This project has received funding from the European Union under grant agreement NUMBER — 101058429 — MaxH2DR

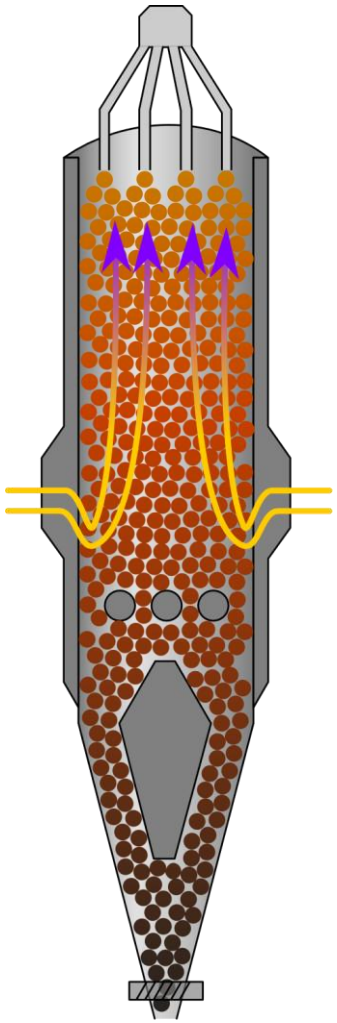
MAXH2DR - MAXIMISE H2 ENRICHMENT IN DIRECT REDUCTION SHAFT FURNACES

2025-02-25 HBI C-FLEX WEBINAR

THOMAS PIONTEK, THORSTEN HAUCK (BFI), VALENTINA COLLA (SSSA)

AGENDA

1. Project overview
2. Fundamental Investigations and Modeling
3. Enabling Industrial Demonstration of H_2-based Direct Reduction
4. Steelmaking based on H_2-based Direct Reduction
5. Outlook

