Scenario analyses to evaluate the effects of hydrogen exploitation in EAF burners

Ismael Matino[1], Valentina Colla[1], Orlando Toscanelli[1], Aintzane Soto Larzabal[2,3], Asier Zubero Lombardia[3]

[1]Scuola Superiore Sant'Anna – TeCIP - ICT-COISP, Pisa, Italy

[2]Sidenor I+D, Bilbao, Spain

[3]Sidenor Aceros Especiales, Bilbao, Spain

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PRIMETALS TECHNOLOGIES

Content

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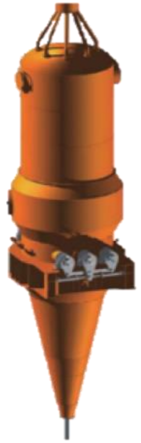
Introduction

Steelmaking sector is strongly committed to reach the European Green Deal objectives of achieving the **climate neutrality by 2050** by targeting **C-lean and green steelmaking**

Introduction

Several solutions are under investigation **for steelmaking decarbonization**

Transition from BF-BOF route to more sustainable ones



Improvement of existing Technologies and of resource efficiencies

Replacement of fossil materials

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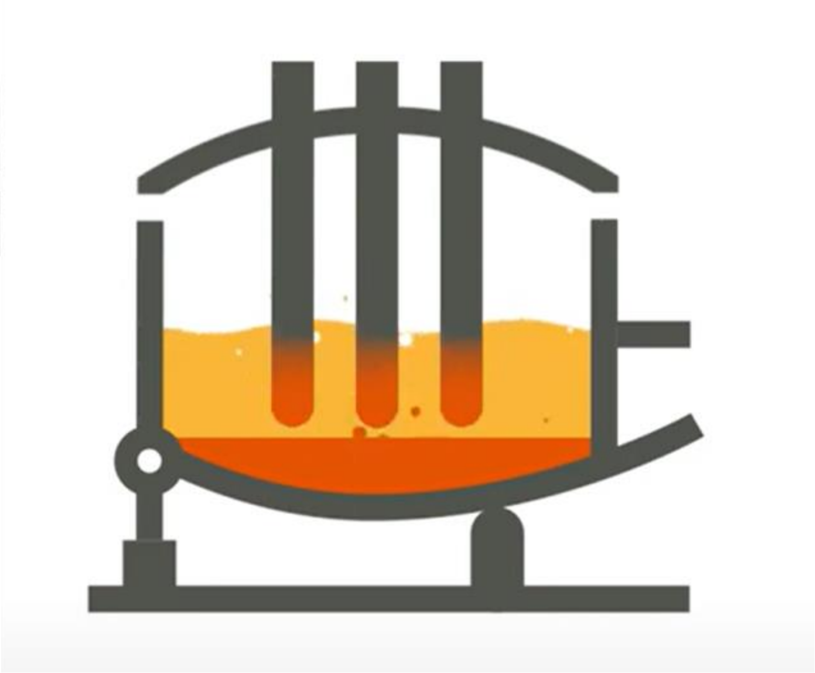
Introduction

- The **EAF**-based steelmaking route **is acquiring a higher role** compared to the past



- Efforts are spent to improve the sustainability of processes that already intrinsically fit the concept of circular economy

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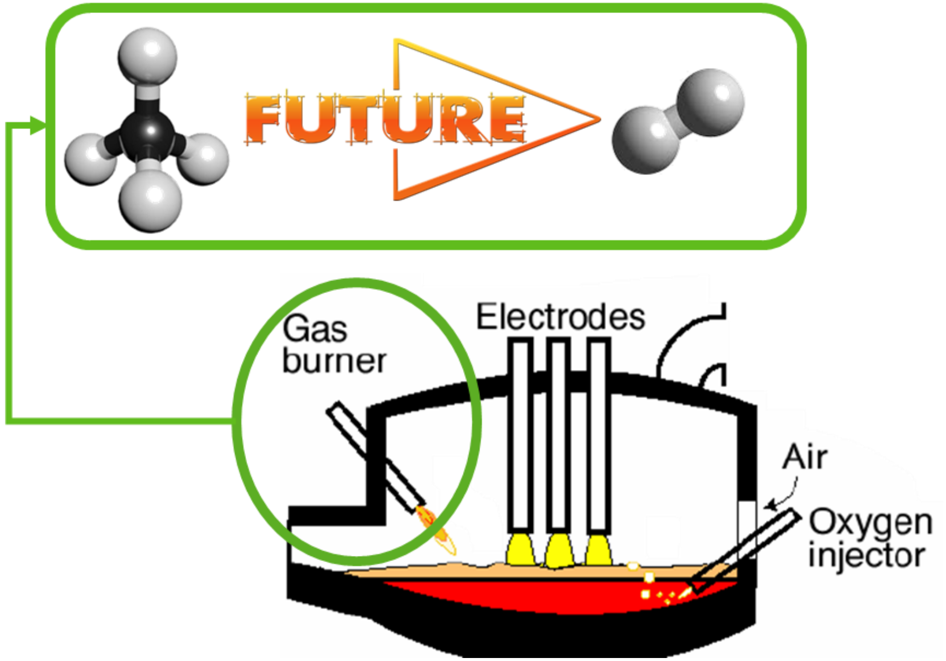
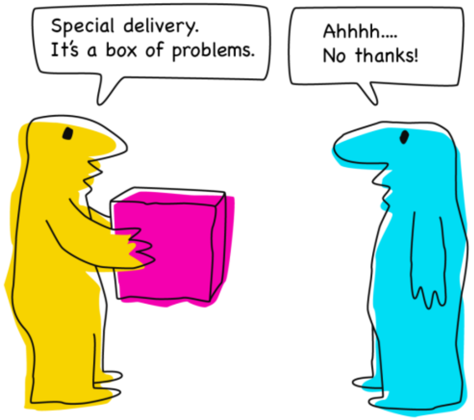
Introduction

