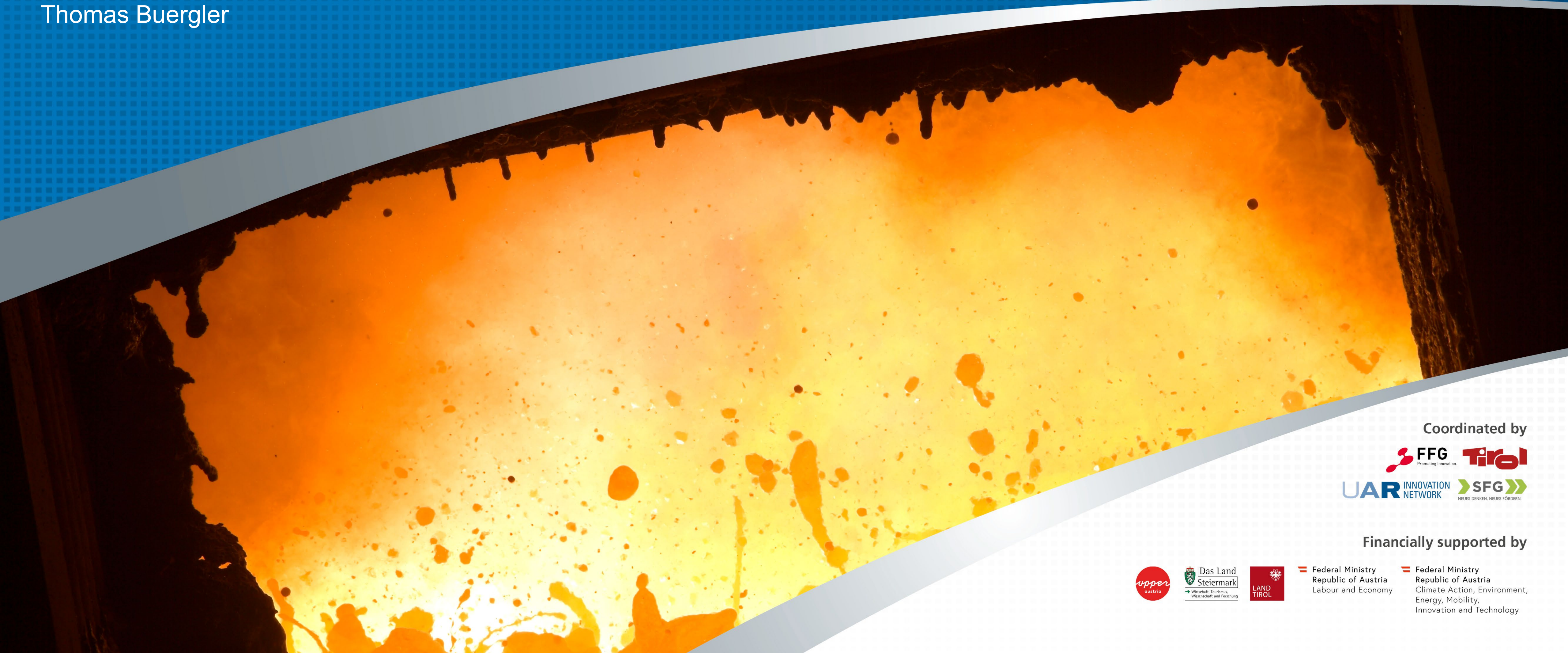
Fast-track in development of new hydrogen based smelting reduction technologies

metallurgical competence center

worldsteel Breakthrough Technology Conference 2025
Singapore, December 03rd, 2025

Thomas Buergler



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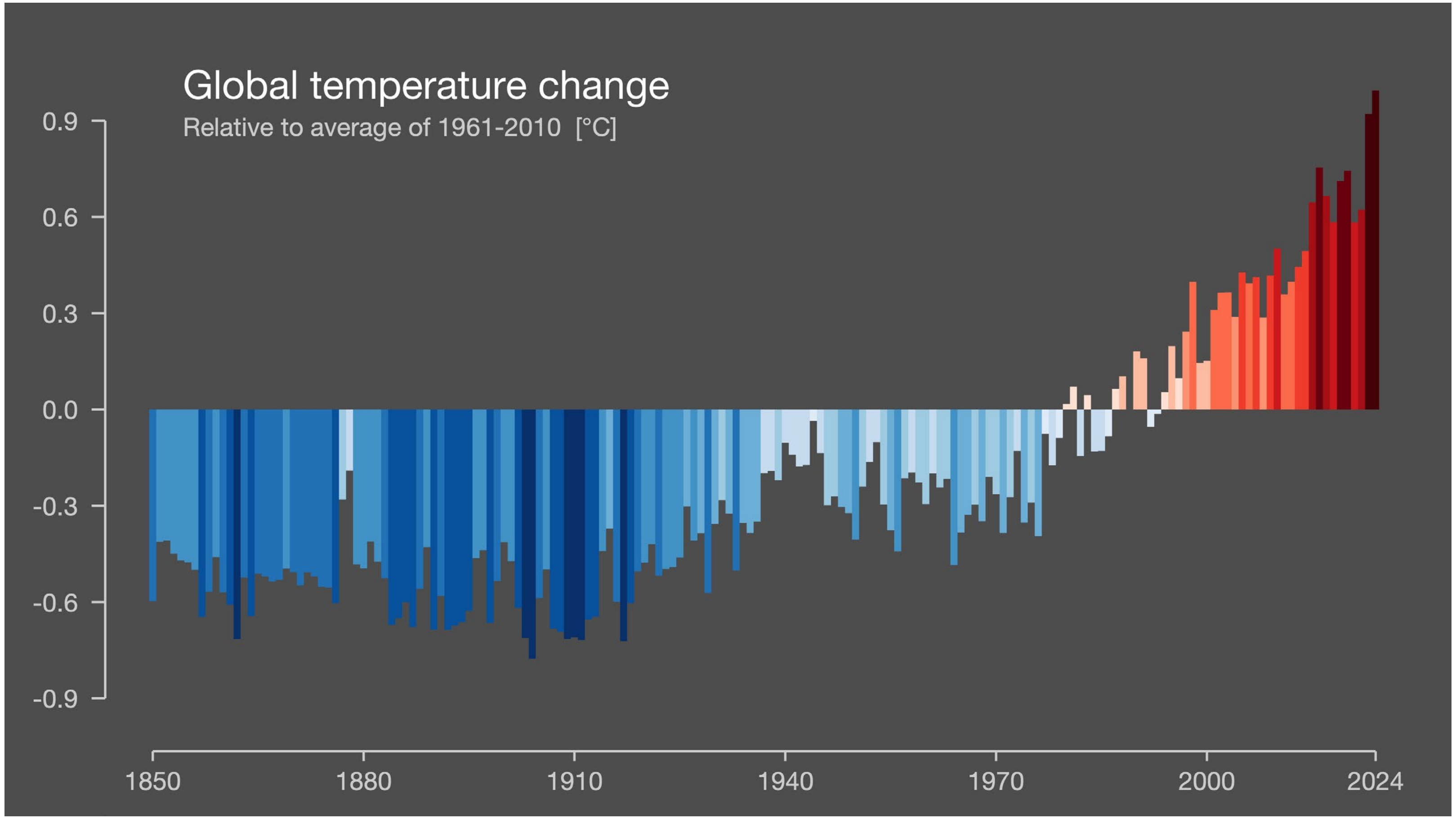
Climate goals

Global temperature increase



- Paris 2015 agreement: max. global temperature increase of 1,5 °C at 2100 compared to levels before industrialization
- Global temperatures have increased by 1,5 °C within the last 170 years

www.showyourstripes.info
Professor Ed Hawkins (University of Reading)