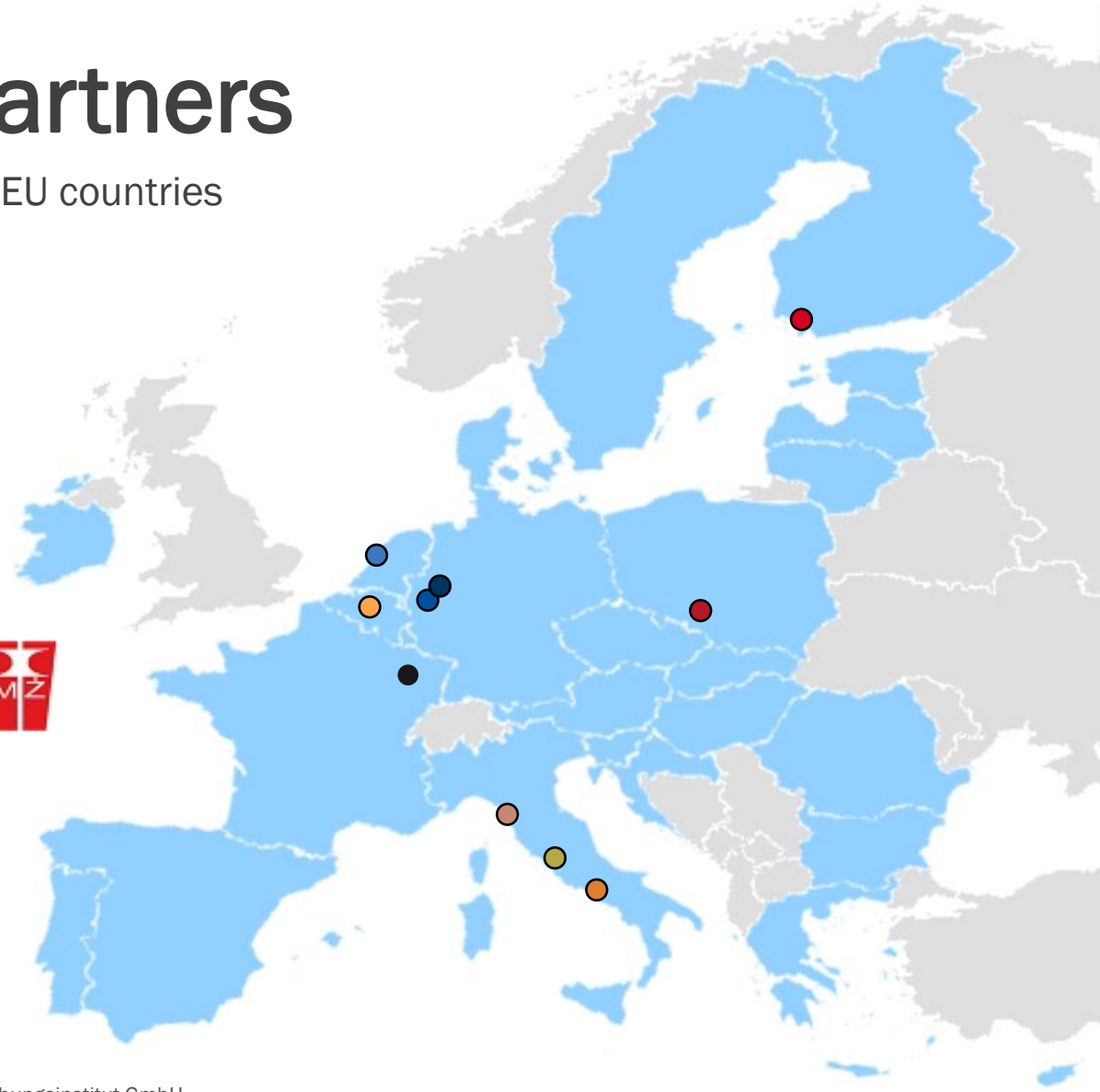


THE CONSORTIUM

10 partners

from 7 EU countries

Excellence in Applied Research



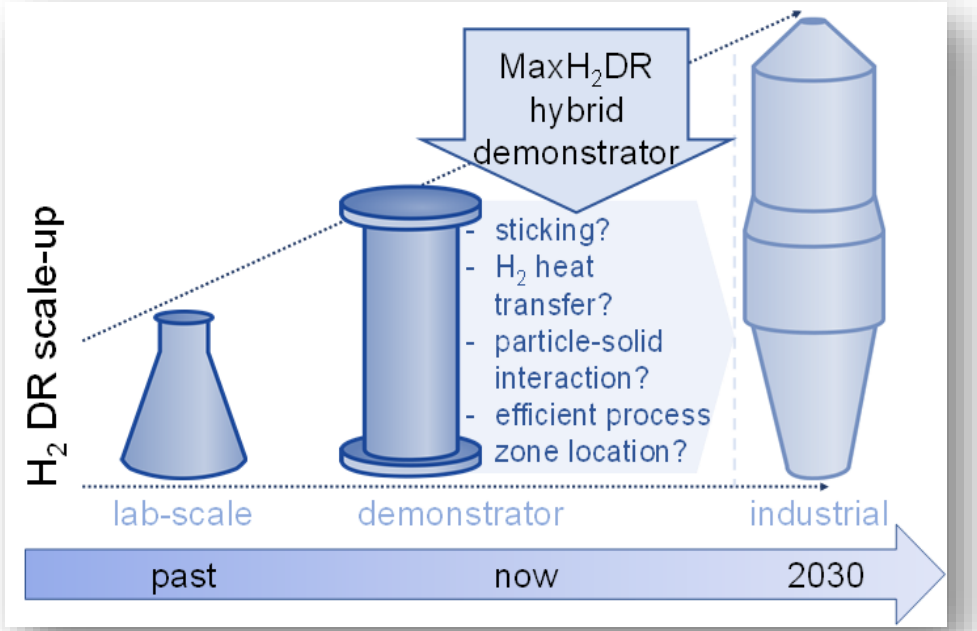
MAXH2DR OVERVIEW: WHAT?

