ESTEP SPRING DISSEMINATION EVENT

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Synergies between RFCS Projects on Hydrogen application in the Blast Furnace process

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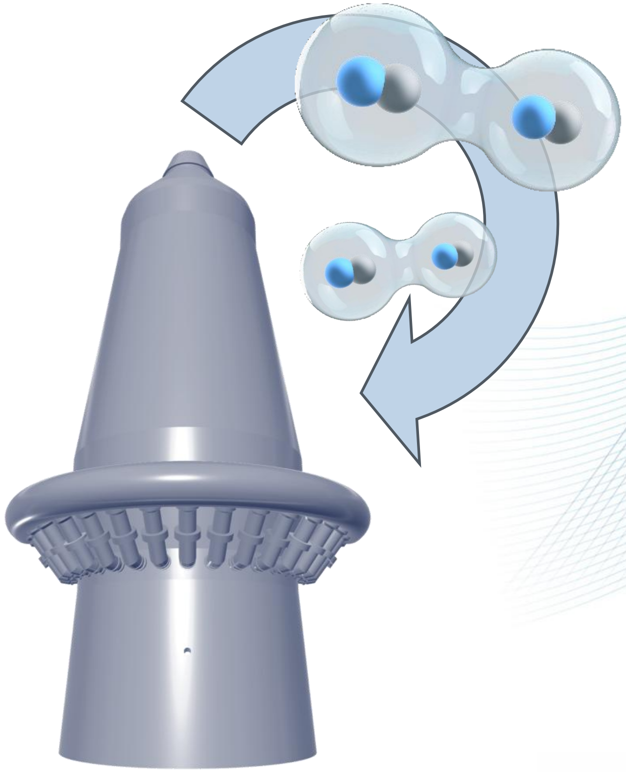
Synergies between RFCS Projects on Hydrogen application in the Blast Furnace process

- H_2TransBF 2030
  (2022 - 2025)
- H_2II
  (2024 - 2027)
- H_2loop
  (2025 - 2028)



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BFI Angewandte Spitzenforschung | VDEh-Betriebsforschungsinstitut GmbH

Stahl

CO_2 Emission target boundary conditions for steel production

BFI Angewandte Spitzenforschung

- To mitigate global warming the EU has set targets to reduce CO_2 emissions by 55% until 2030 and to become carbon neutral until 2025.
- Until 2025 the steel sector receives free CO_2 emission certificates following a benchmark system.
- Carbon Border Adjustment Mechanism (CBAM) will start in 2026, in parallel new benchmarks for CO_2 emission certificate allocations to the steel industry will be set up.
- With the ramp-up of CBAM after 2026, it is foreseen to reduce the amount of freely allocated certificates.
- CO_2 Emission certificate prices in average were around 65€ in 2024.

- The steel industry requires solutions to reduce CO_2 emissions at short notice
- Application of Hydrogen to the Blast Furnace has been demonstrated to be technical solvable and is reported to have a CO_2 Emission reduction potential of up to 20% technically

Questions to be answered to optimise the Hydrogen use in the BF process

› What are optimal BF operational conditions to maximise CO_2 mitigation?

› How can Hydrogen be injected into the BF to maximise the gas utilisation?

› How can Hydrogen be produced on site considering fluctuating energy prices and stepwise site transformation?

What are optimal BF operational conditions to maximise CO_2 mitigation?

H2TransBF 2030

Minimisation of CO_2 Emissions from the BF by hydrogen containing injectants and use of DRI/HBI during transition to new Ironmaking processes until 2030