- Among the different analysed possibilities, the **replacement of natural gas used in EAF burners** to provide part of the chemical energy required in EAF with green hydrogen has increasingly been considered





- However, **effects on the process and product have to be investigated** to avoid unexpected issues

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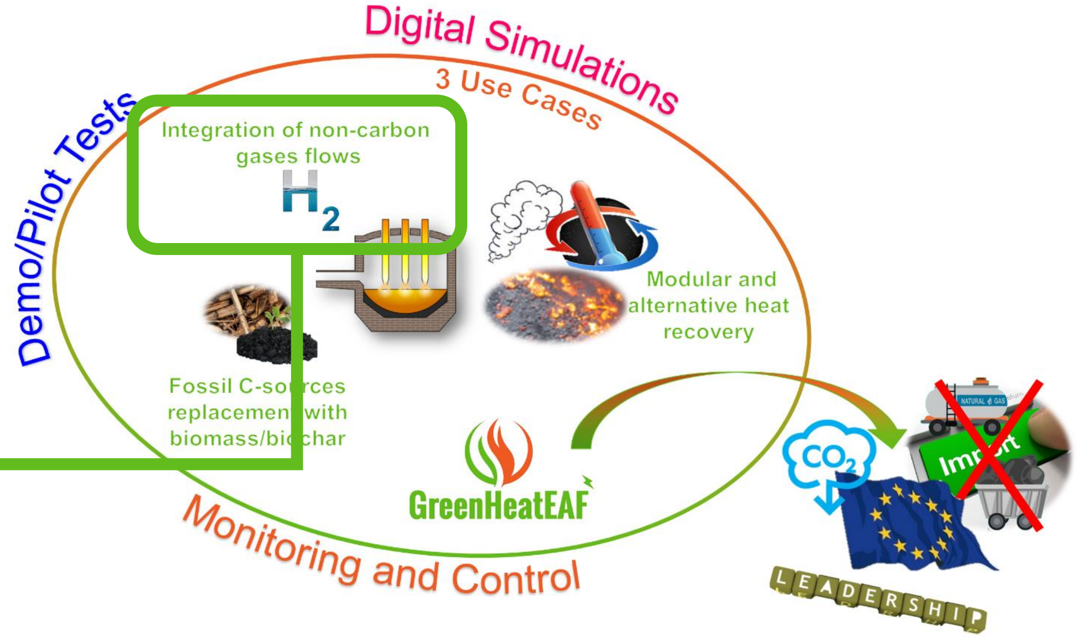
The GreenHeatEAF project

"Gradual integration of Renewable non-fossil Energy sources and modular HEATing technologies in EAF for progressive CO_2 decrease" G.A. No. 101092328



- Among other activities, **the effect of use of hydrogen in EAF burners is under investigations:**
  - trials with conventional and innovative burners
  - EAF pilot tests
  - **scenario analyses with ad-hoc simulation studies**

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Stationary flowsheet model of EAF production route: starting point

- **The first version of the flowsheet model was developed in Aspen Plus during the EIRES RFCS project and upgraded during the years within different projects** [1-3]
- **Main involved steps and considered phenomena are:**
  - sum of effects in terms of both mass and energy flows, chemical and physical balances, reactions and thermodynamic equilibria and transformations
  - Aspen Plus internal and customized unit blocks are combined together with ad-hoc calculators and design specs units to reproduce the various involved phenomena (e.g. melting, oxidation, tapping, refining, degassing, heat exchange)
- **The model is easily adaptable and transferable**
- **Tuning, validation and test on different steel families and on different steelworks** (e.g. Sidenor), generally using industrial data related to some thousands heats are used

[1] Matino, I. et al. (2016). Process modelling and simulation of electric arc furnace steelmaking to allow prognostic evaluations of process environmental and energy impacts. Matériaux & Techniques, 104(1), 104.
[2] Petrucciani, A. et al. (2022). Flowsheet Model and simulation of produced slag in electric steelmaking to improve resource management and circular production. Chemical Engineering Transactions, 96, 121-126.
[3] Matino, I. et al. (2024). Esplorare l'uso di fonti alternative e non fossili di carbonio nelle acciaierie elettriche attraverso un modello flowsheet dedicato. La Metallurgia Italiana, 24.