Project key facts:

- June 2022 – May 2026, Budget: 4.5 million Euro

Baseline:

- H_2-based direct reduction:
  Groundbreaking technology for CO_2-neutral steelmaking
- Natural gas based direct reduction industrially established
- No industrial experience with H_2 content >80%



MAXH2DR: PROBLEM & APPROACH

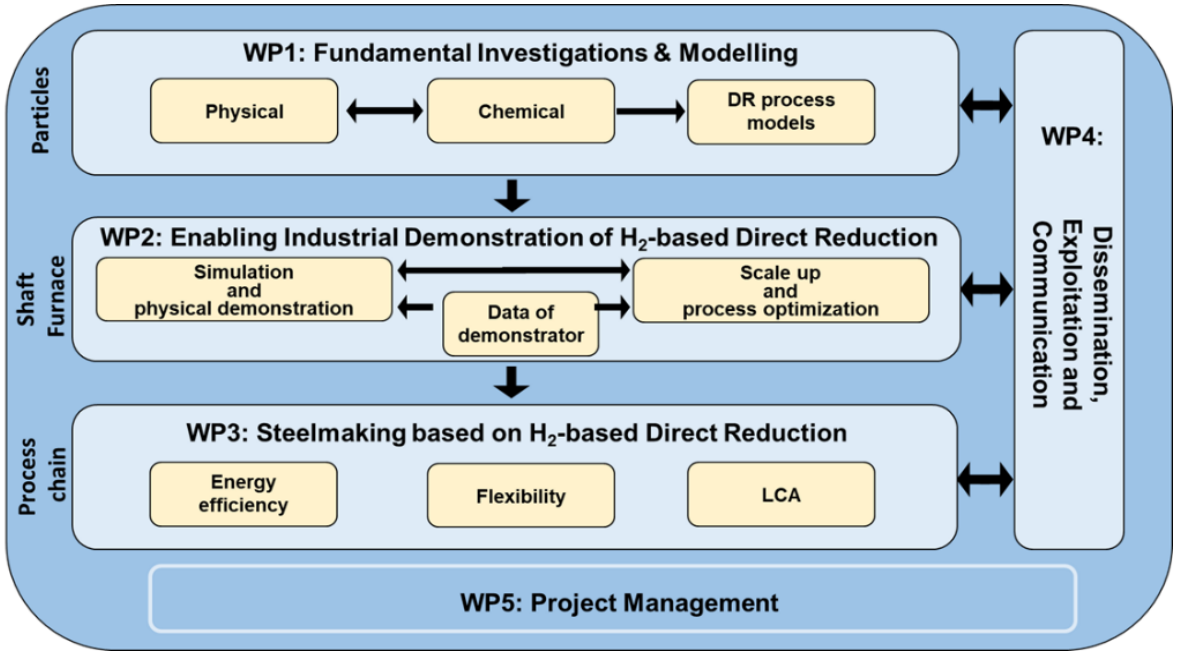
Problem:

Demonstration scale trials are expensive and time consuming but limited transfer to industrial level

- Crucial aspects:
  - Uniformity of gas and burden and flow distribution
  - Forces and movement of particles
  - Reaction kinetics and energies
  - Process stability and efficiency issues

Approach:

- MaxH2DR structure separated into 3 scopes: Particles (WP1), Furnace (WP2), Process Chain (WP3)
- WP1: Reduction Kinetics & Modelling & Sticking
- WP2: Process optimization by hybrid-demonstration
- WP3: Process integration into integrated steelplants