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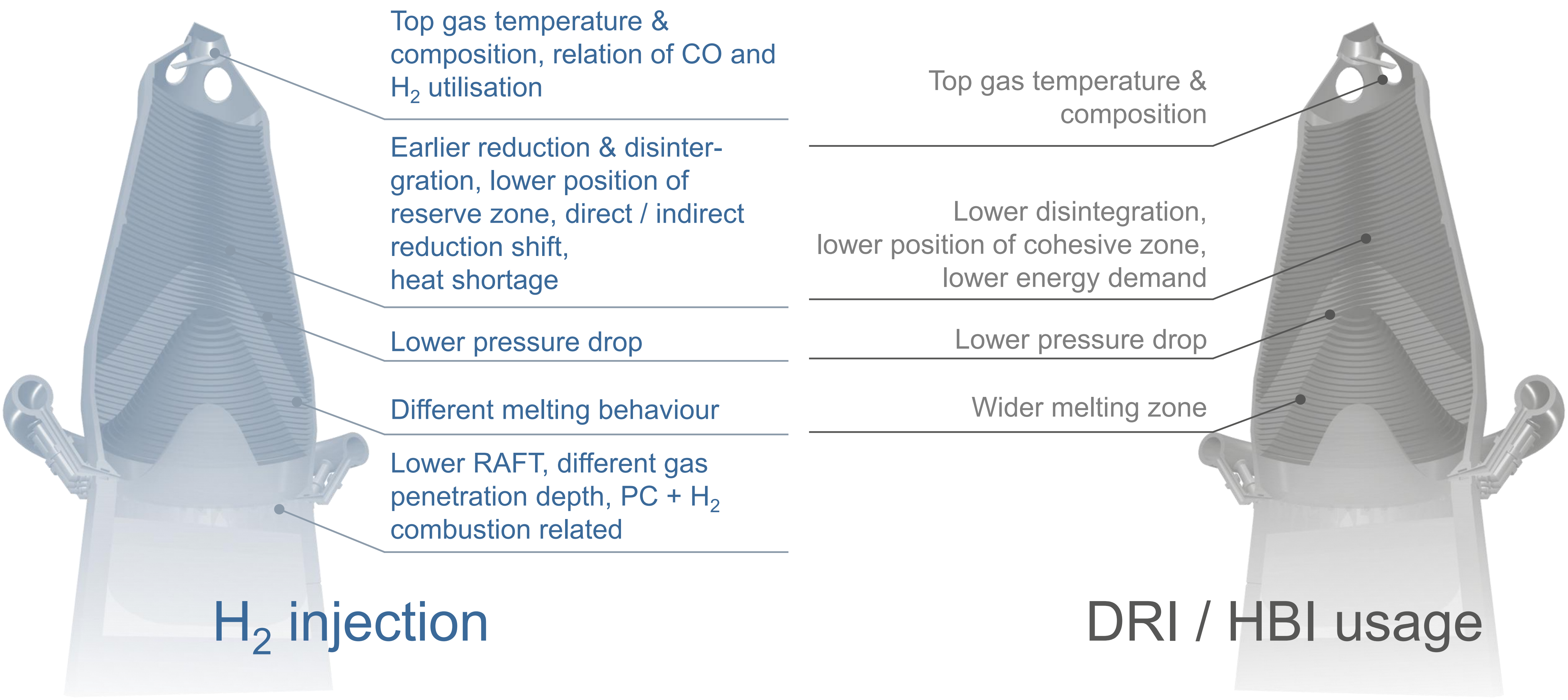
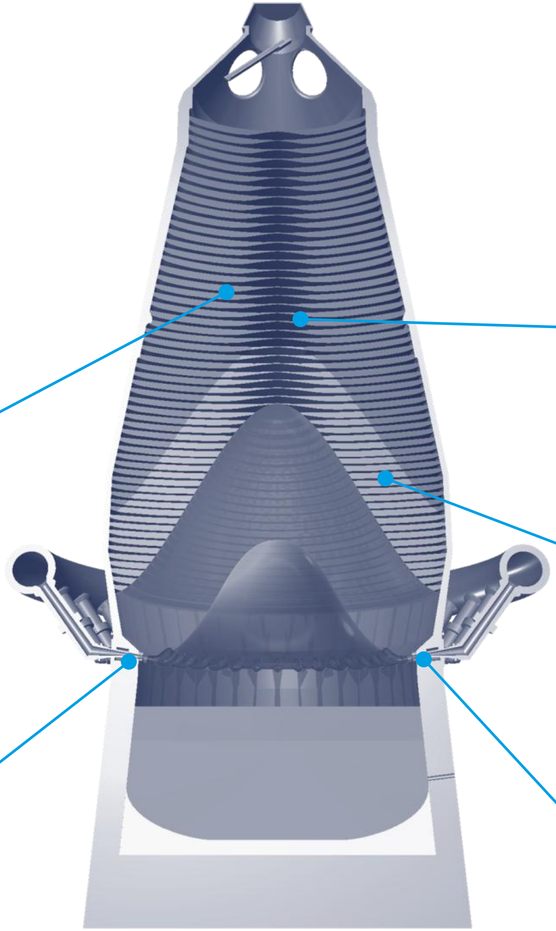
Knowledge about influence of H2-Injection and use of DRI/HBI on the BF process



H2TransBF2030 - Project focus and activities

Angewandte Spitzenforschung



Reaction kinetics of ores and coke with high hydrogen content in the reduction gas (University Oulu & ABO, Tata)

Simulation of process zones (BFI, CRM, Tata)

Influence of high hydrogen share in process gas on permeability (AM, CRM)

Simulation of coke oven gas injection (Paul Wurth)
Injection of fossile free methanol (swerim)

Evaluation of coke oven gas injection periods (HKM, Dillinger, BFI)
Raceway Monitoring (swerim, Tata)

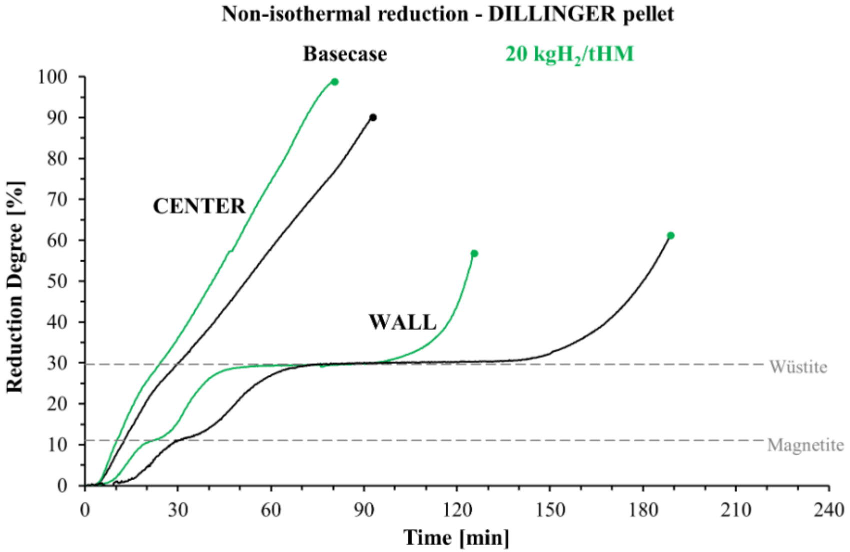
impact on downstream aggregates and plant wide balances (PW, Tata)

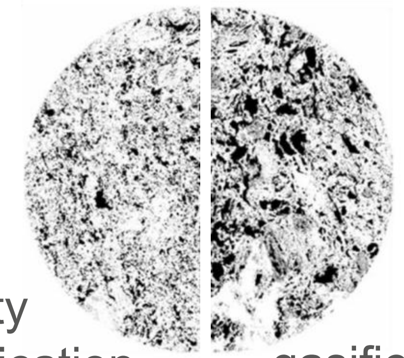
Results (1) - Impact of higher hydrogen content in the reduction gas on ore and coke (Oulu Univiersity)

- Hydrogen injection enhances initial reduction rate - its overall impact varies by temperature. At 700 °C the reduction with hydrogen sometimes plateaus at lower final values, while at 900 and 1100 °C, it generally expedites the formation of metallic iron.