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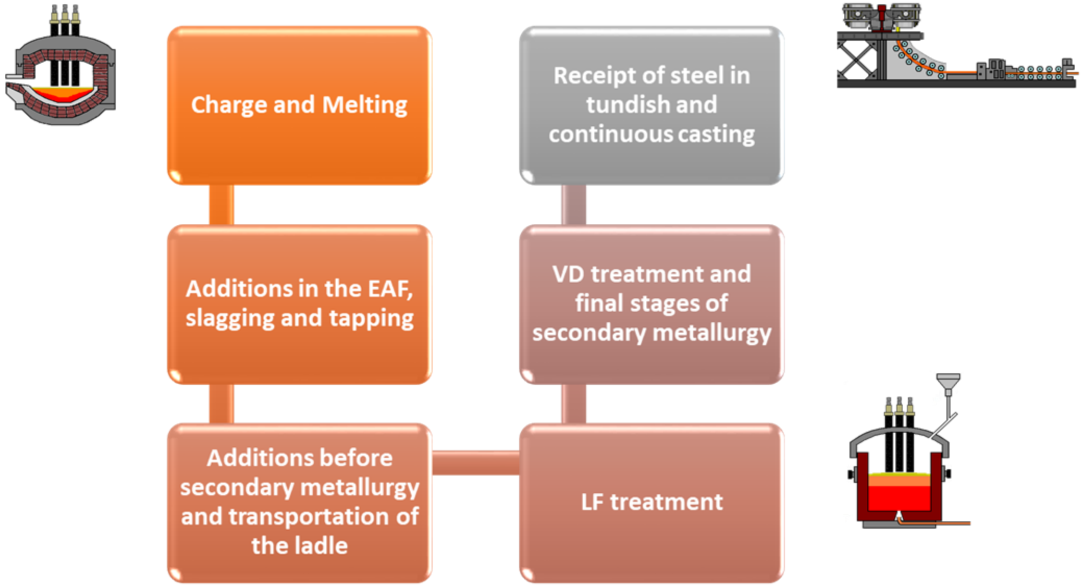
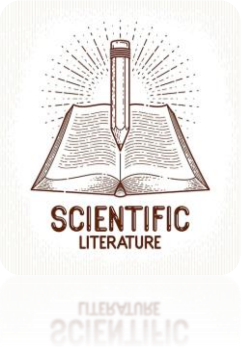


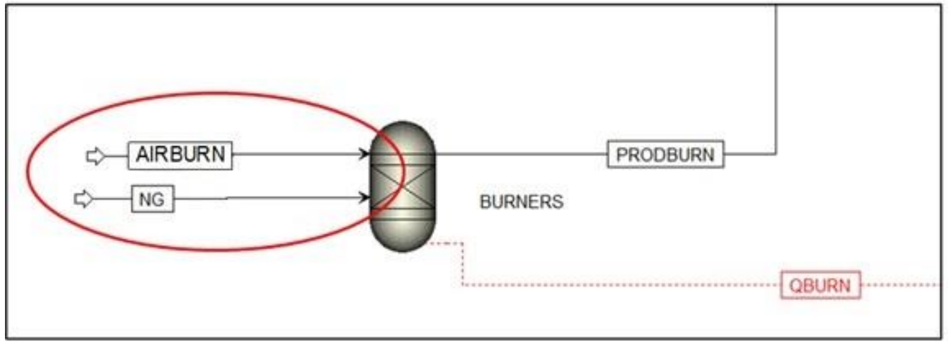
- **The flowsheet model allows simulating scrap-based EAF steelmaking route until start of continuous casting, and the effects of changing operating conditions and feeds**
- Among others, it allows computing and monitoring the **evolution of main process parameters during the different process steps:** temperatures, liquid steel and slag amount and composition (including H_2 content in steel), energy exploitation, CO_2 emissions, efficiencies

Stationary flowsheet model of EAF production route: improvements

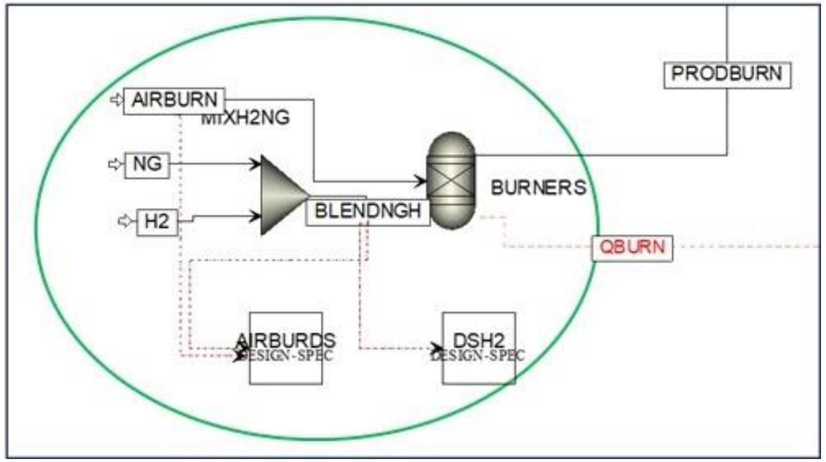
- Among the **improvements** carried out in GreenHeatEAF there is the model adaptation **for managing the use hydrogen in EAF burners and evaluating related effects**
  - For this improvement, **literature data have been exploited** for first version of updated model
  - Further information and data will be available during the evolution of the project and the model will be further refined
  - **Streams and new dedicated blocks (i.e. design specification blocks)** have been included for the use of hydrogen in EAF burners, alone or blended with natural gas