Roadmap to climate neutral steelmaking

Global CO_2 emissions reduction and TRL of technology

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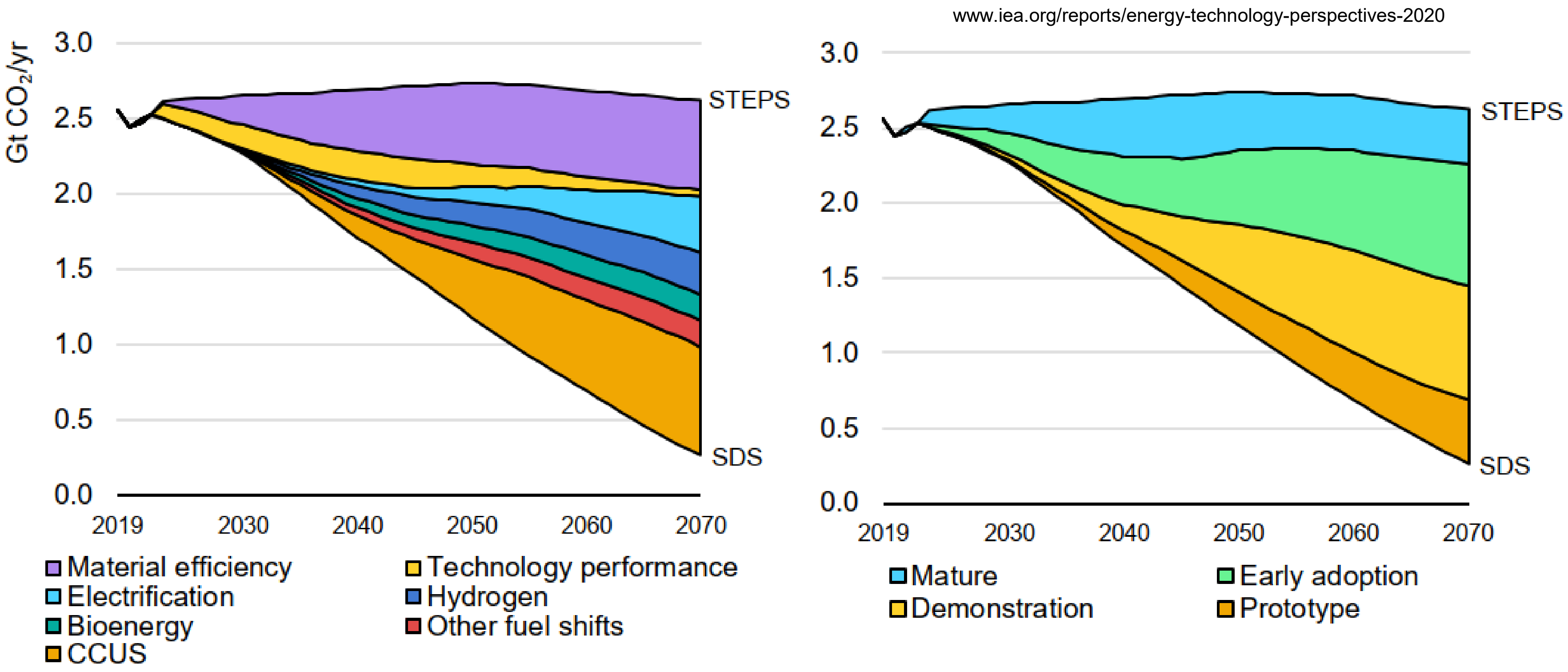
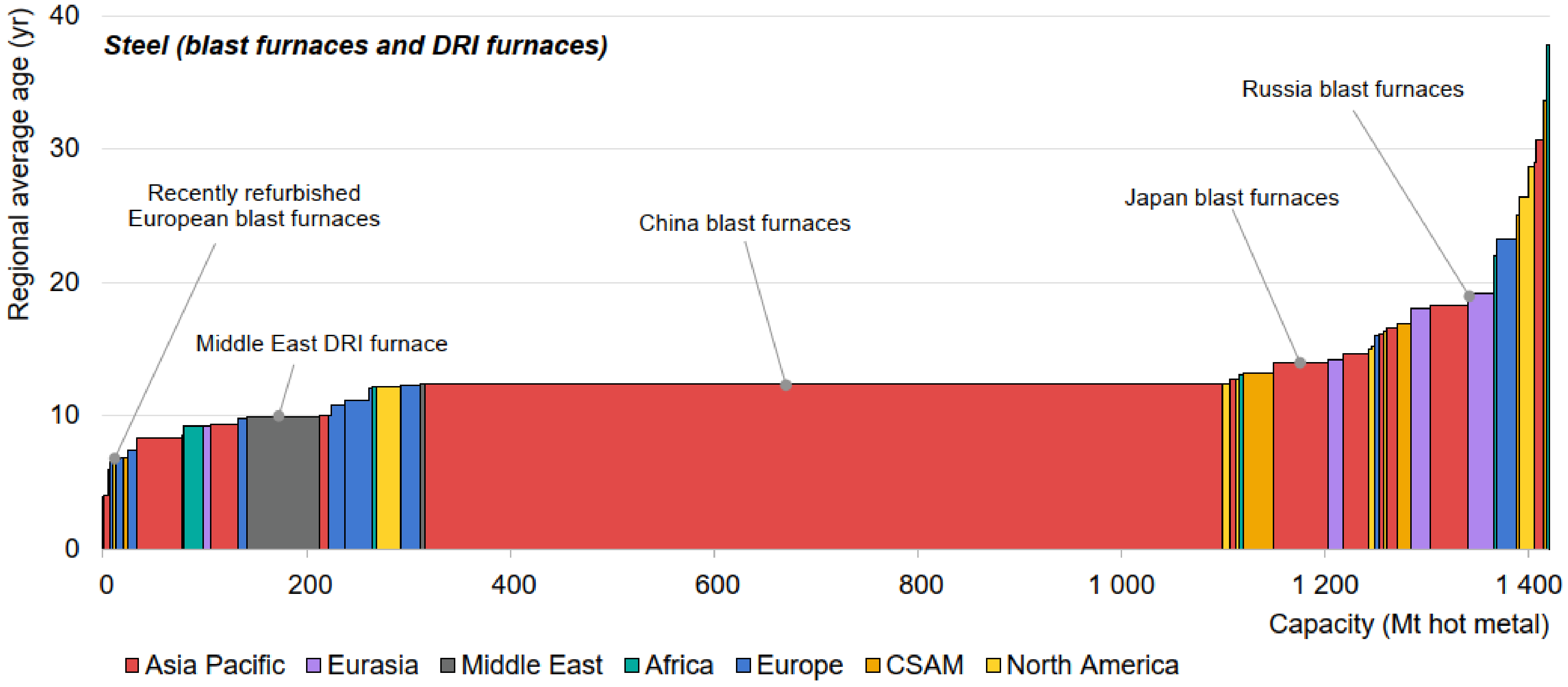


- STEPS = Stated Policies Scenario SDS = Sustainable Development Scenario
- Mature and Early adoption technologies are key tasks to achieving early emissions reductions, while the long-term trend relies more on Demonstration and Prototype technologies

Roadmap to climate neutral steelmaking

Age profile of global production capacity for OBM



www.iea.org/reports/energy-technology-perspectives-2020

- Majority of OBM production capacity is at the younger end of the age range below 20 years
- Typical lifetime of 40 years for steel sectors key assets BF and DR plants, therefore much of the capital stock will remain in operation two decades into the future
- There is scope to retire some assets earlier or re-purpose them (e.g. increase of H_2 in DR or CCSU for BF)

Integrated steelmaking in Austria

voestalpine sites in Linz and Donawitz

Phased transformation of steelmaking

Projects on schedule

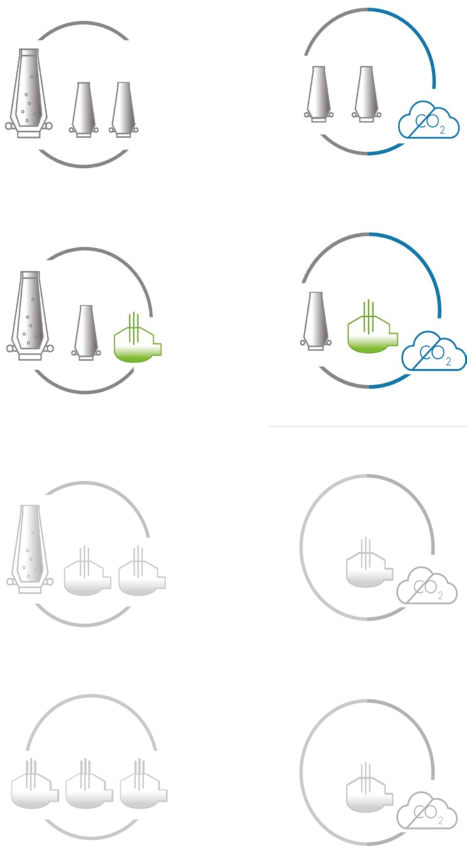
Steel Division | Metal Engineering Division

CURRENT
BF/BOF

FROM 2027
BF/BOF/EAF
+ OBM

2030 – 2035
BF/BOF/EAF
+ OBM

2035 – 2050
Breakthrough technologies
+ EAF/Smelter



OBM … Ore Based Metallics internal/external

from 2027 — One Electric Arc Furnace (EAF) in both Linz and Donawitz — Investment volume: EUR 1.5 billion

by 2029 — Up to 30% reduction in CO_2 emissions*

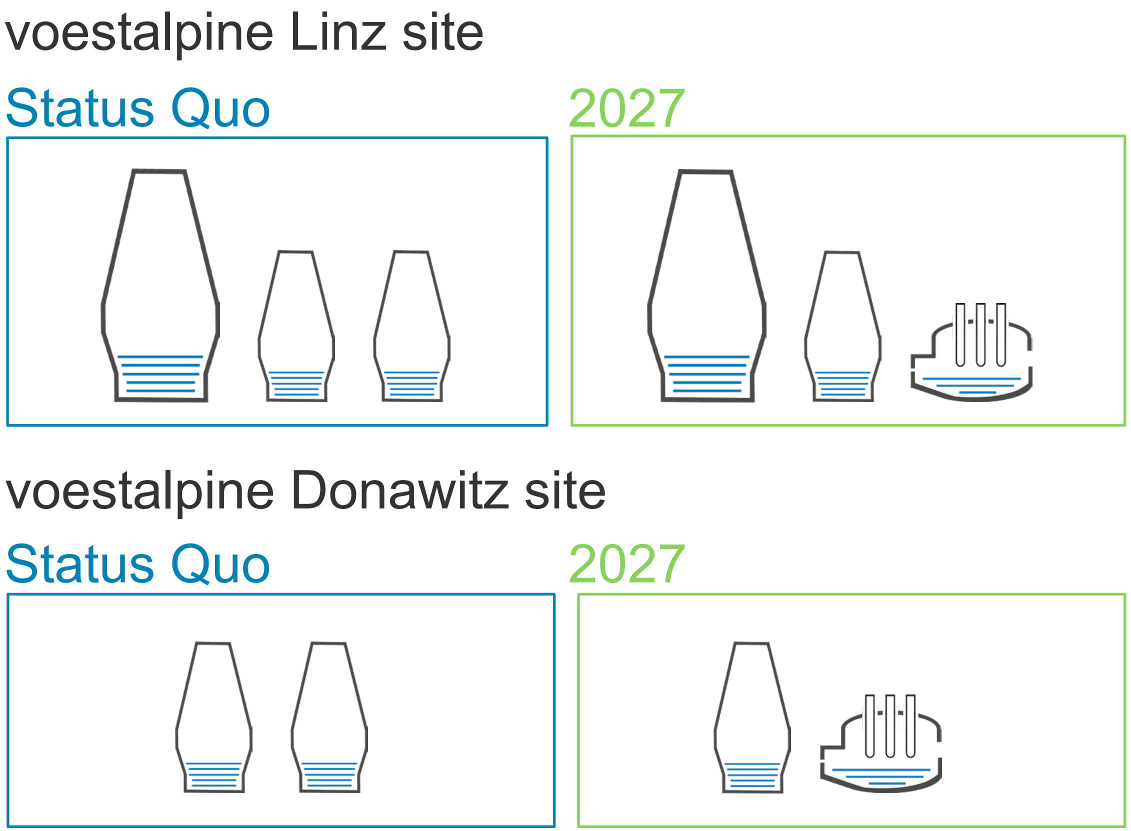
from 2030 — Replacement of another Blast Furnace at each of the sites in Linz and Donawitz (- 50% CO_2 emissions*)

by 2050 — Goal: Net-zero CO_2 emissions

* Scope 1 and Scope 2 emissions compared to the reference year 2019

First step of transformation

Hybrid steelmaking with EAF integration



- Hybrid technology with EAF process additional to BF/DR/BOF at integrated sites until 2030
- Stepwise decrease of BF/BOF production
- Up to 60 % CO_2 reduction for the EAF based part independent from green hydrogen
- High potential for further CO_2 decrease as soon as renewable electrical energy and green hydrogen are economical available
- Concept ready for integration of breakthrough technologies 2035+

