative approach. State-of-the-art combustion systems are developed in Tenova using a integrated approach spanning from computational modelling to experimental tests and continuous improvement of its burner portfolio.	Via conferences, steel industry exhibitions, publications, company webpage, LinkedIn and Twitter posts, commercial offers for revampings and new combustion systems, connections with policymakers and stakeholders
As support of all ArcelorMittal plants, these results will be used by plants to	AMMR	AMMR is involved in several research projects	Specialised congress and

move faster in this energy transition and for some of them to a near 0 CO2 target at short term (AM Sestao). Technical solutions regarding combustion, burners, H2 supply are of 1st interests, as the knowledge that will be established about steel quality and the effect of the new combustion atmosphere on oxidation.		of ArcelorMittal aiming to reduce the CO2 emissions through the use of hydrogen instead of natural gas or internal gases, as well as NOx emissions to meet local regulations while providing green steel with the required quality	fares, social media, webpage and dedicated workshop
With the demonstration that existing burners can function with a mix of H2 / CH4, the decarbonization transition can be sped up by deferring the need for large capital mobilization. Determining the characteristics of such combustion processes and finding solutions to the challenges such as increased NOx emissions and flame stability are critical in this transition.	TATA	TATA is actively involved in the research concerning the use of hydrogen in both upstream and downstream processes of steelmaking.	Specialised congress and fares, social media, webpage and dedicated workshop

The advantages for the reduction of CO2 emissions and environment provided by the project results are relevant to boost decarbonization of downstream processes and to generate a first industrial applications of reheating processed fed by hydrogen, opening also to different businesses opportunities (hydrogen production and services, new flexible and hybrid burners) overarching objective of sustainability and greening of industries.
There might be potential inputs, through the partners and associations engaged, to ease the integration and spreading of project (direct and induced) benefits at
wider level at EU scale:
• Local authorities levies on installations of new facilities (RES and electrolysers)
• Reduced fiscal pressure for the enterprises investing in new technologies and creating the conditions for
creating new, highly skilled workplaces
• Reduced atmospheric emissions, leading to white and green certificates
All these elements further support the already positive industrial sustainability of the thermal production processes.

Conclusions

This Deliverables describes the KPIs that will be used to evaluate the achievements of MIRIA objectives.
KPIs can be mainly grouped in

- ✓ High Level KPIs, to demonstrate the achievement of MIRIA global aim

- ✓ Low Level KPIs, to monitor the specific technical objectives
- ✓ Communication & Dissemination KPIs to monitor the effectiveness of the communication and dissemination activities

For each KPI a target value is proposed and, where relevant, details on the evaluation procedure and data to be gathered will be provided.