Before



Now



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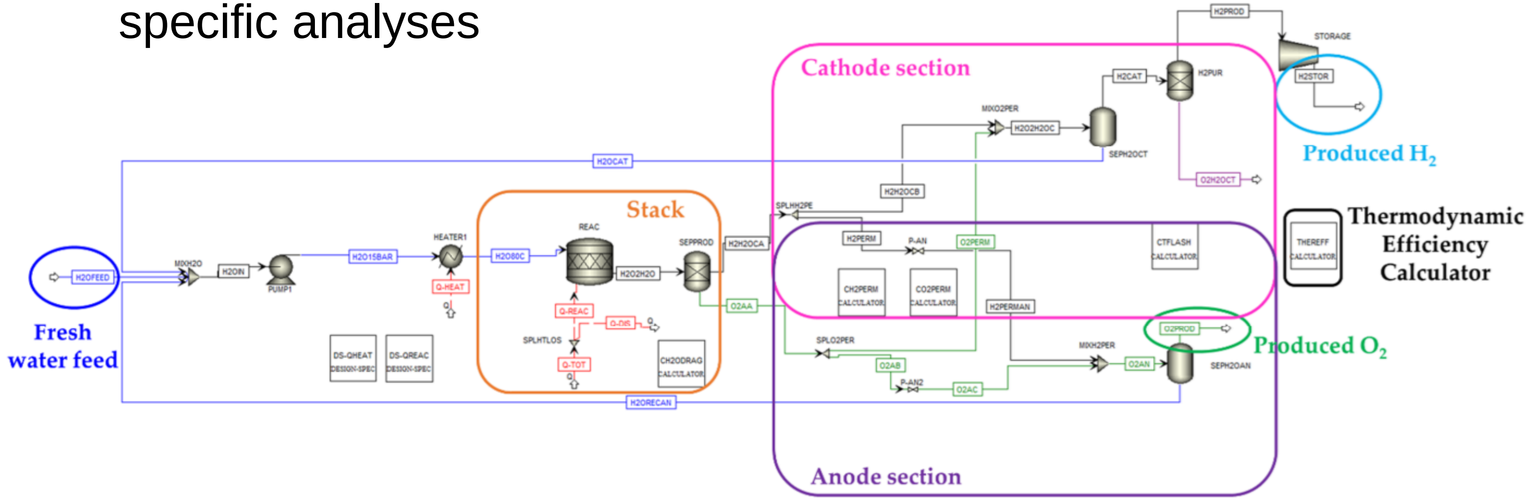
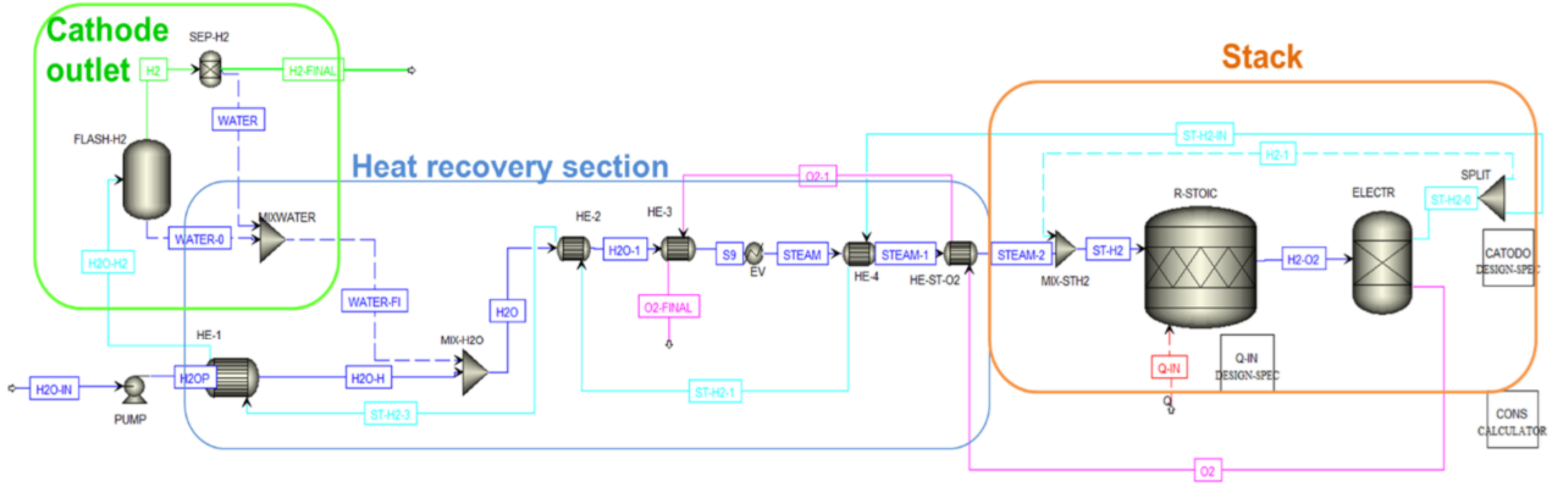
Stationary flowsheet model of EAF production route: further models to be coupled

- Available **models for PEM and SOEC electrolysers** [4] **can be integrated in the EAF route model** for specific analyses



PEM electrolyser flowsheet model

SOEC electrolyser flowsheet model



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[4] Zaccara, A., Petrucciani, A., Matino, I., Branca, T. A., Dettori, S., Iannino, V., Colla, V., Bampaou, Panopoulos, K. (2020). Renewable hydrogen production processes for the off-gas valorization in integrated steelworks through hydrogen intensified methane and methanol syntheses. Metals, 10(11), 1535.