- SEM-EDS analyses show that the sample periphery typically undergoes reduction earlier and exhibit greater pore development than the core. Pellet porosity exhibits almost linearly with reduction degree in isothermal reduction.

- According to combined results of carbon conversion and porosity development during the gasification of coke, it is suggested that water and hydrogen in the system promote surface reaction, which may cause issues with the BF operation.





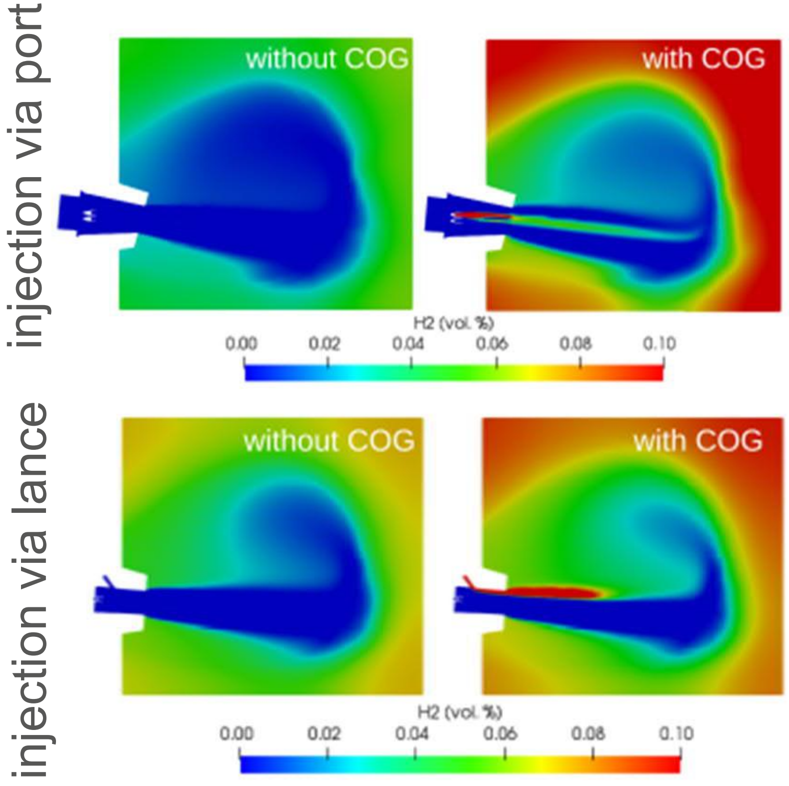
coke porosity before gasification

after gasification

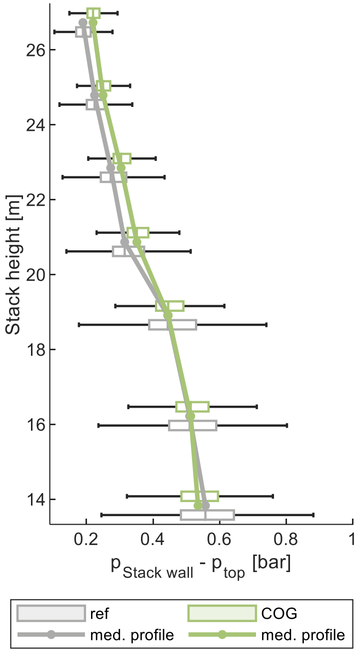
Results (2) - Injection of hydrogen containing gases (Paul Wurth)

- COG increases the blast velocity at tuyere nose.
- The combustion of pulverized coal can be enhanced by improving the mixing between PCI plume and COG jet.
- Oxygen levels must be adjusted to maintain combustion stoichiometry and RAFT.
- With COG co-injection, the gases exiting the raceway become richer in H2 (higher production of H_2O compared to CO_2 in the raceway, faster reaction rates of steam gasification)
- If COG is injected via port, the rate must be sufficient to ensure good penetration into the blast. If COG is injected via lance, it may impose additional heat loads on the tips of the lances.

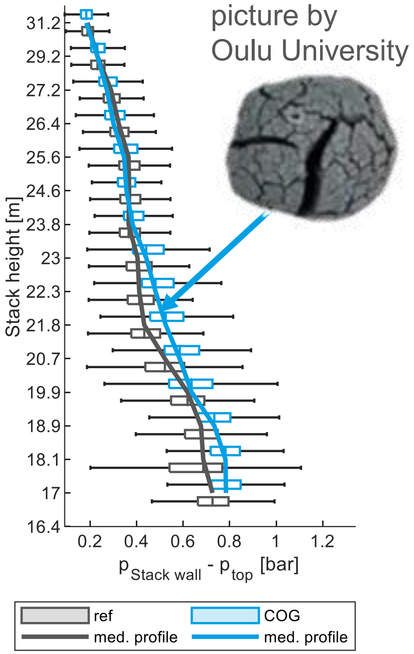
H2 distribution in raceway



Results (3) - Impact of higher hydrogen content in the reduction gas on process zones (HKM, Dillinger, BFI, Tata)