Hybrid steelmaking

Installation EAF technology in Linz and Donawitz

EAF construction site Linz

PRIMETALS TECHNOLOGIES

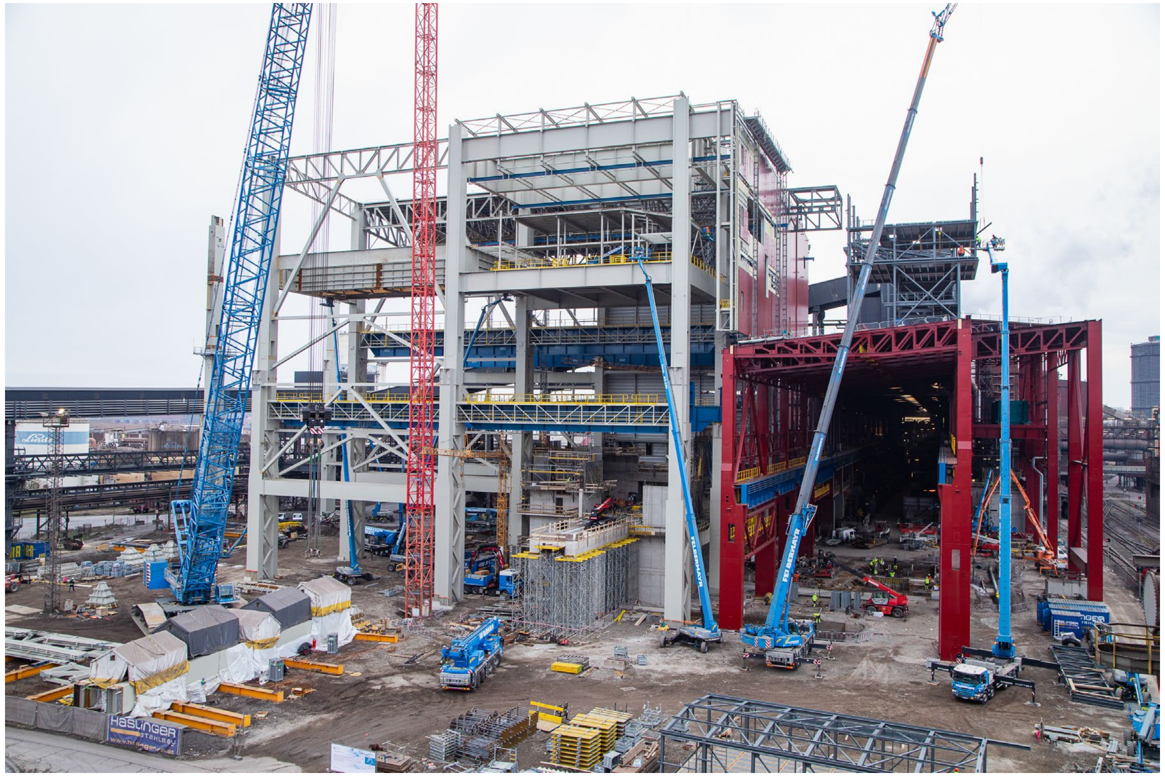
EAF construction site Donawitz

DANIELI

- Installation of 2 EAF units with a production capacity of 1,6 mt per year in Linz and 0,85 mt per year in Donawitz until 2027
- Largest running CO_2 reduction project in Austria with up to 5 % national decrease in greenhouse gas emissions

Hybrid steelmaking

Status EAF construction Linz and Donawitz



EAF construction site Linz

PRIMETALS TECHNOLOGIES

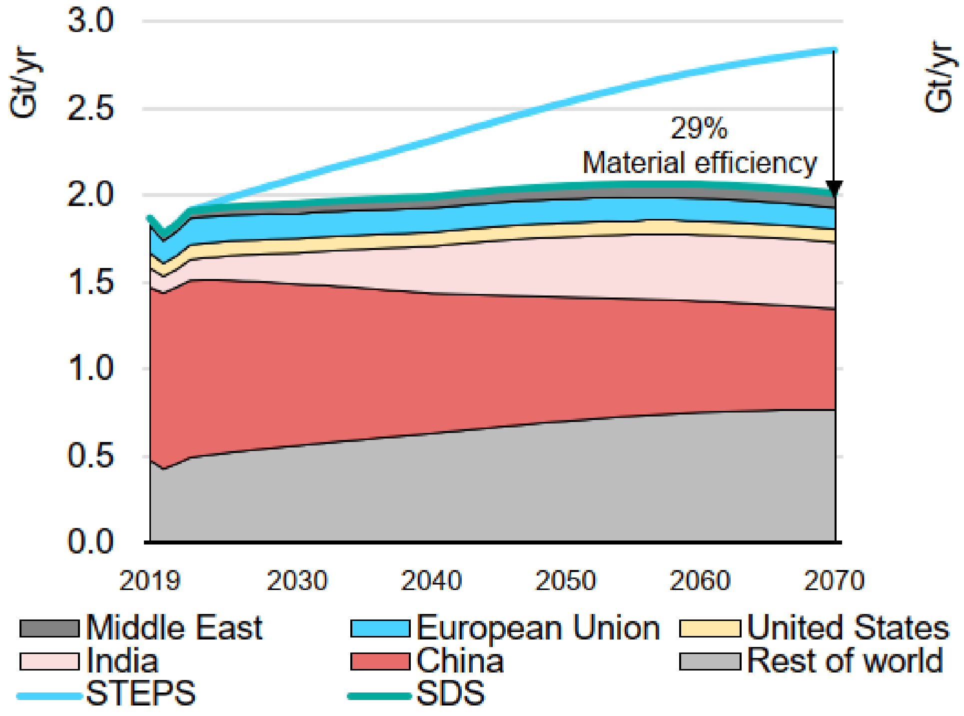
EAF construction site Donawitz

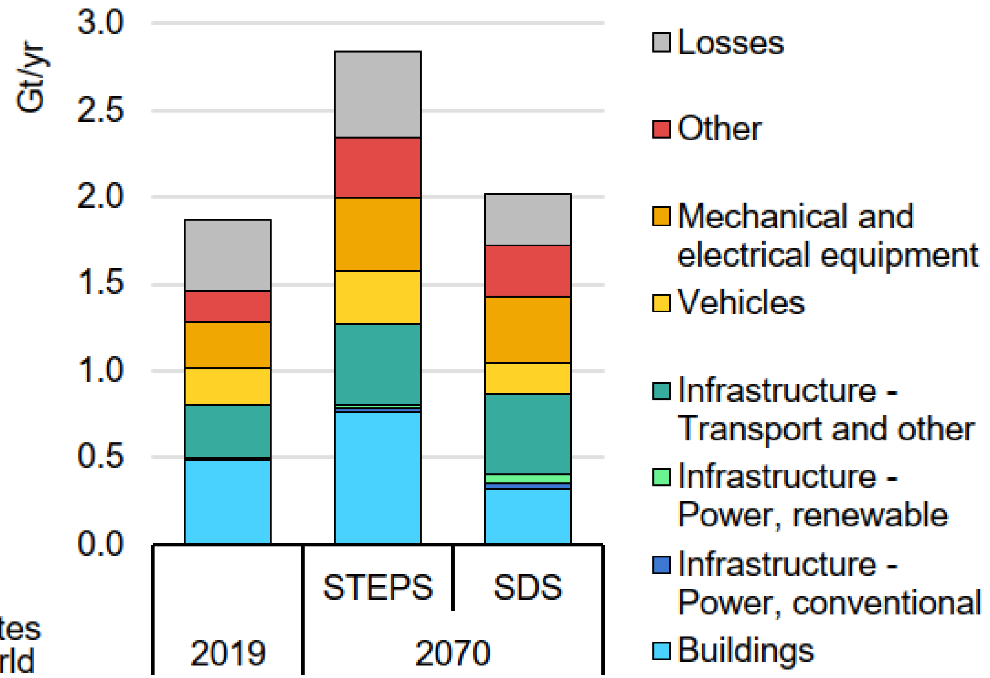
DANIELI

- Civil work finished, steel construction EAF building and raw material/scrap supply ongoing
- Erection of electric energy supply from external grid, start of delivering components

Roadmap to climate neutral steelmaking

Global steel production by region and end use



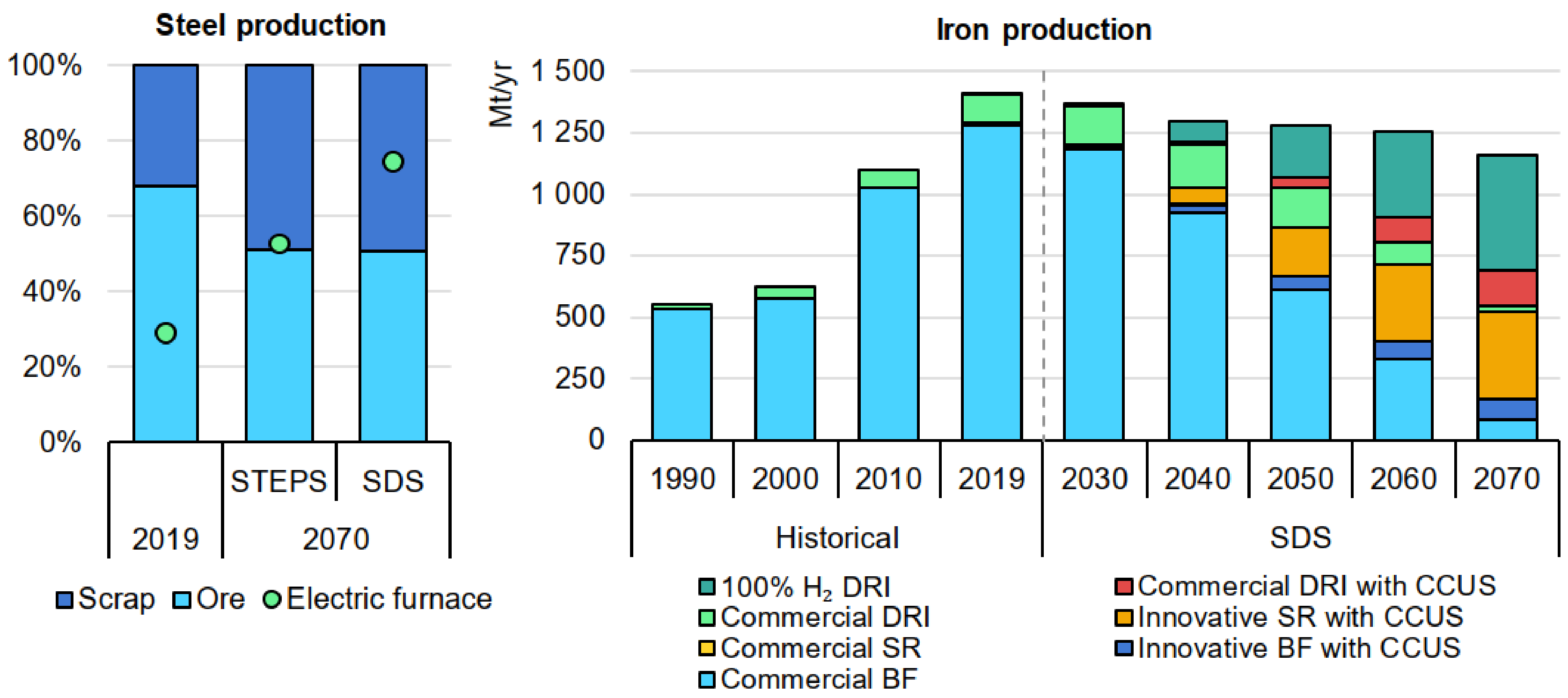


- Material efficiency strategies help reduce global demand on steel by 29 % in 2070
- Losses are equivalent to scrap generated in the semi-manufacturing and manufacturing stages