First scenario analyses

EAF production heats of two steel families (i.e. groups of similar steel grades) **were simulated**

Reference case

use of standard production data (reference: Sidenor) consisting in the use of natural gas (NG) in burners

New scenarios

substitution each step of 10% of NG energy contribution with related H_2 amount

EAF electric energy

Off gases

- CO_2, CO, H_2O content in EAF
- Temperature

Tapped steel composition

- Including H_2 content

Slag composition

Main monitored parameters

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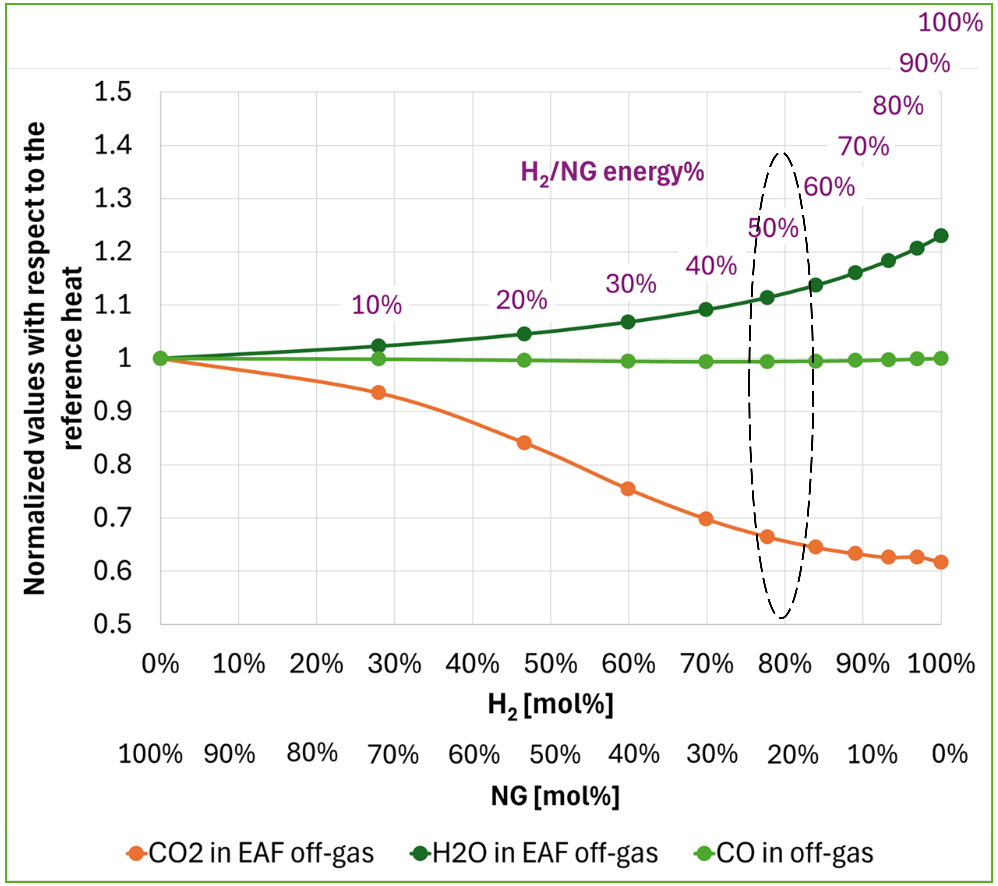
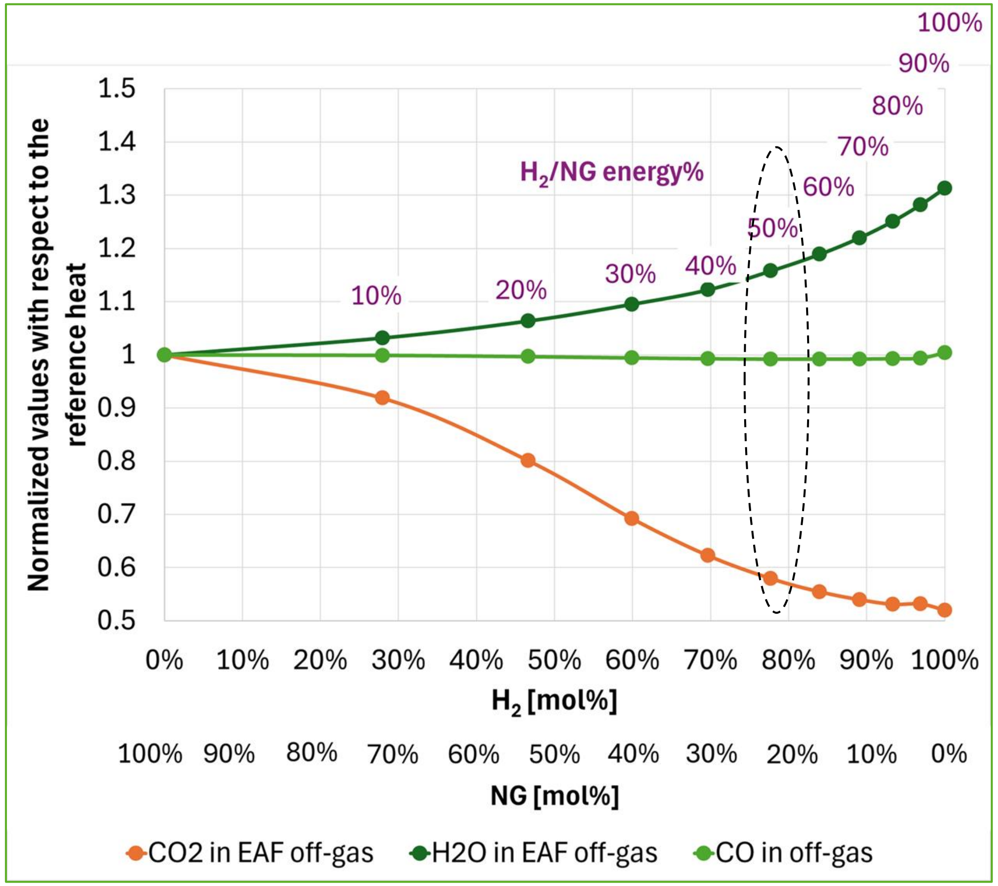
First scenario analyses