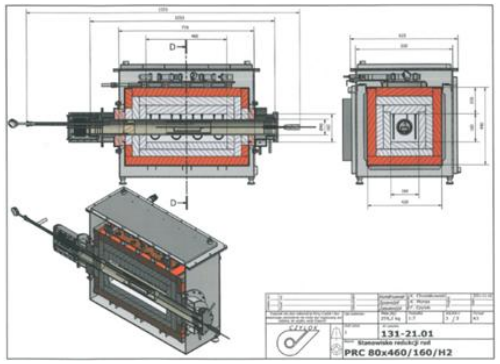


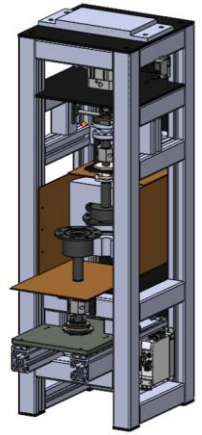
FUNDAMENTAL INVESTIGATIONS AND MODELING

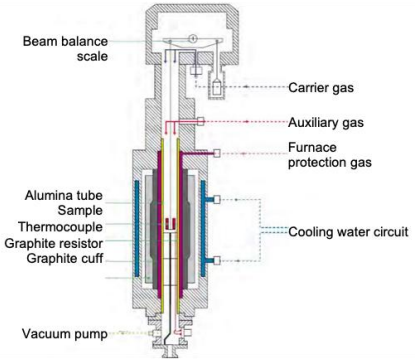
Objective:

Close existing knowledge gaps regarding the reduction process (chemical and physical properties)

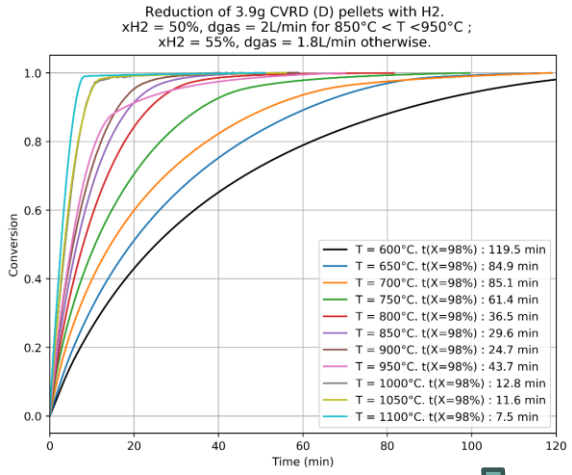
- Experiments on different scales, development of a new kinetic model for enriched hydrogen atmosphere
- World-first test rig to measure adhesive forces of pellet bulks at industrial H_2-enriched DR shaft conditions
- Include cohesion forces in DEM to describe movement of real particles in H_2-enriched DR shaft furnace
- Implementation of the new kinetics sub-model into overall DR process model

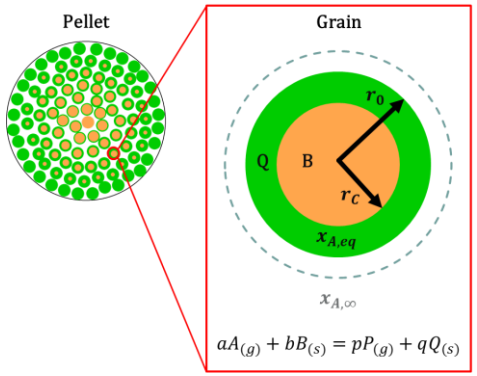






FUNDAMENTAL INVESTIGATIONS AND MODELING





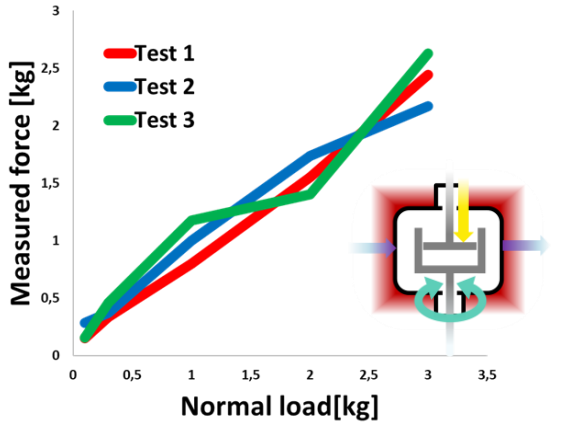
Lab experiments in different scale (powder, single pellet, 500g bulk)