Roadmap to climate neutral steelmaking

Global steel production by route and OBM production by processes

K1 MET metallurgical competence center

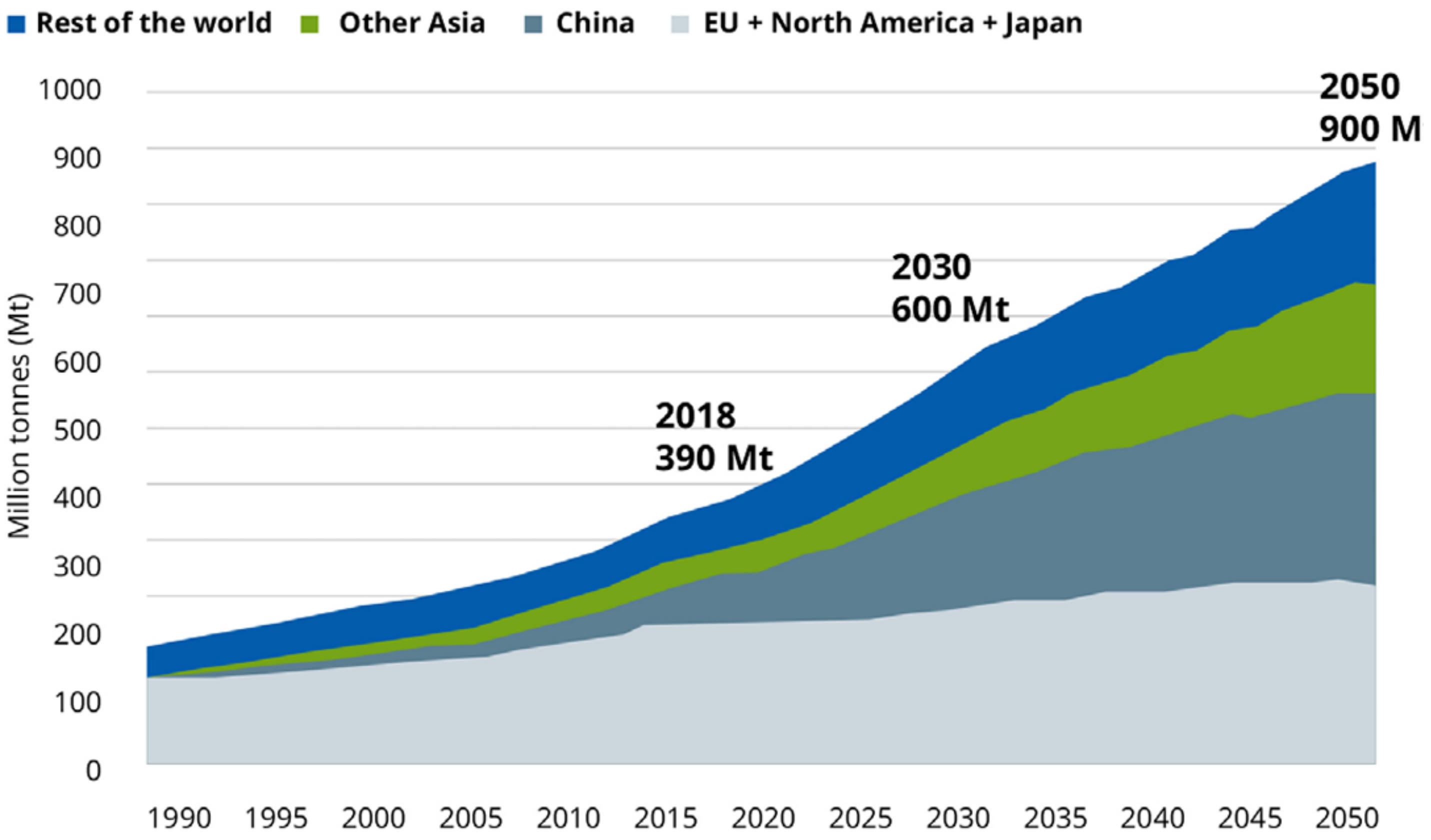


www.iea.org/reports/energy-technology-perspectives-2020

- Projects with scrap based EAF production and DR/EAF increase the share of electricity in the Sustainable Development Scenario until 2040
- In the longer term, alternative process concepts for OBM with green hydrogen and CCUS will finally replace the classical BF

Climate neutral steelmaking

Global trend for scrap availability and region

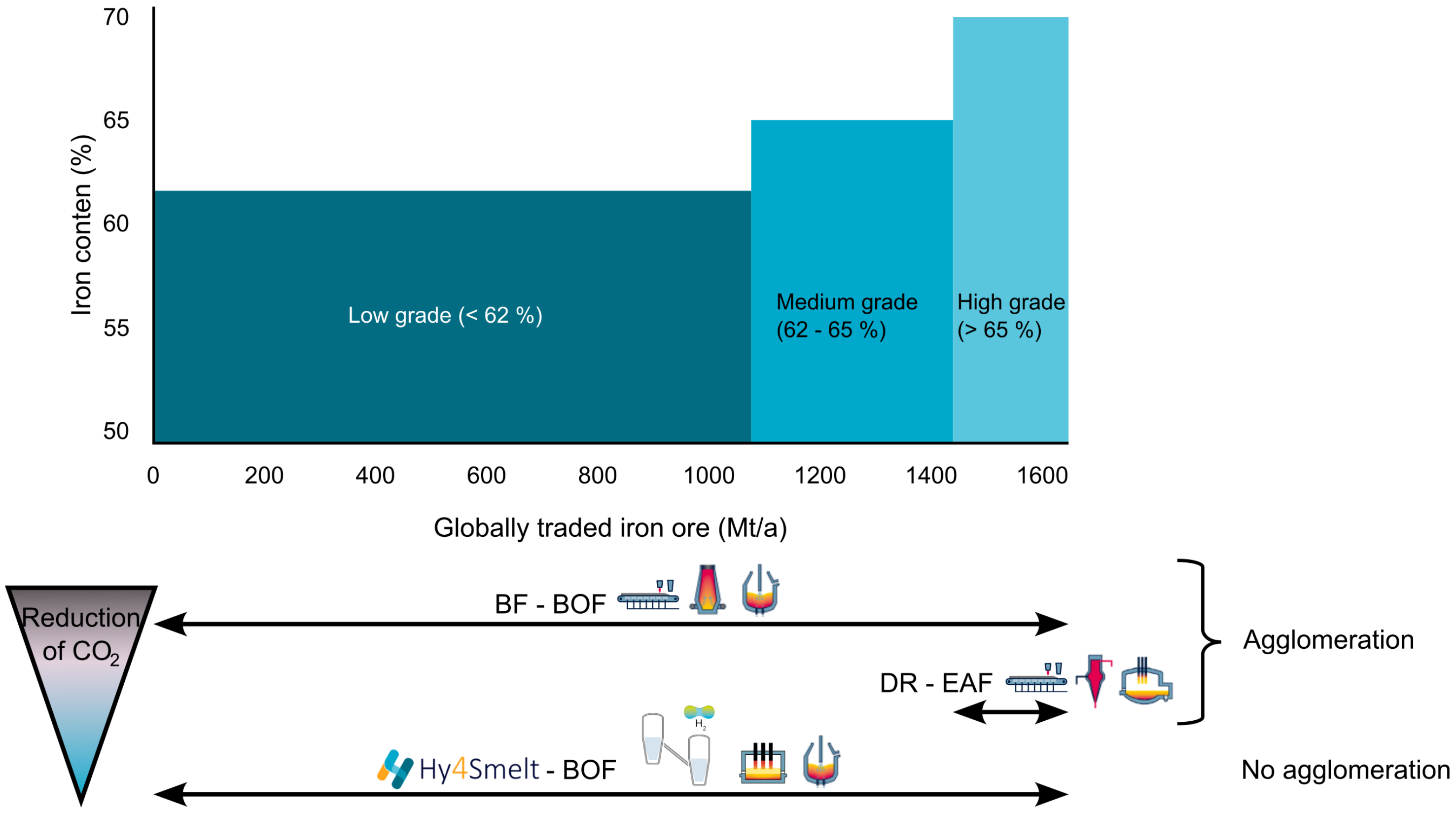


https://worldsteel.org/

- Crude steel demand will be 30 % higher in 2050 than it is today
- Much of this growth will be in emerging economies with declining demand in China, Europe, Japan, and South Korea
- Contribution of scrap in the total steel charge will likely grow to 40 % in 2050 from 30 % than today
- Process technologies for OBM (ore based metallics) will have an important role in future CO_2 neutral steelmaking