DILLINGER



STAHL. DAS SIND WIR. HKM

COG injection of 8.000 m³/h at Dillinger resp. 22.000 m³/h at HKM

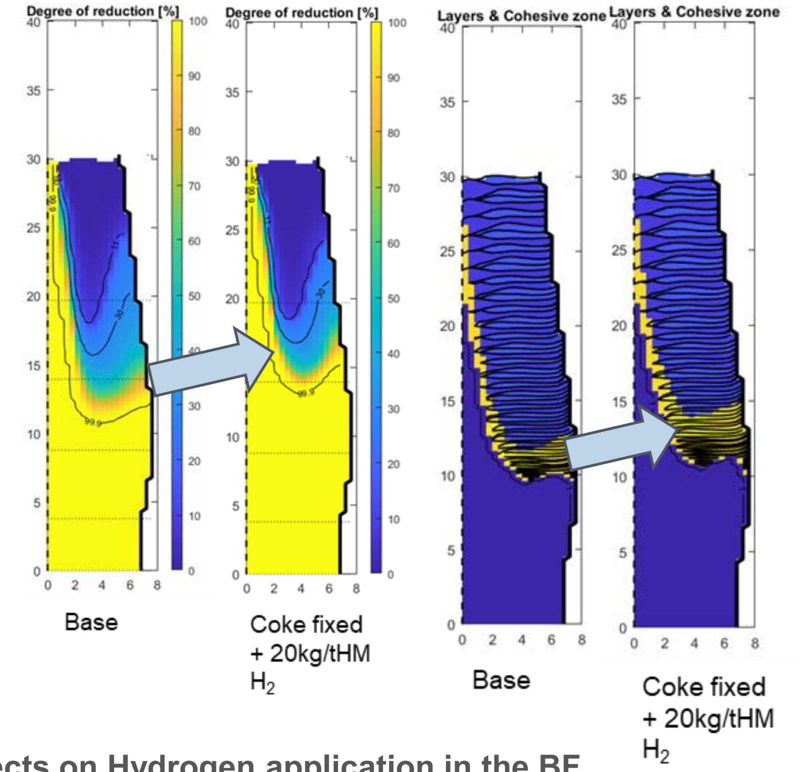
› increased pressure drop from hot blast to top,

› but a more even distributed pressure drop of the process gas during passage of the burden column especially in the cohesive zone,

Simulation of normal operation vs. 20kg$_{H2}$ / t$_{HM}$

› faster start of reduction

› wider cohesive zone



Conclusions so far

Coke oven gas injection is beneficial for the BF

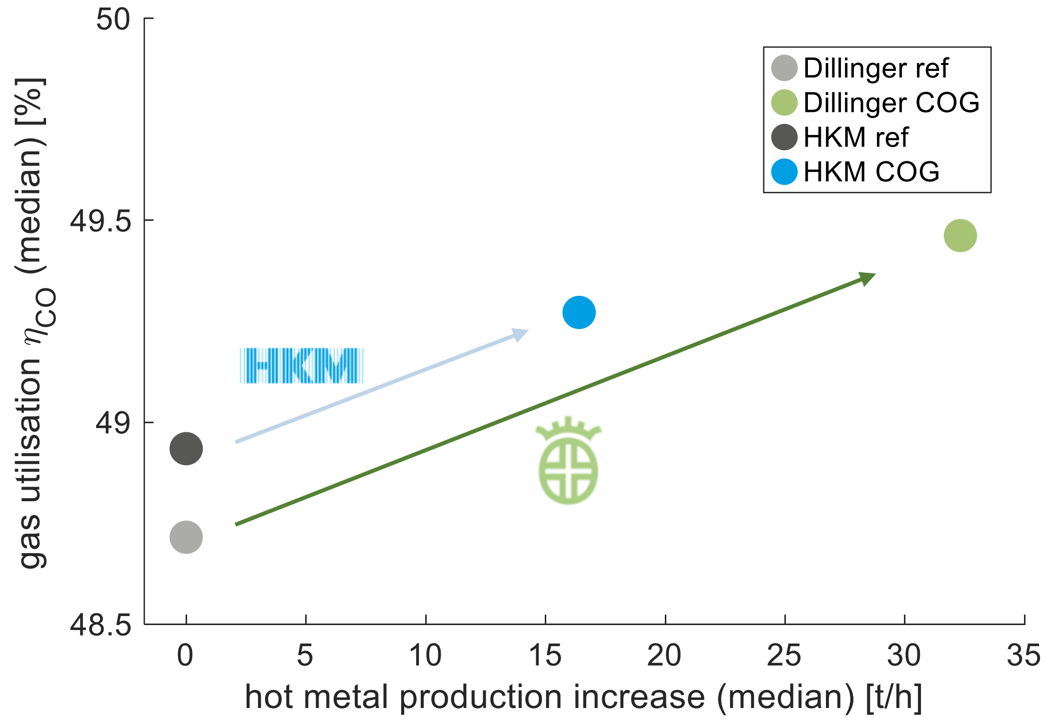
› earlier start of reduction enables higher productivity

› gas utilisation of carbon monoxide is increased

Attention must be paid to

› process requires optimisation of working point (replacement of coke / coal, charging pattern)

› Monitoring of permeability due to possible material degradation at lower temperatures



How can Hydrogen be injected into the BF to maximise the gas utilisation?