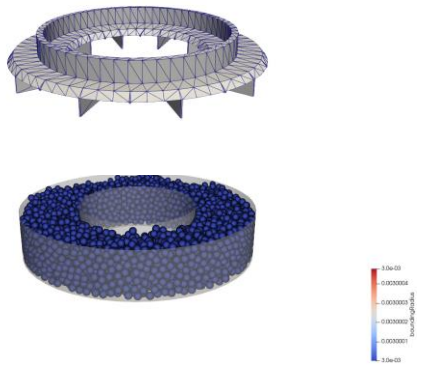
Different raw materials

- 2 types of BF- pellets
- 2 Types of DR-pellets
- Different sinter types

Kinetic modeling with a grain model

- Consider changes in microstructure
- Implementation in FEM, FVM and CFD-DEM simulations





New method of shear cell experiments

Force measurements under DR-conditions

- Normal load of 800 kPa
- High temperature up to 1000 °C

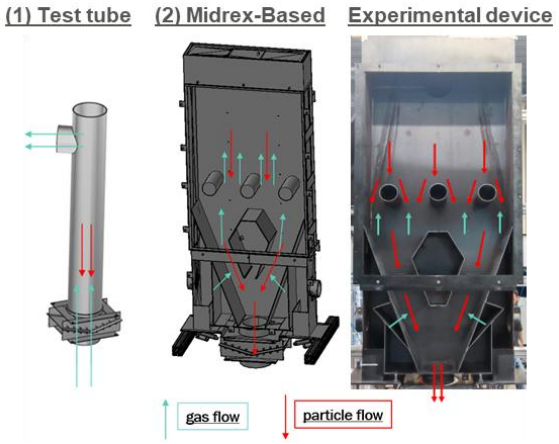
Additional experiments of crushing strength, swelling and softening

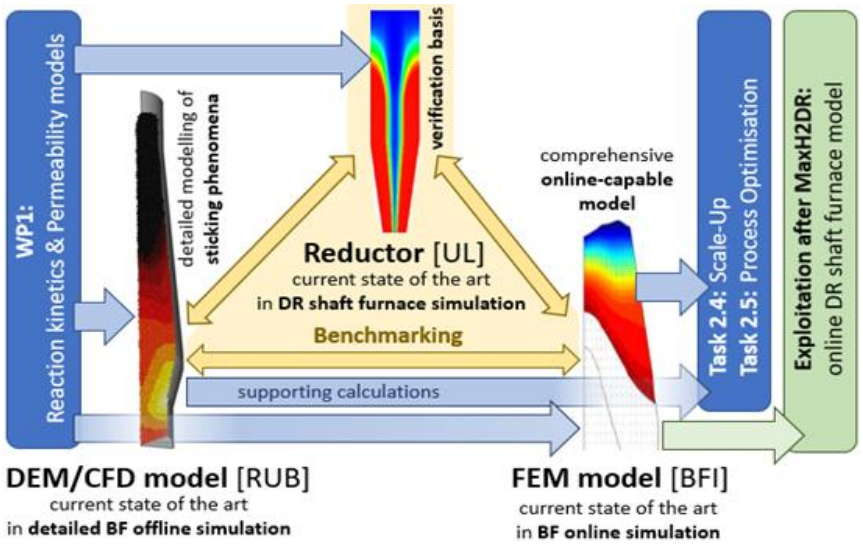
Calibration of the CFD-DEM code with shear cell results

Detailed modeling of particle movement and forces

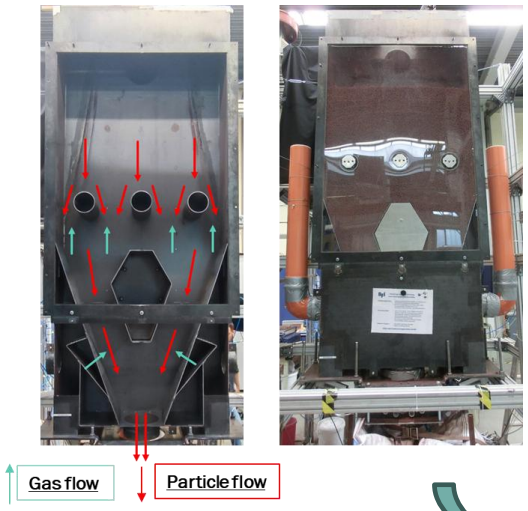
HYBRID-DEMONSTRATION (PHYSICAL + DIGITAL)