Climate neutral steelmaking

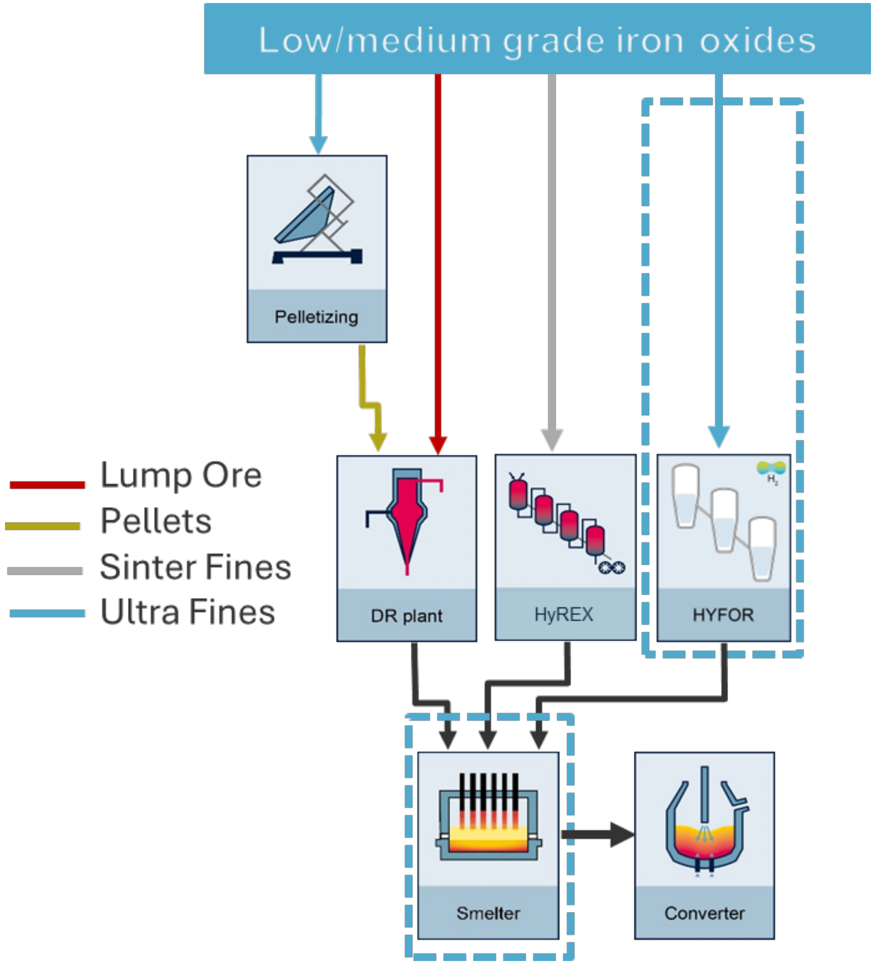
Iron ore grades and process routes



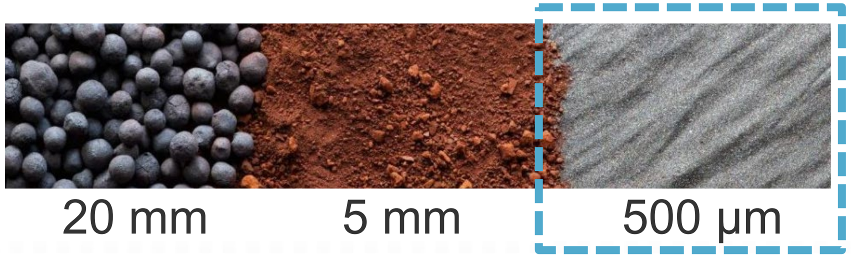
- Majority of iron ores for steel production are fine ores with Fe < 65 %
- EAF process is not suitable for melting DRI/HBI with high slag quantities
- Iron ores with Fe > 65 % will not be able to replace low/medium grade ores in the future
- Electric smelting furnace (Smelter) in combination with direct reduction enables slag separation for BOF and EAF similar to BF process

Climate neutral steelmaking

Process routes for green hot metal



- HYFOR is an alternative direct reduction process for ultrafine iron ores that will not require any agglomeration steps
- A combination with Smelter technology is used for melting and final reduction of direct reduced iron (DRI) based on low and medium grade iron ores with Fe < 65 %
- In that way green hot metal is produced with hydrogen for BOF or EAF steelmaking



Climate neutral steelmaking

Pilot and demonstration projects in Linz and Donawitz

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H2Future demonstration plant

Industrial scale PEM electrolyser for hydrogen production with dynamic response for all kinds of grid services

voestalpine ONE STEP AHEAD.
SIEMENS energy
PRIMETALS TECHNOLOGIES
Verbund
APG AUSTRIAN POWER GRID
FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING
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TNO
FFG Promoting Innovation.

HYFOR pilot plant

Direct reduction of ultrafine iron ores with hydrogen in a fluidized bed process

SuSteel pilot plant

Direct steelmaking by hydrogen plasma smelting reduction of ultrafine iron ores

Climate neutral hydrogen production

PEM demonstration plant Linz

- Stable operation tested from 1,5 MW to 9,0 MW
- Dynamic response for all kind of grid services
- Stack efficiency up to 83% at rated load
- H_2 purity 99,9%, O_2 purity 99,0%

Climate neutral hydrogen production

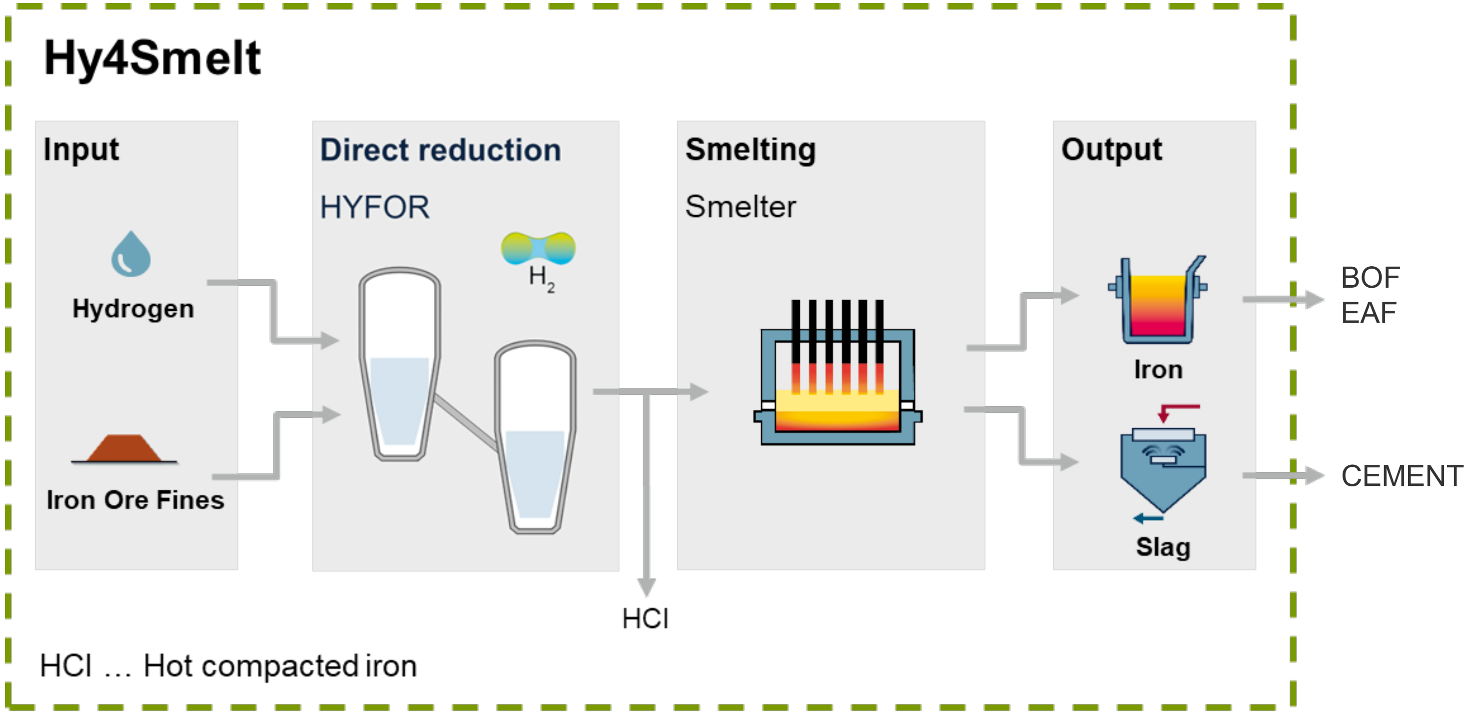
Upgrading of H2Future pilot plant

- Grid services for optimisation of hydrogen costs und enabling sector coupling
- Dynamic two stage compression (20/50 bar) and purification (H2 5.0)
- Storage tanks for 1 t hydrogen at 50 bar
- Compression up to 500 bar and additional trailer storage of 450 kg hydrogen

Demonstration plant

Building blocks for green hot metal

- Processing of all global available iron ore grades in a continuous operation mode
- Fluidized bed technology requires no upstream agglomeration step (sintering, pelletizing) as for BF and shaft based DR process
- Flexible output of ore based metallics for downstream EAF and BOF process by HCI, hot metal and pig iron
- Green energy and bio-carbon allow carbon neutral iron production without NG or coke oven plant
- Recycling of iron and steelmaking by-products in the smelting process and sector coupling with cement industry