Alloyed Case Hardening Heat



Carbon Case Hardening Heat



- As expected, there are **a decrease of CO_2 and an increase of H_2O content in off-gases**
  - **The decrease of CO_2 is more evident until a blend of 20 mol% of natural gas and 80 mol% of H_2**

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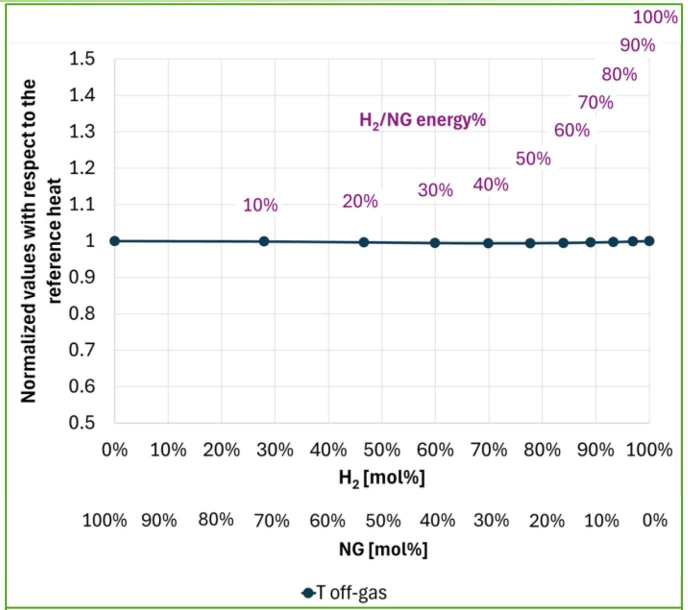
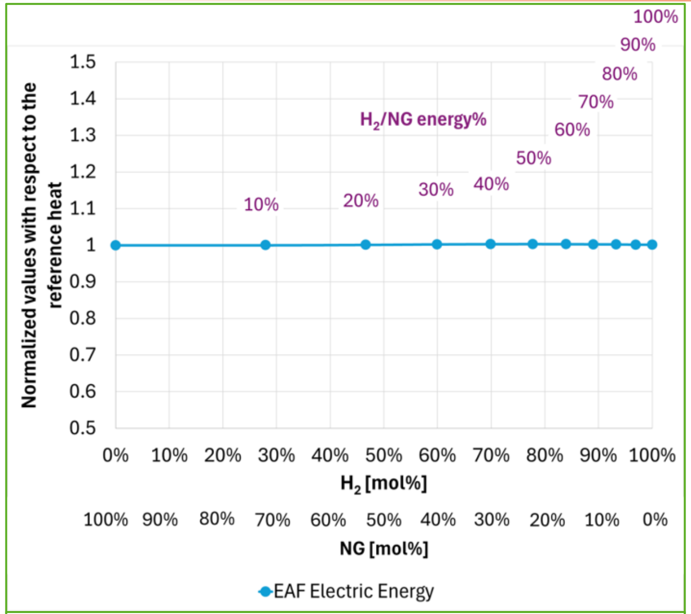
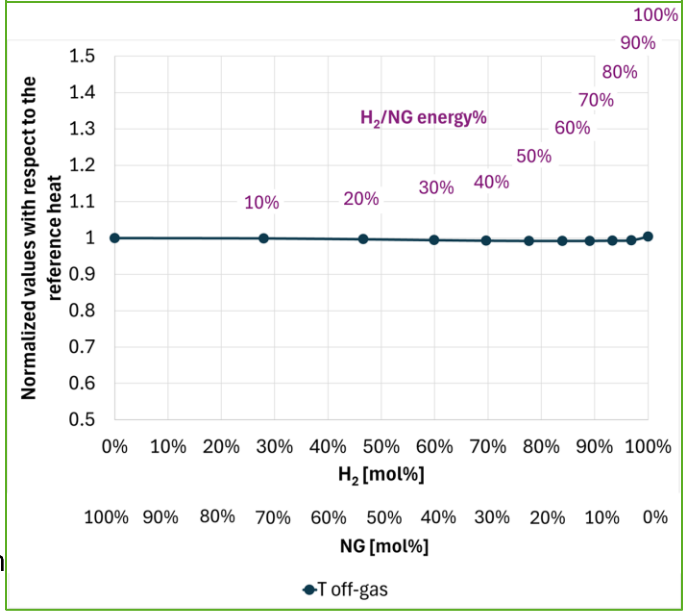
First scenario analyses