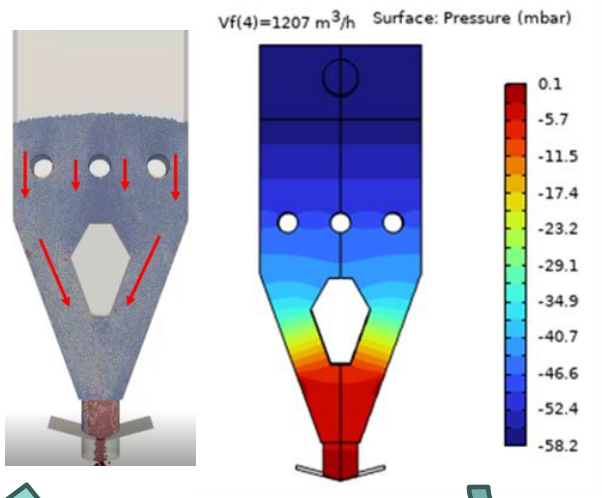
- **Physical component** of “hybrid demonstration”:
  - Physical and Chemical Lab experiments with 0.001 – 10 kg material at various partners (→ reaction kinetics)
  - Bulkflow experiments with gas counterflow with 1 – 1.5 t material in BFI pilot plant (→ flow modelling)
- **Digital component** of “hybrid demonstration”:
  - Development of digital simulation tools for H_2-based Direct Reduction Shafts
  - Benchmarking and combined utilisation of three detailed DR Shaft Furnace models
  - Long-term goal: Development of online model to improve monitoring and control
  - Complemented by Steelmaking Chain Process Simulations

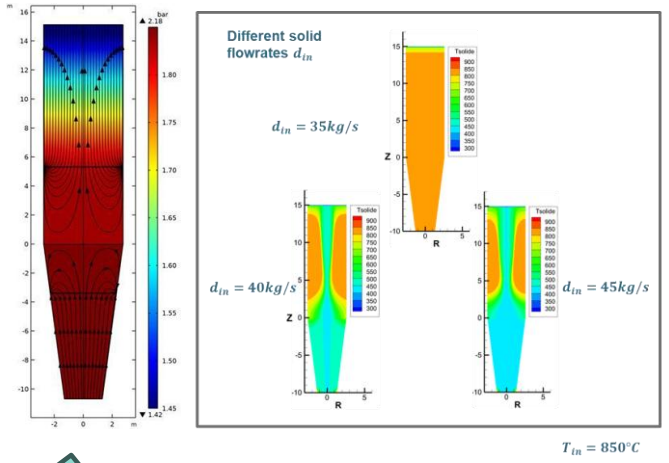




PROCESS OPTIMIZATION BY HYBRID-DEMONSTRATION







Investigation of particle movement,

Bulk permeability,

Interaction of Gas-/solid flow

Lab experiments with different materials

- Wooden spheres (d=12mm, 15 mm)
- Clay spheres ($\bar{d}$ =5.9 mm)
- DR-Pellets ($\bar{d}$=14.5 mm)

CFD-DEM and FEM simulation of experiments

- Calibration of particle movement
- Reduction of the simulation error through upscaling
- Benchmarking of the simulation methods

Investigations on the impact of installations

Upscaling to DR-shaft dimensions

- Includes physical and kinetic models
- Benchmarking of the simulations

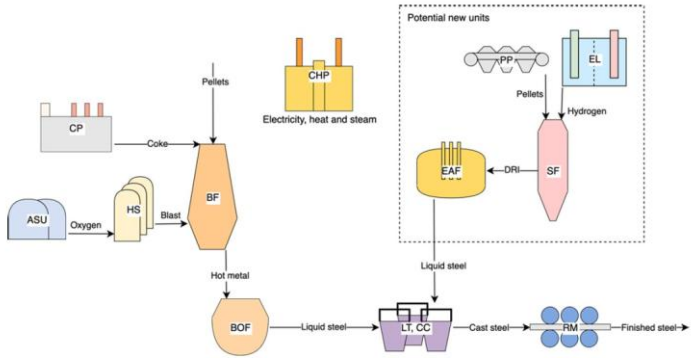
Process optimisation with different H_2 content