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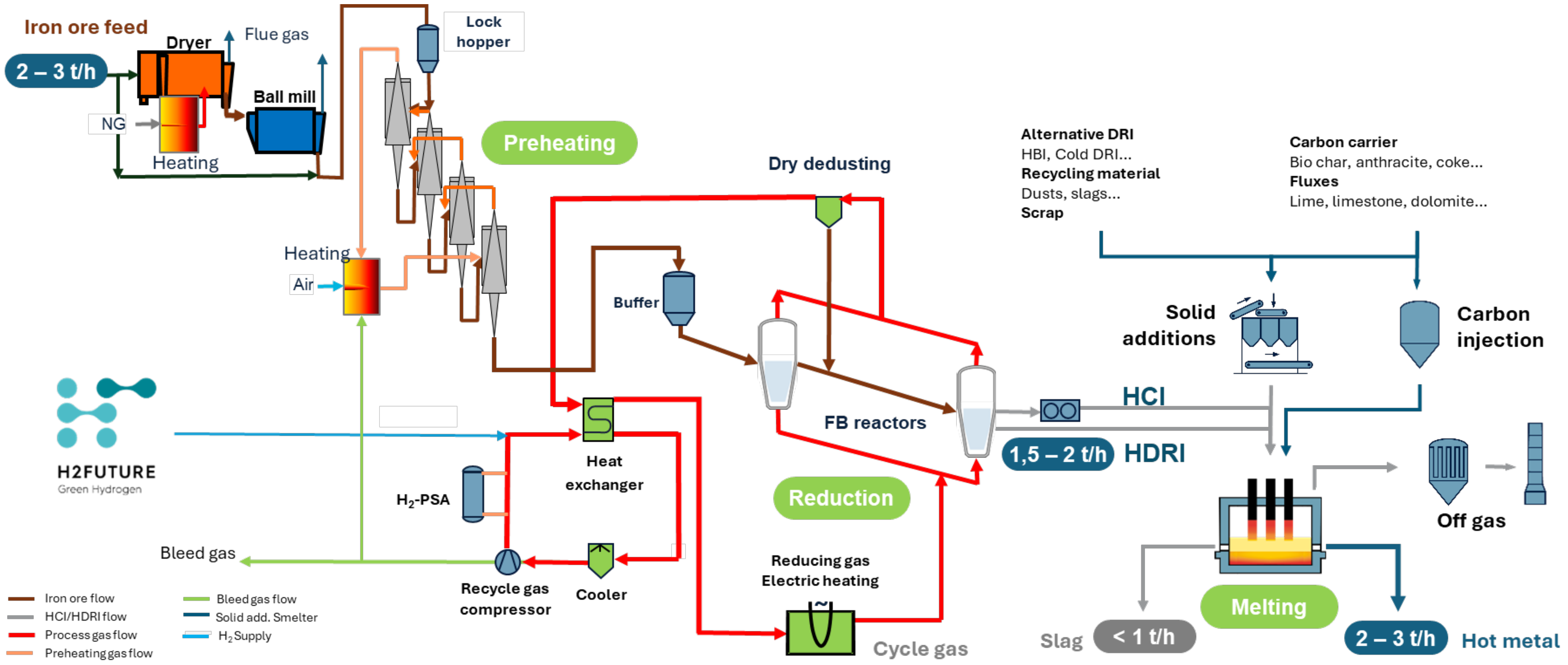
Demonstration plant

Process flowsheet



Demonstration plant

Reactor cascade

Hy4Smelt

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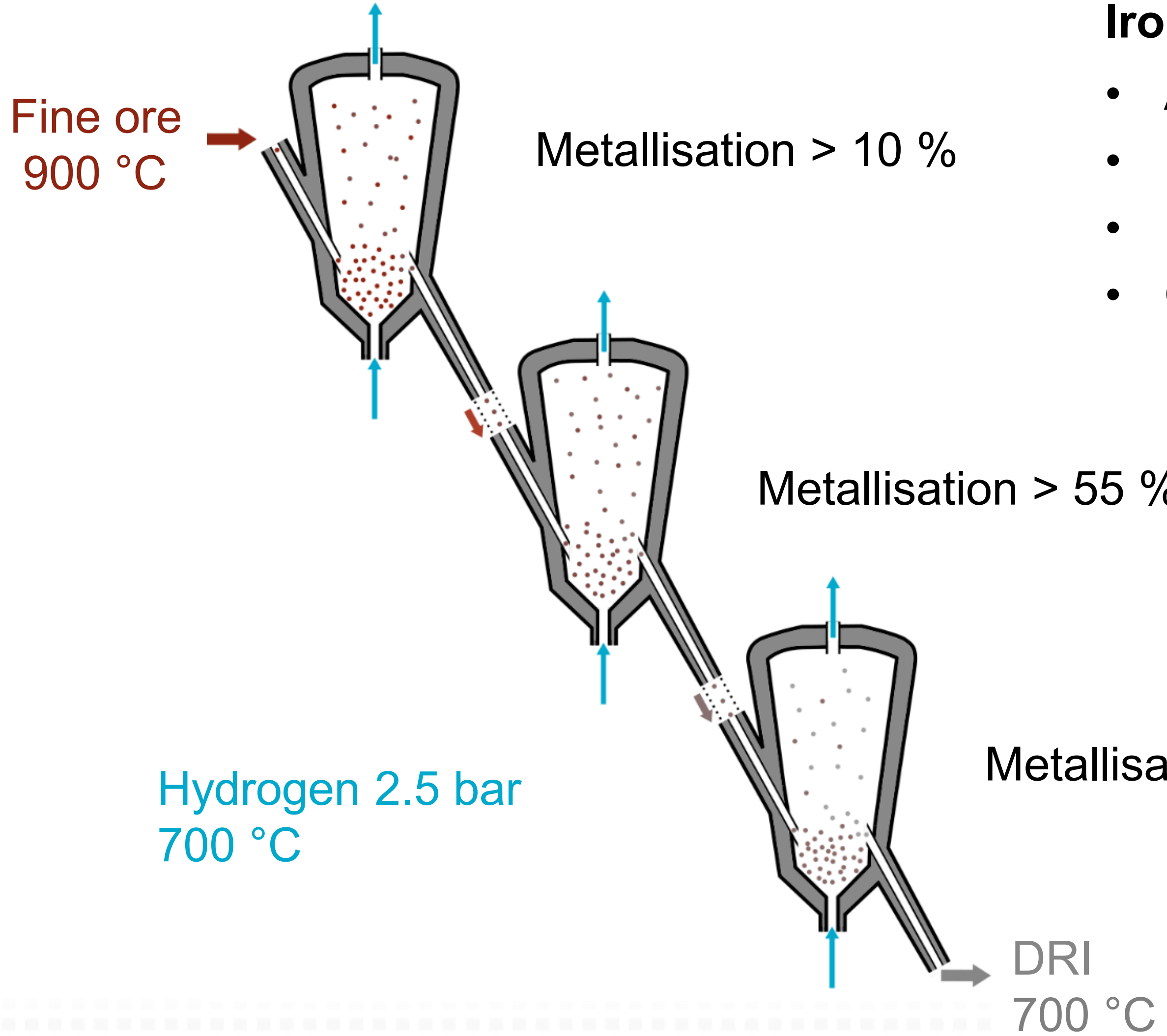


Iron ores

- All global available iron ore grades
- Hematitic/Magnetitic/Sideritic mineralogy
- Fe-content 50 – 70 %
- Grinding step for sinter feed

Input design parameters

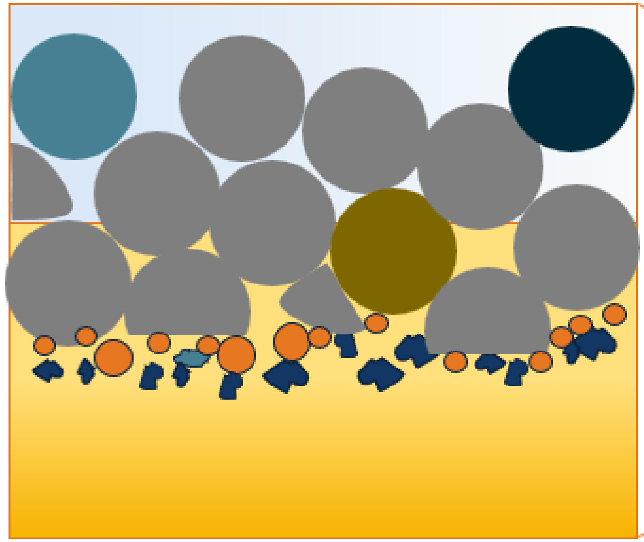
- Ultrafine iron ores < 500 µm: 2.3 – 3.8 t h^{-1}
- Calcined/oxidised to FeO/Fe_2O_3
- Hydrogen: 1200 – 1500 Nm^3h^{-1}

Output design parameters

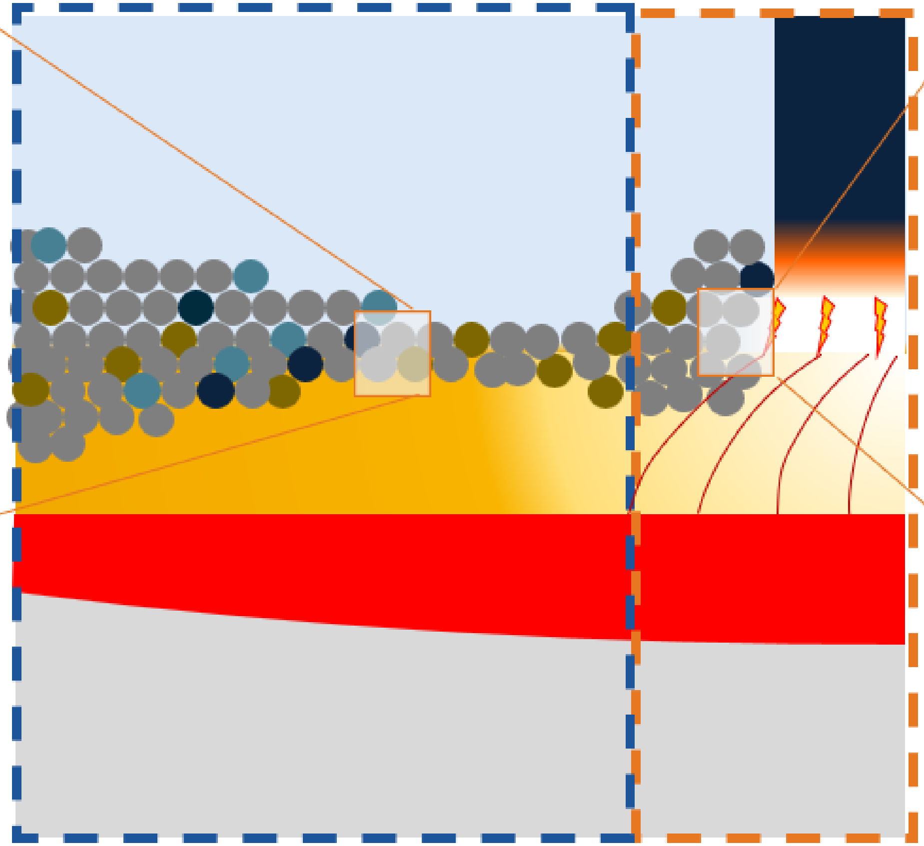
- Direct reduced iron (DRI): 1.8 – 2.6 t h^{-1}
- Metallisation of 85 – 93 %
- Remaining gangue specific to the ore