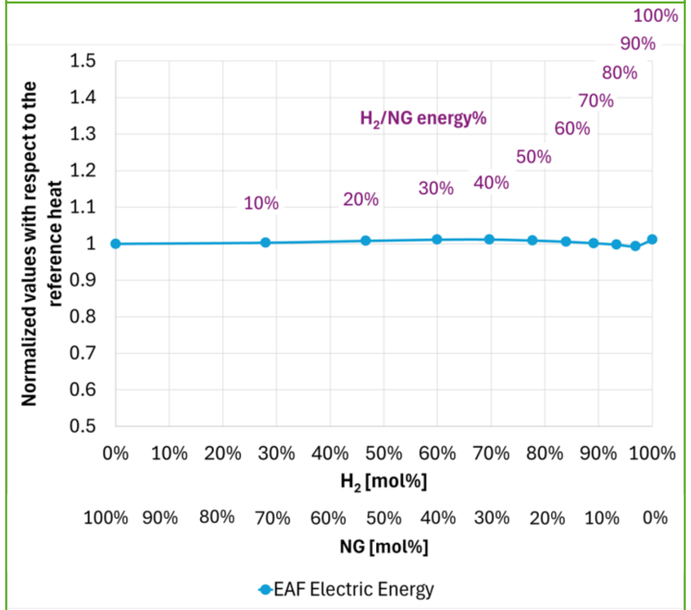
Alloyed Case Hardening Heat





Carbon Case Hardening Heat





Negligible changes were observed also in:

- **Tapped steel** (except for the H_2 content → as in next slide)
- **Slag**

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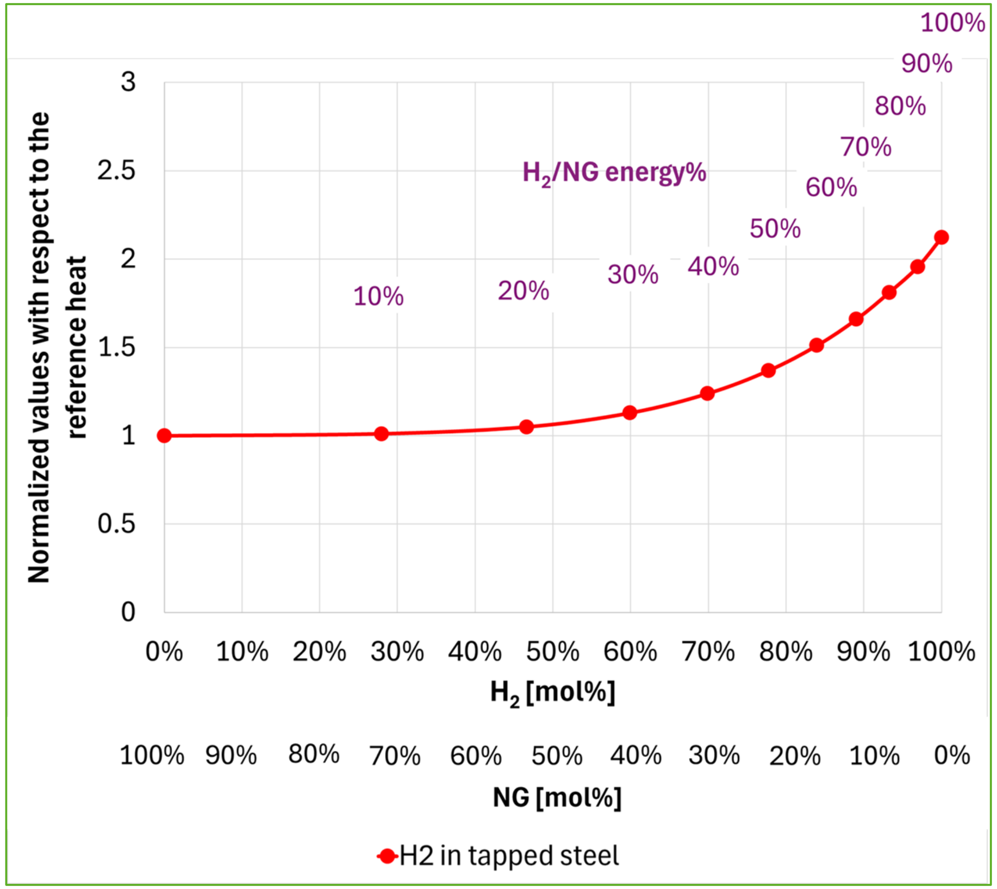
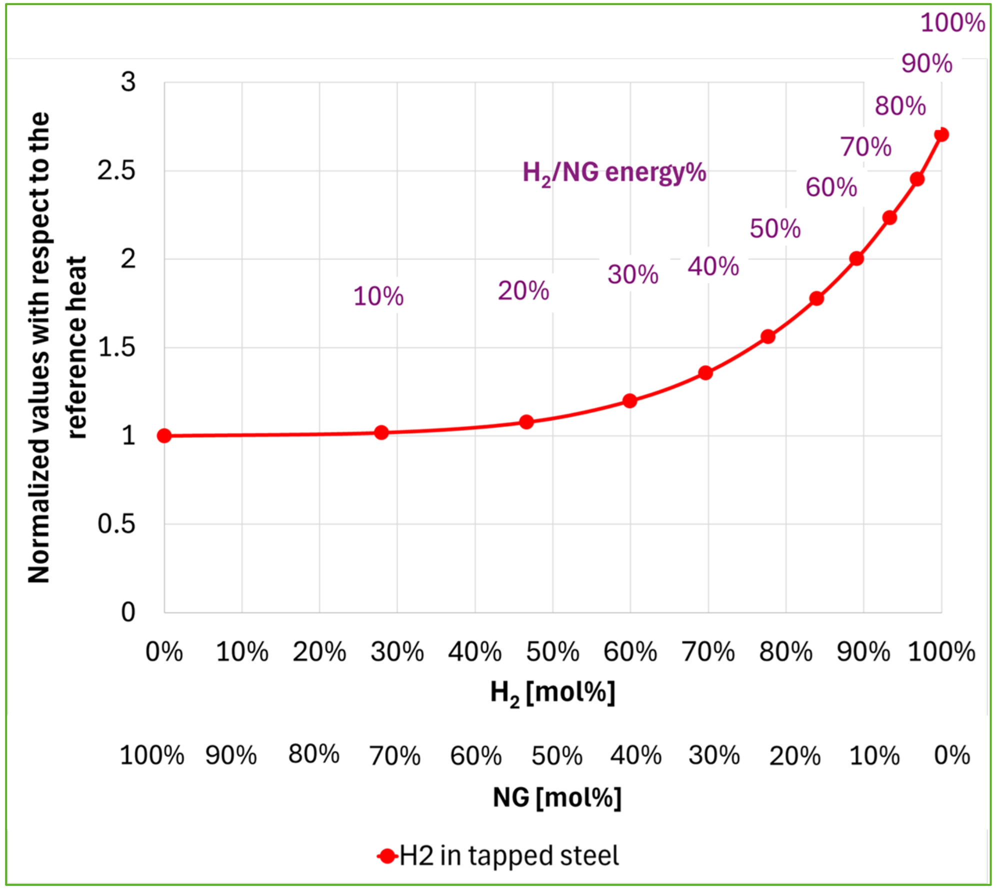
First scenario analyses