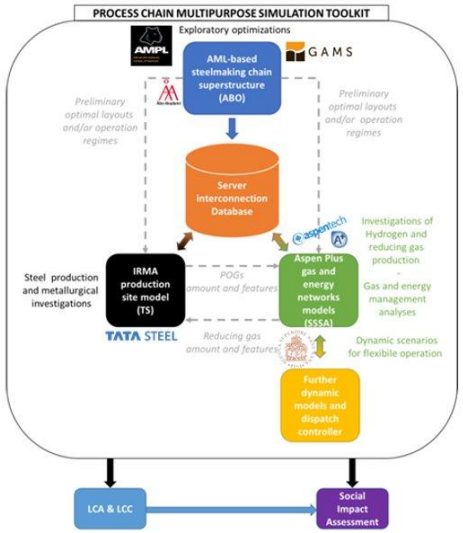
Recommendations and guidelines for enriched hydrogen atmosphere

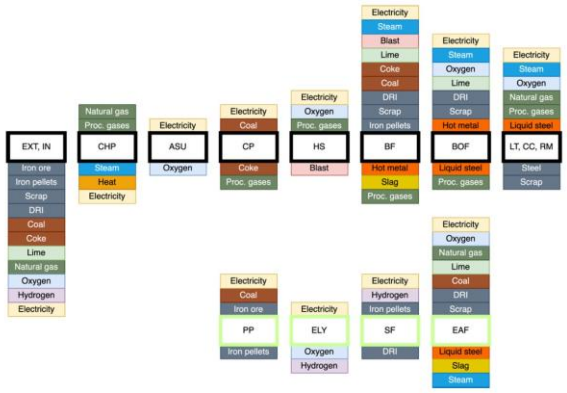
PROCESS INTEGRATION INTO INTEGRATED STEELPLANTS

Objectives:

- Digital assessment of promising steel process chains based on H_2-enriched DR
- Effective process integration of H_2-DR furnaces in different kinds of steelworks
- Digital tools for investment planning with potential of later online site management
- Assessment of optimal energy and material usage and costs including LCA