Demonstration plant

Melting and reduction in Smelter

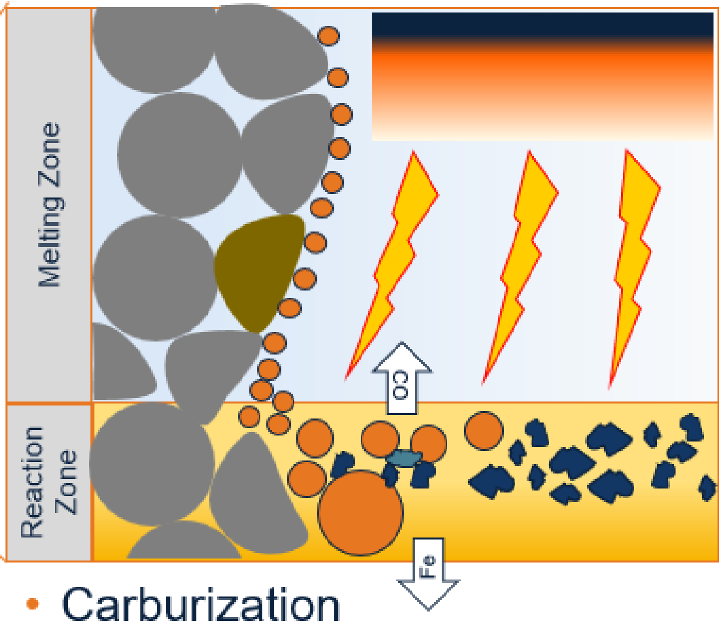


Contact burden with slag – minor melting of DRI will take place here



Wall zone

Process zone



- Carburization
- Reduction

$$(FeO) + [C] \Leftrightarrow [Fe] + \{CO\}$$

$$(SiO_2) + 2[C] \Leftrightarrow [Si] + 2\{CO\}$$

- Sulfur removal

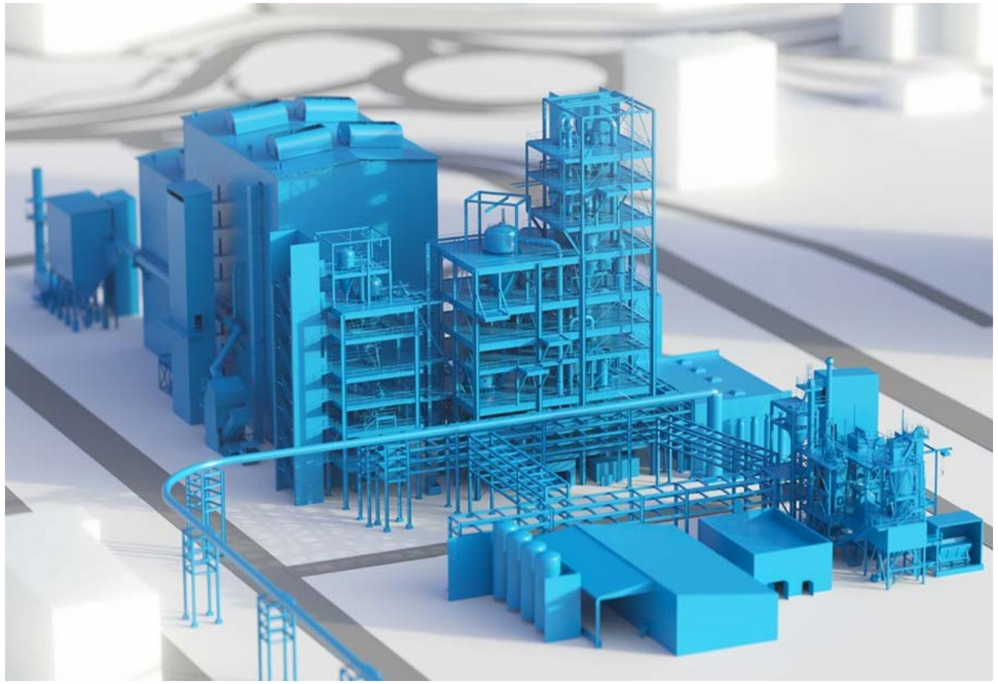
$$[S] + (CaO) + [C] \Leftrightarrow (CaS) + \{CO\}$$

Demonstration plant

Key figures

Hy4Smelt

K1-MET metallurgical competence center



Goundbreaking Hy4Smelt 09/25/2025

Iron ore	2 – 3 t/h
Hydrogen	1.500 m^3/h
Hot metal	2 – 3 t/h
Slag	< 1 t/h

Location voestalpine Linz site

CAPEX	EUR 130 million
OPEX	EUR 40 million
FID	04/2025
SOP	11/2027

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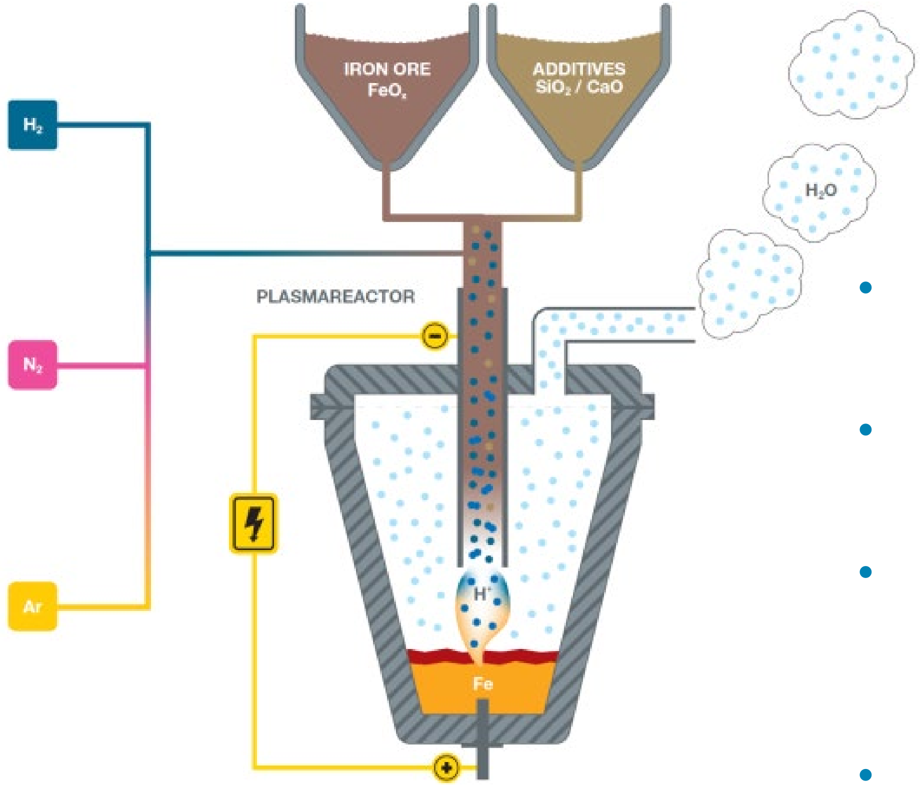
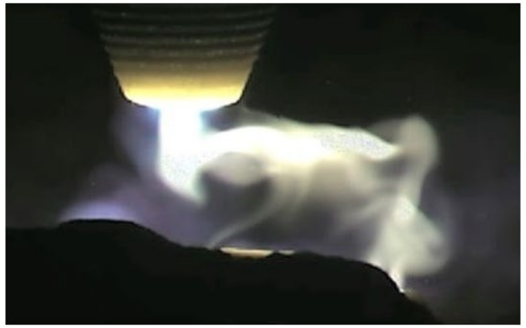
Demonstration plant
Construction site Linz

- Civil work started in October 2025, ercetion of steel construction will follow in April 2026

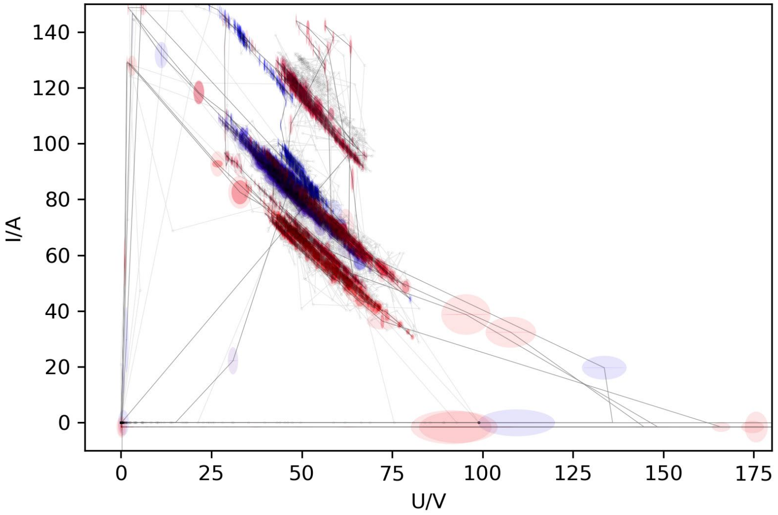
Process development SuSteel

HPSR experimental and simulation approach





- Iron ore and hydrogen enter the reactor via a hollow electrode
- Transferred arc for the energy input
- Hydrogen is ionised into plasma where iron ore is melted and reduced
- Developmet of process and electrical models for advances process control and upscaling