Alloyed Case Hardening Heat



Carbon Case Hardening Heat



- Although still of the order of magnitude of ppm, **H_2 content in tapped steel significantly increases**
  - **More than two times of the reference case with a full hydrogen use**

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Conclusions

A hot topic in steel sector is the reduction of fossil fuels dependence and use

Investigations of the use of hydrogen in EAF burners is considered fundamental for avoiding unexpected issues

A flowsheet model of scrap-based EAF route was improved for allowing related simulations

Heats of two steel families were simulated considering a standard use of NG in EAF burner and gradually increasing the H_2 content in fuel blend

Main results concerns the composition of off-gases and hydrogen content in tapped steel

- CO_2 decrease is more evident until a blend of 20 mol% of natural gas and 80 mol% of hydrogen
- H_2 content in tapped steel becomes more than two times of the reference case with a full hydrogen use

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Ongoing and Future Works

Collection of more info and data from real trials for further refining the model (e.g. on NO_x emissions)

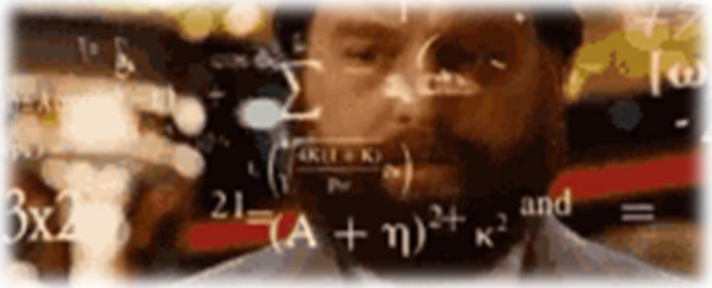
Making more scenario simulations

- for comparing the behaviour of several heats and of more steel families
- for exploring process integration solutions (e.g. of electrolysers)
- For investigating further aspects

Exploring deeper the reasons of some obtained behaviour

- What is the reason of the obtained increase of H_2 in tapped steel? Unreacted H_2 or H_2O richer atmosphere and consequent H_2O split at electrode?

Selecting best solutions for facilitating the use of H_2 in EAF burners and for solving potential issues



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GreenHeatEAF

Gradual integration of REnewable non-fossil ENergy sources and modular HEATing technologies in EAF for progressive CO2 decrease

Thank you

ismael.matino@santannapisa.it

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