H2II

Hydrogen sequence impulse injection
into the Blast Furnace shaft

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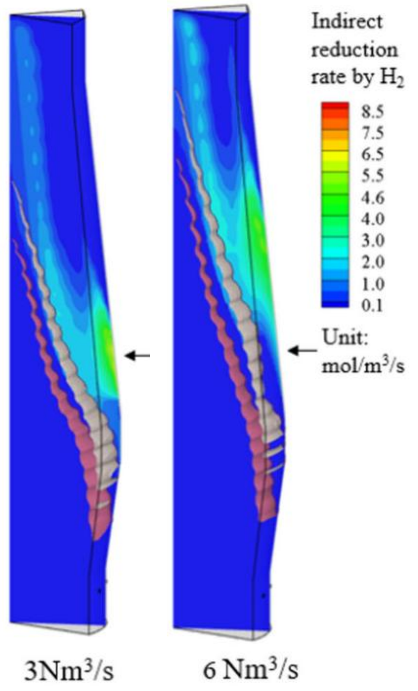
Impulse injection of hydrogen – State of the art

- State of the art
  - Hydrogen reduction can save up to 20% of the CO_2 emissions of a blast furnace
  - Hydrogen achieves higher reduction rates already at lower temperatures than CO (from approx. 800-900°C).
  - Due to the low density of the hydrogen gas, it is difficult to achieve high penetration depths (applies to blast furnaces, but also direct reduction plants)
  - Pulse injection technology with Oxygen at tuyere level has shown higher penetration depths and better shaft gas flow in industrial application



Li, J. et al. Numerical modeling and analysis of hydrogen blast furnace ironmaking process. Fuel 323, 124368 (2022).

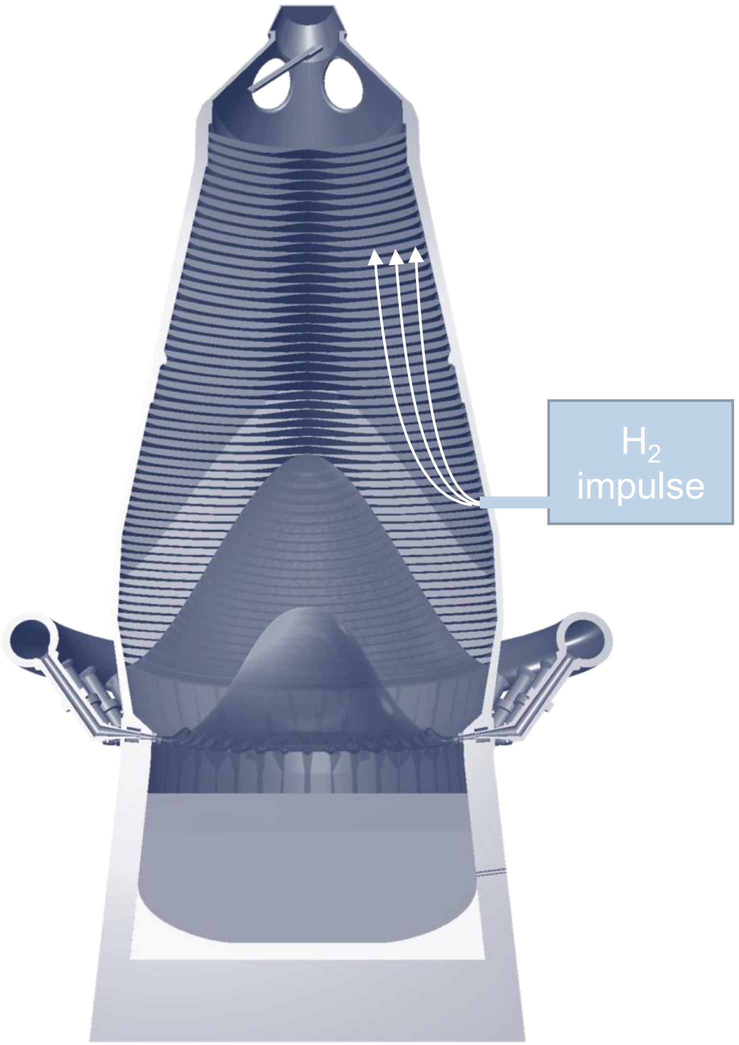
Why pulse shaft injection and not injection via tuyeres?

› Challenges of H_2 tuyere injection

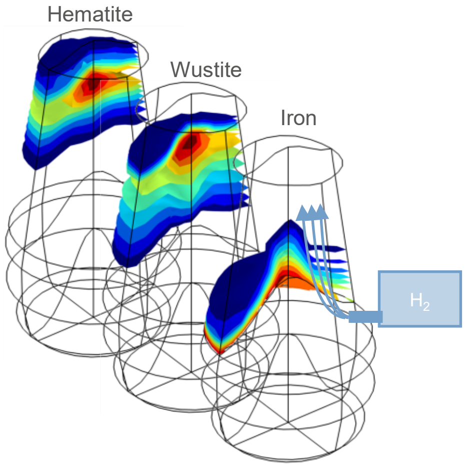
› **Reaction Kinetics** - H_2 reacts more rapidly than coal with available oxygen, potentially reducing coal conversion efficiency.

› **Flame Characteristics** - H_2 combustion is highly exothermic, generating extremely high temperatures at lance tip and tuyere. Upon reaching the coke bed, H_2O vapor reacts with coke in an endothermic reaction.