Process development SuSteel

Hydrogen plasma smelting reduction process

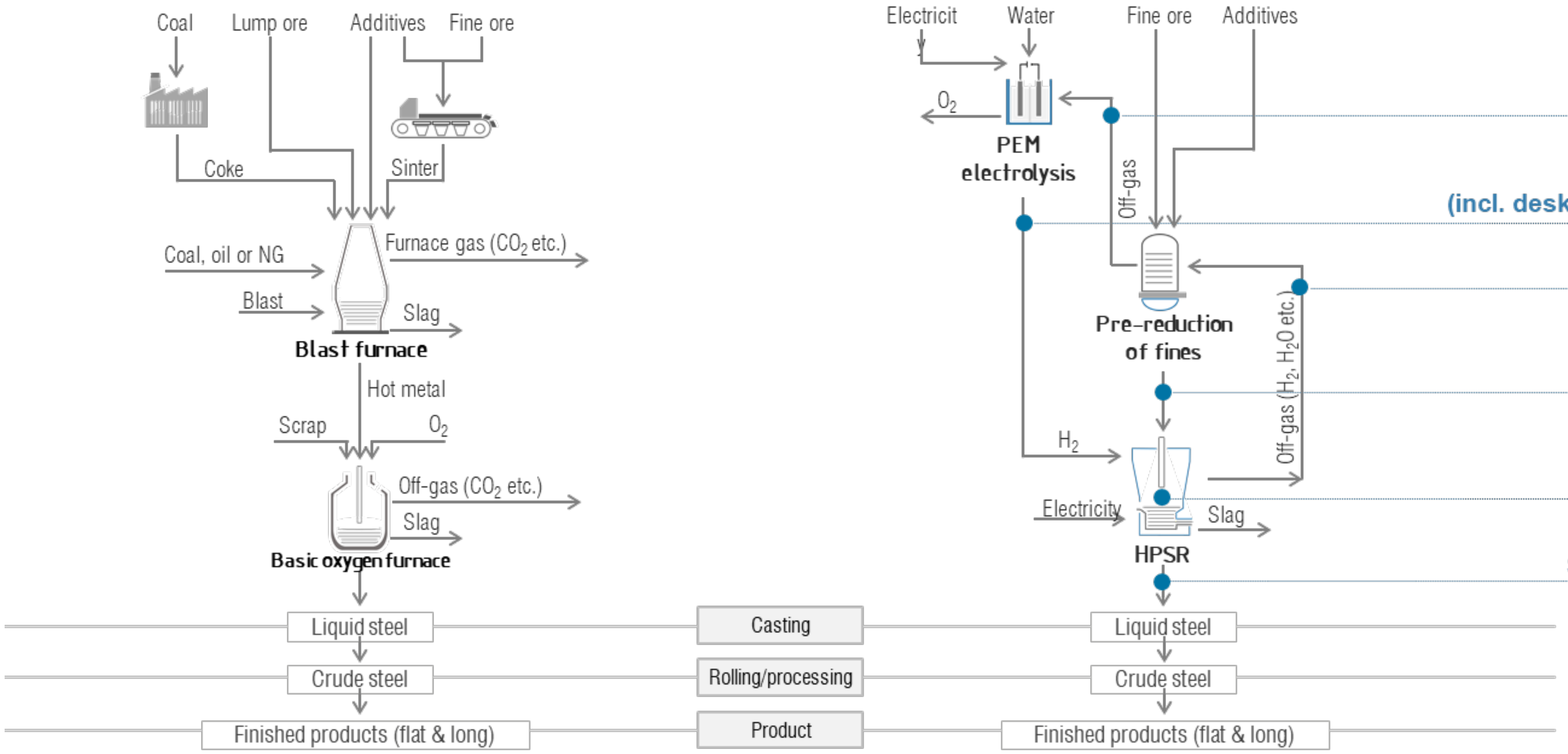
- Fundamental research project for direct steelmaking from iron oxides with H_2 plasma smelting reduction (HPSR)
- Verify of process concept with batch operation in a DC electric arc furnace (EAF) with 250 kVA
- Upscaling of the technology from 100 g to 50 kg tapping weight
- Creating design parameters for an increased reactor size and continuous operation
- Pilot plant with TRL 5 for this breakthrough technology is located at voestalpine Donawitz site

SuSteel pilot plant voestalpine Donawitz site

Process development SuSteel

Technological tasks for upscaling

INTEGRATED ROUTE (STATE OF THE ART)	HYDROGEN PLASMA SMELTING REDUCTION
Integrated route consisting of raw material preparation, blast furnace (iron making) and basic oxygen furnace (steel making)	HPSR route consisting of green hydrogen supply, pre-reduction of fines and HPSR



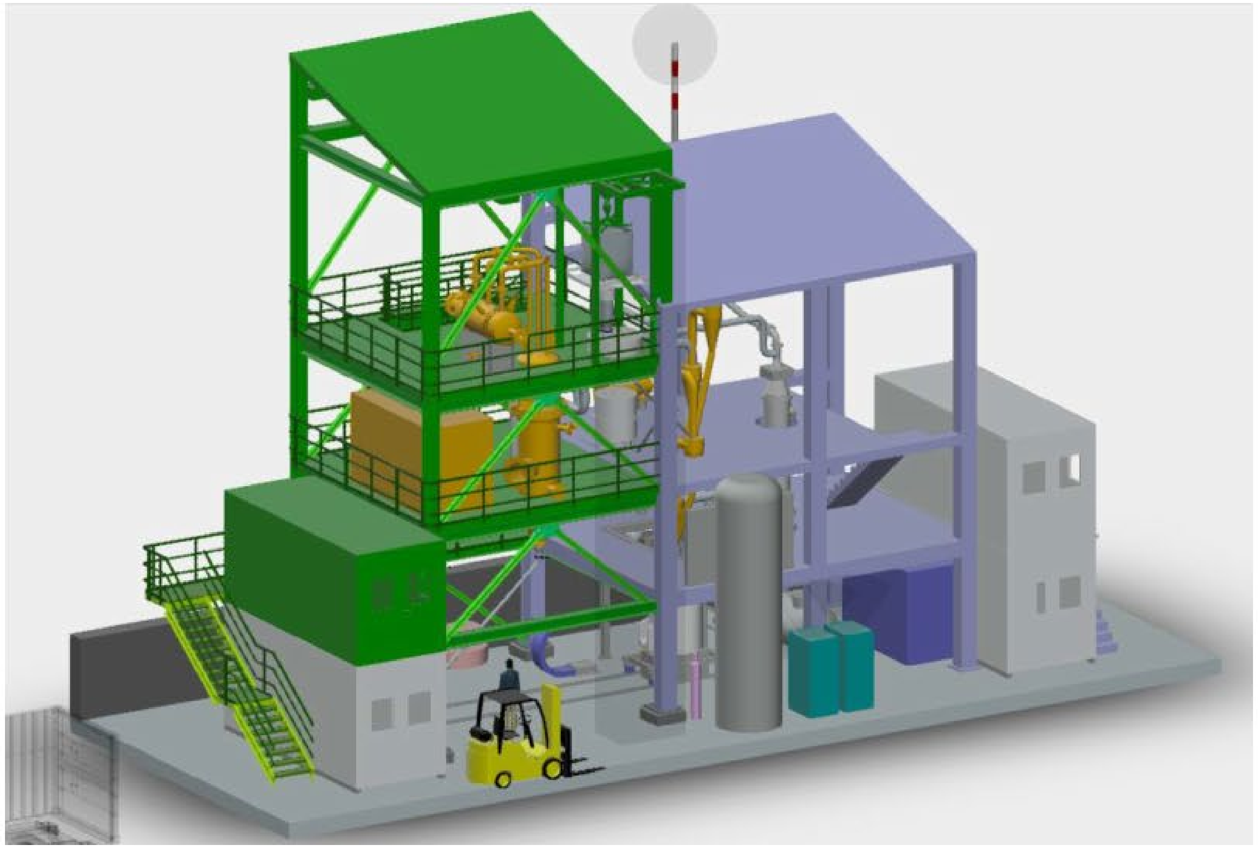
SuS-F

Objectives

- Recycling of water
- Continuous supply of green hydrogen (incl. desktop study of integrated hydrogen production)
- Recycling & further use of off-gas
- Continuous feeding of ultra fine ore
- Automated and digitalized system
- Semi-continuous tapping of carbon lean steel
- Dissemination

Process development SuSteel

HPSR pilot plant for continuous production



- Upgrade of the HPSR pilot plant with iron oxide preheating, gas recycling and continuous tapping for a melting rate up to 200 kg/h

Thank you! Questions?

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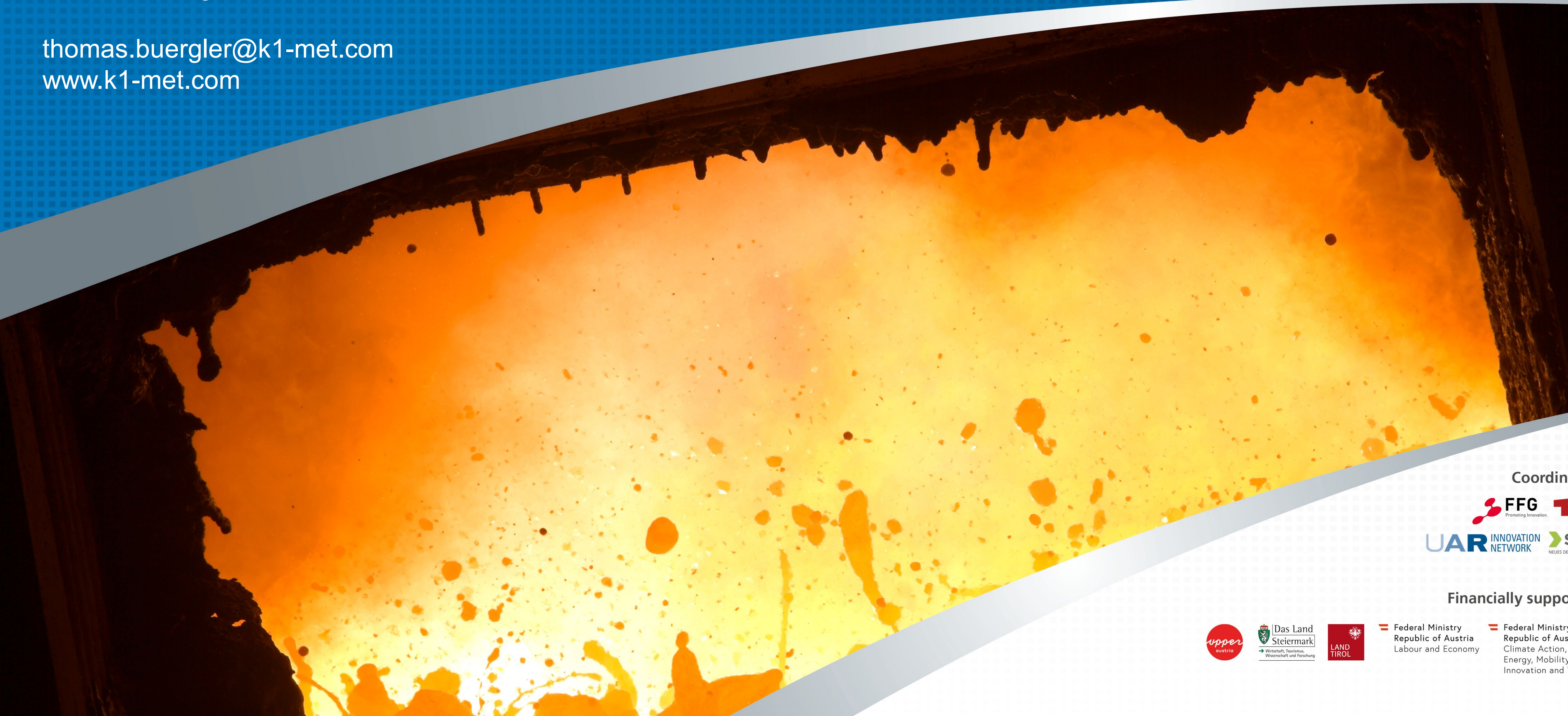
Thomas Buergler

thomas.buergler@k1-met.com
www.k1-met.com



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