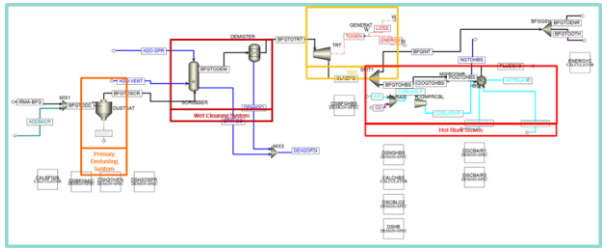


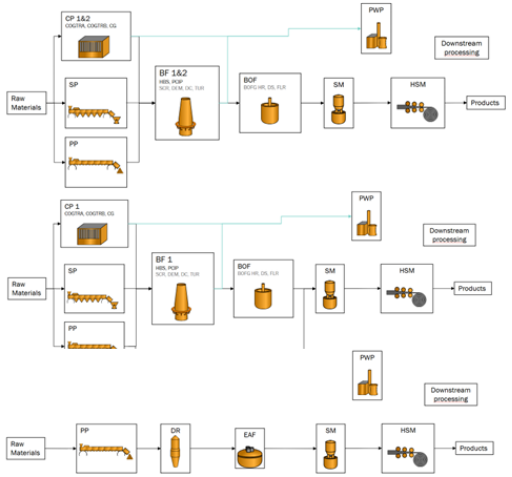




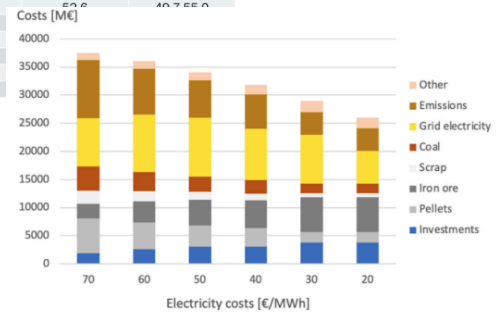
PROCESS INTEGRATION INTO INTEGRATED STEELPLANTS

Section	Sub - process	Modelling tool
Raw Materials	Sinter plant	IRMA
	Pellet plant	IRMA
	Cokes plant 1 & 2	IRMA
	Coal grinding line	IRMA
Iron and steel making	Blast furnaces 1 & 2	TS HMB integrated in IRMA
	Basic oxygen steel plant	TS TCM integrated in IRMA
	Casters	Black box[1] in IRMA
	Hot strip mill	Black box in IRMA
Gas – energy	BFG Treatment area	Aspen Plus
	BOFG Treatment area	Aspen Plus
	COG Treatment area	Aspen Plus
	Mixing and Enrichment Station	Aspen Plus
	Auxiliary Boilers	Aspen Plus
	Power plant	Aspen Plus
	Air Separation Unit	Aspen Plus





MIDREX MODEL RESULTS			
Variable	*Unit of Measurement*	*Simulation*	*Reference*
Iron Input Material	t/t_{DRI}	1.35	1.36-1.45
NG consumption	Nm^3/t_{DRI}	294.3	257-300
O_2 consumption	Nm^3/t_{DRI}	38.3	12-30
DRI metallic Fe	%wt	85	81-90
DRI Metallization	%	94	92-96
DRI C Content	%wt	2(50% as Fe_3C)	1-4
HDRI Temperature	°C	657	650-730
Bustle Gas CO Content	%vol.	33.2	29.8-36.0
Bustle Gas H_2 Content	%vol.		
Bustle Gas CH_4 Content	%vol.		
Bustle Gas CO_2 Content	%vol.		
Bustle Gas H_2O Content	%vol.		
Bustle Gas Temperature	°C		
Top Gas Temperature	°C		



Coupling of different models and databases

Modeling of specific units in aspen plus

- Definition of the possible process value ranges

Implementation of the optimized DR-shaft model

Static and dynamic simulation of the process chain

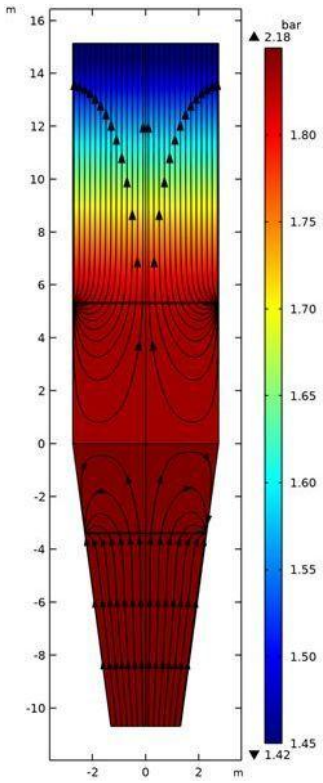
- Different scenarios like BF-route or DR-route
- Including power plants and production of input material (coke, sinter, pellets)

Evaluation of different scenarios

Considering different developments of costs like electricity

Cost minimisation towards H_2 enrichment

OUTLOOK: CONTENTS OF MAXH2DR AND SUCCESSORS



MaxH2DR contents in coming years:

- Physical properties of DR raw materials, intermediates and products (2025)
- Validated process models (hybrid-demonstrator)
- Recommendations & guidelines for H_2 enriched DR shaft operation (2026)
- Promising steelworks configurations for transition (2025)
- 23 public reports, newsletters, 3 webinars … and a big final event

Further / successor projects in HEU - CSP:

- GreenHeatEAF: Non-fossil energy sources, heat recovery & energy efficiency
- TransZeroWaste: Valorisation of future residue cycles
- AgiFlex: Agent-based support of investment planning and demand side management

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MaxH2DR Project website: https://www.estep.eu/clean-steel-partnership/list-of-csp-projects/maxh2dr

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Max H2 DR

Maximise H2 Enrichment in Direct Reduction Shaft Furnaces