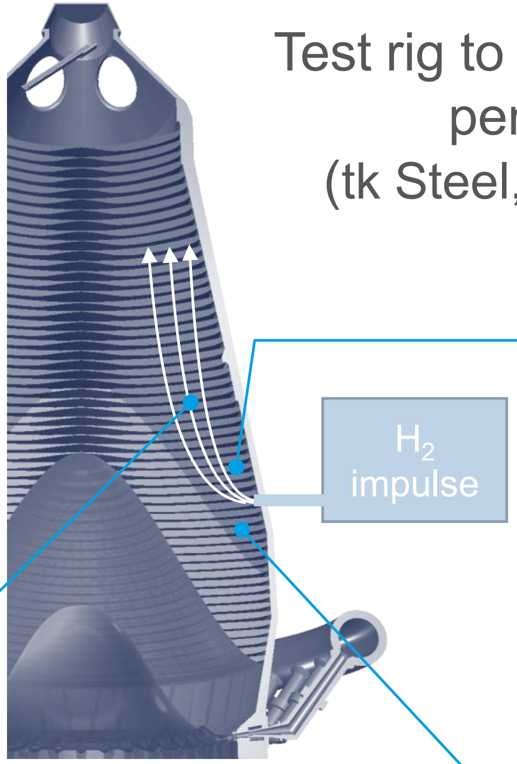
› **Gas Utilisation** - A portion of the injected H_2 enters the central coke chimney, where little ore is present, resulting in suboptimal gas utilization



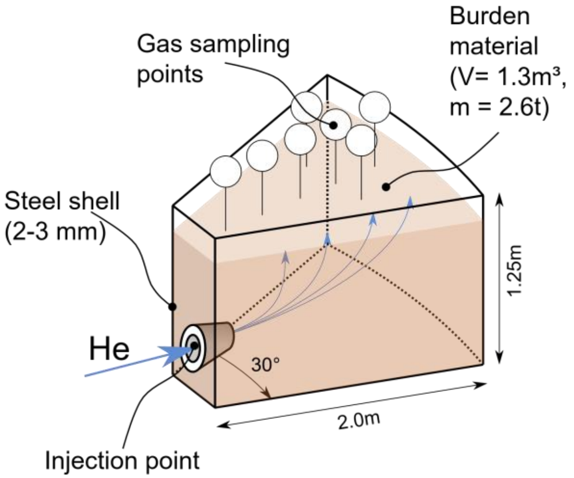
Project focus and activities



Position of optimal injection level and simulation of overall process response (BFI)



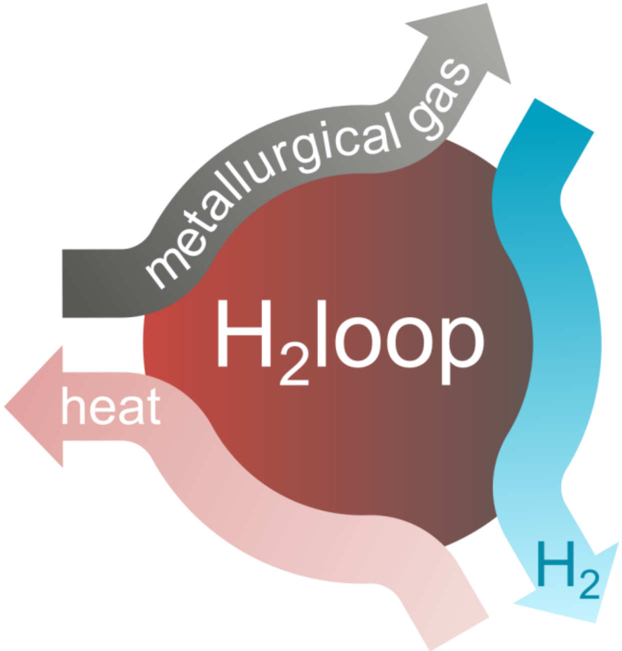
Test rig to examine pulse penetration depth (tk Steel, tk AT.PRO tec, BFI)



Simulation of the interrelation between pulse and packed bed (K1-MET)

Demonstration at an industrial scale BF (voestalpine, Primetals, tk AT.PRO tec)

How can Hydrogen be produced on site considering fluctuating energy prices and stepwise site transformation?



Sustainable decarbonisation of integrated steel plants by hydrogen production from chemical looping (H2Loop)

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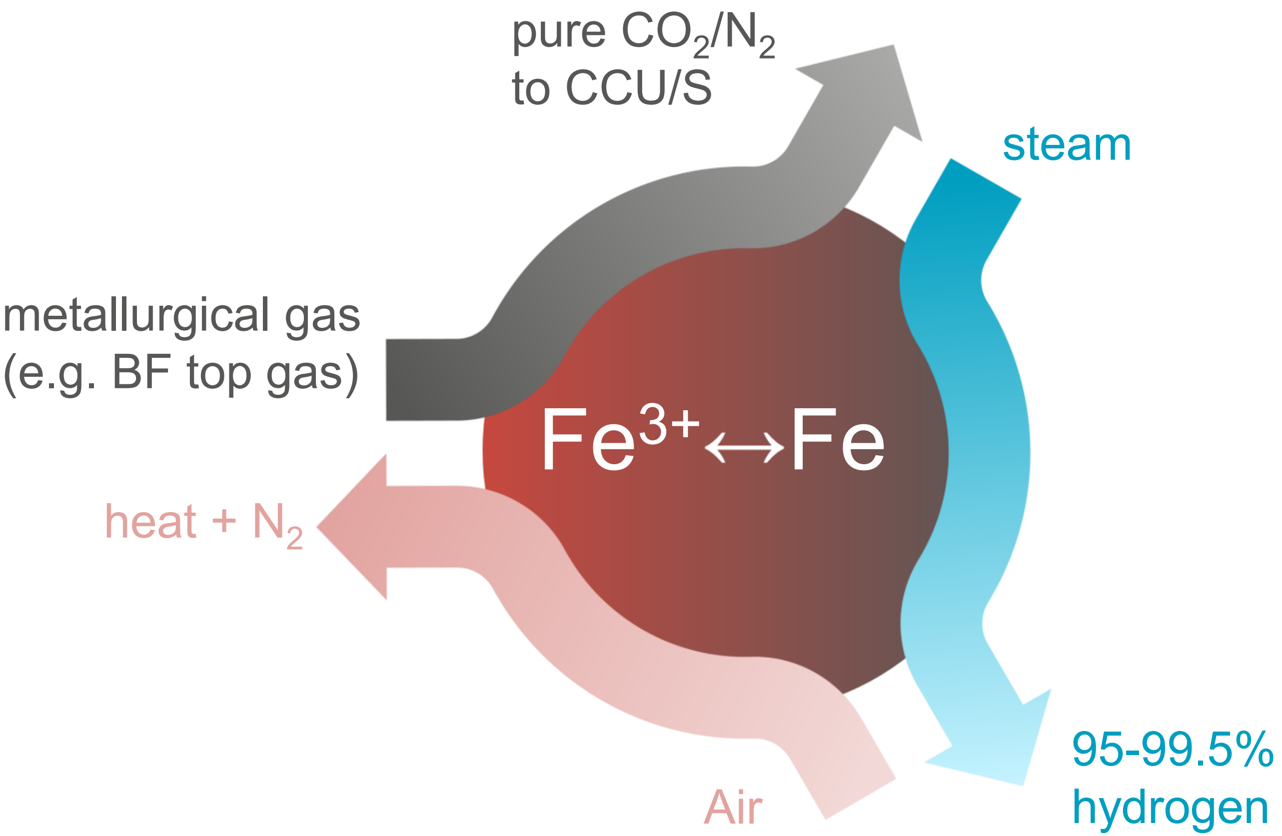
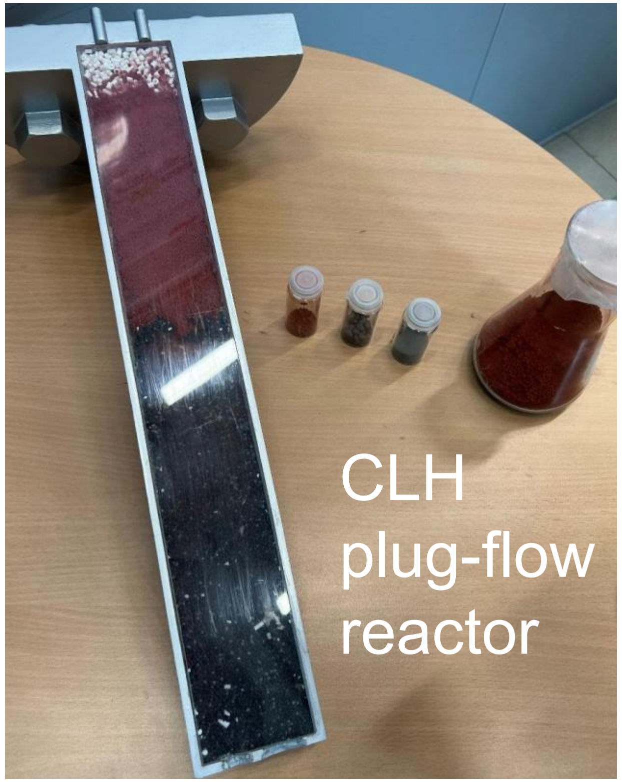
the European Union

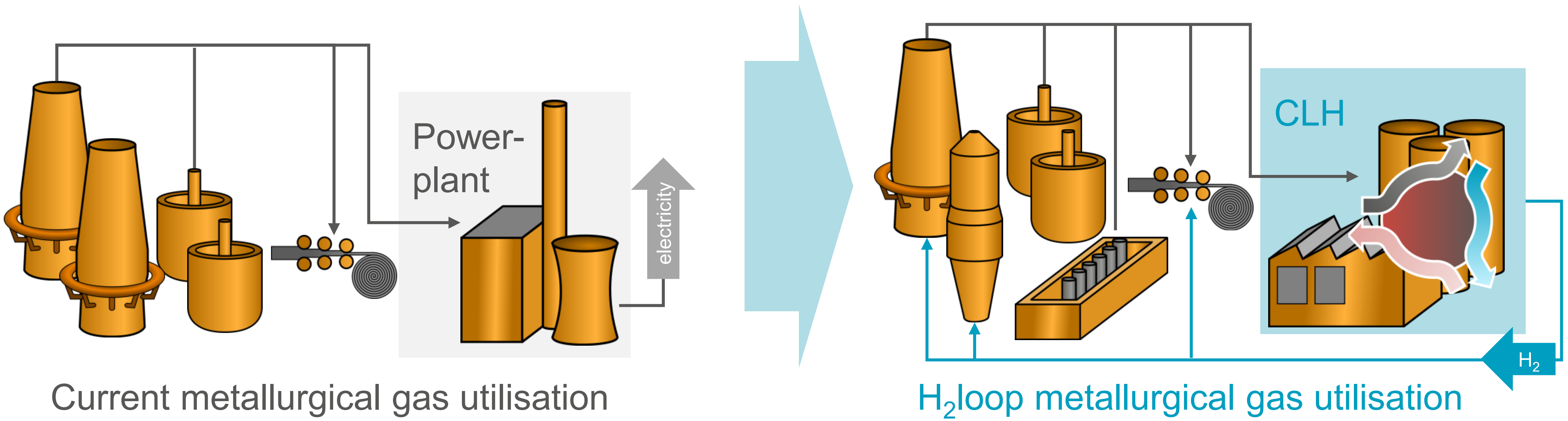
Project core | The chemical looping hydrogen Process





The CLH process passes through three process stages (i) reduction of oxygen carrier by metallurgical gas, (ii) production of hydrogen from steam and (iii) recovery of rest oxidation potential to supply heat

Integration scenario for chemical looping process

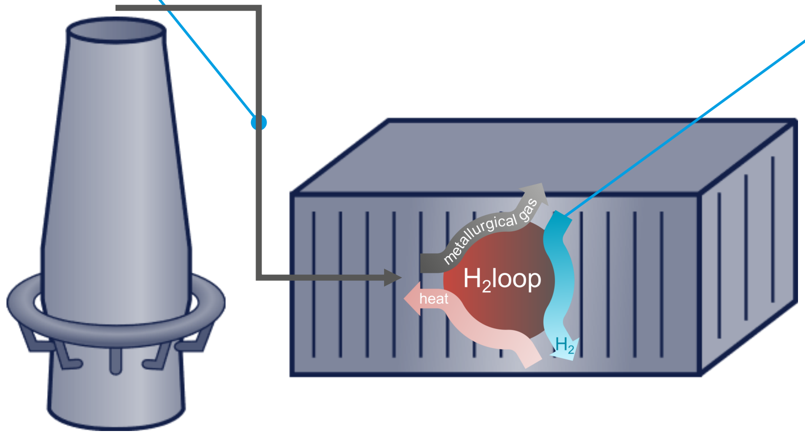


Due to the possibility to use metallurgical gases and to supply hydrogen the CLH process has a high integration potential into current and future steel plant layouts

Project focus and activities

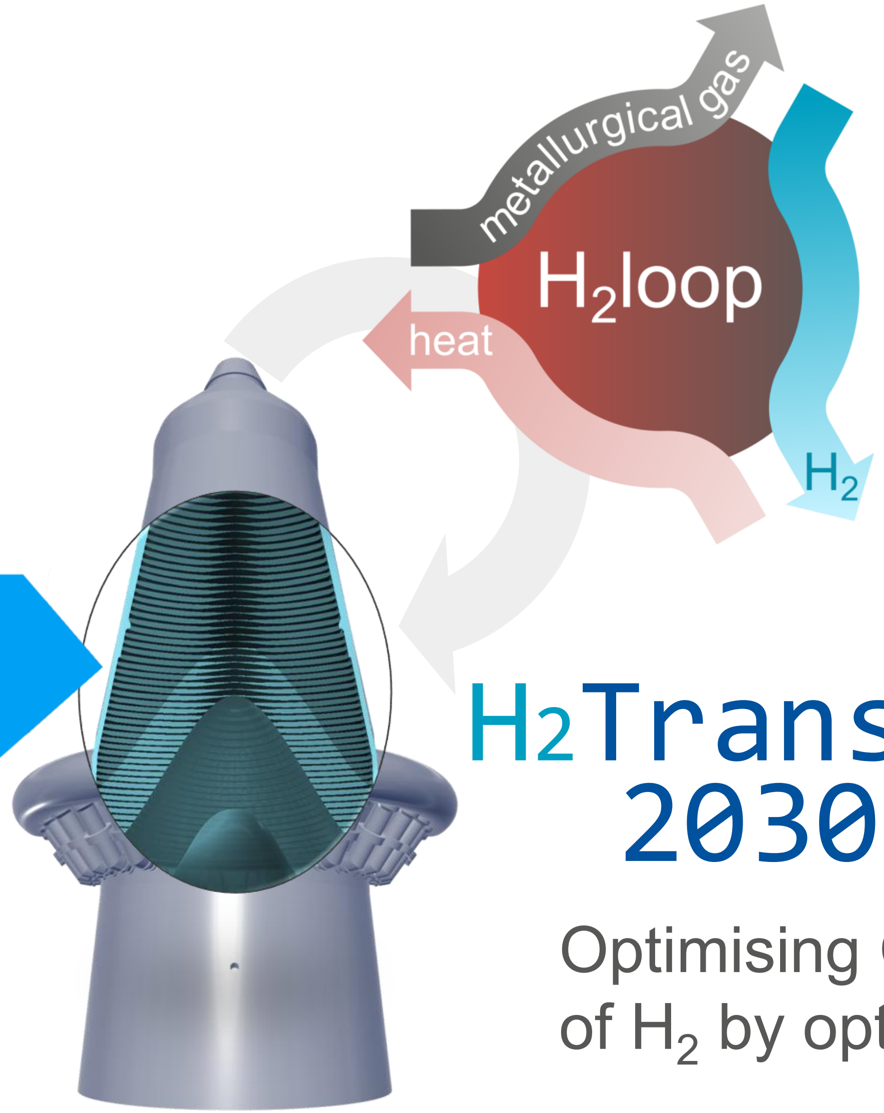
pilot- and demonstration scale on-site tests (RGH2, ADI)

Test with a variety of different gases from steelmaking, digital twin of the chemical looping process (BFI)



Integrability in different sites layouts, holistic evaluations including LCA and consideration of relevant boundary conditions as e.g. the development of energy markets (PoliTO)

Summary : three RFCS projects – one holistic concept – multiple synergies



Enhancing efficiency of H_2 generation and top gas utilisation

Hydrogen sequence impulse injection into the Blast Furnace shaft

H2II

Optimising H_2 usage by pulse injection

H2TransBF 2030

Optimising CO_2 reduction potential of H_2 by optimal BF work-points

Project – Funding

Funded by
the European Union

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Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.”

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