

# ESTEP 2025 Annual Event

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Udine (ITALY)

How decarbonization, digitization  
and circular solutions forge the  
sustainable European steel future?

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# UPDATE ON HY4SMELT

## Hydrogen-based direct reduction and smelting of ultrafine iron ores to green hot metal

 Federal Ministry  
Innovation, Mobility  
and Infrastructure  
Republic of Austria

 Federal Ministry  
Economy, Energy  
and Tourism  
Republic of Austria



Co-funded by  
the European Union



**DIGIMET**

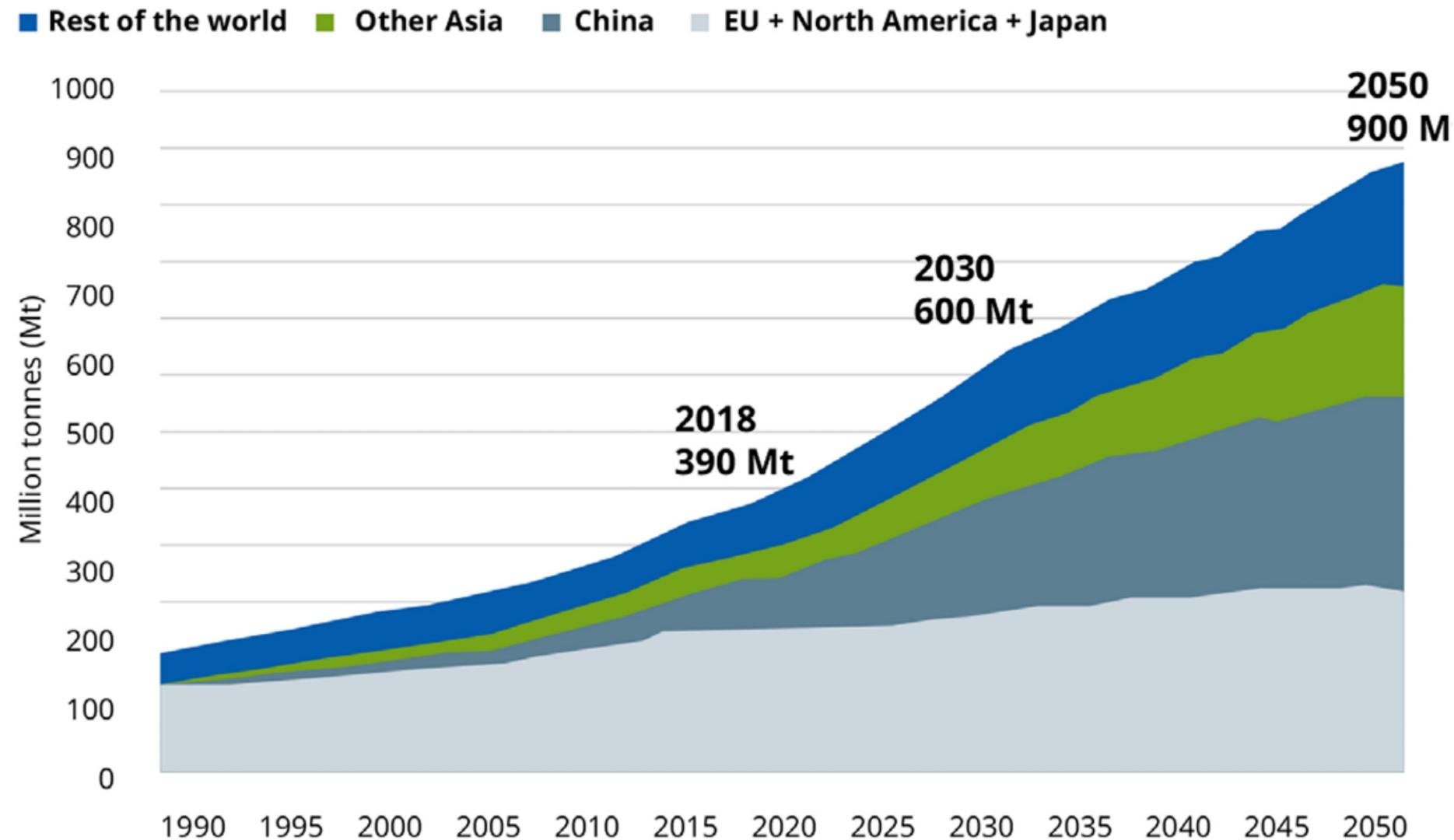


**DANIEMI AUTOMATION**



**UNIVERSITÀ  
DEGLI STUDI  
DI UDINE**  
HIC SUNT FUTURA

# Global trends for scrap availability

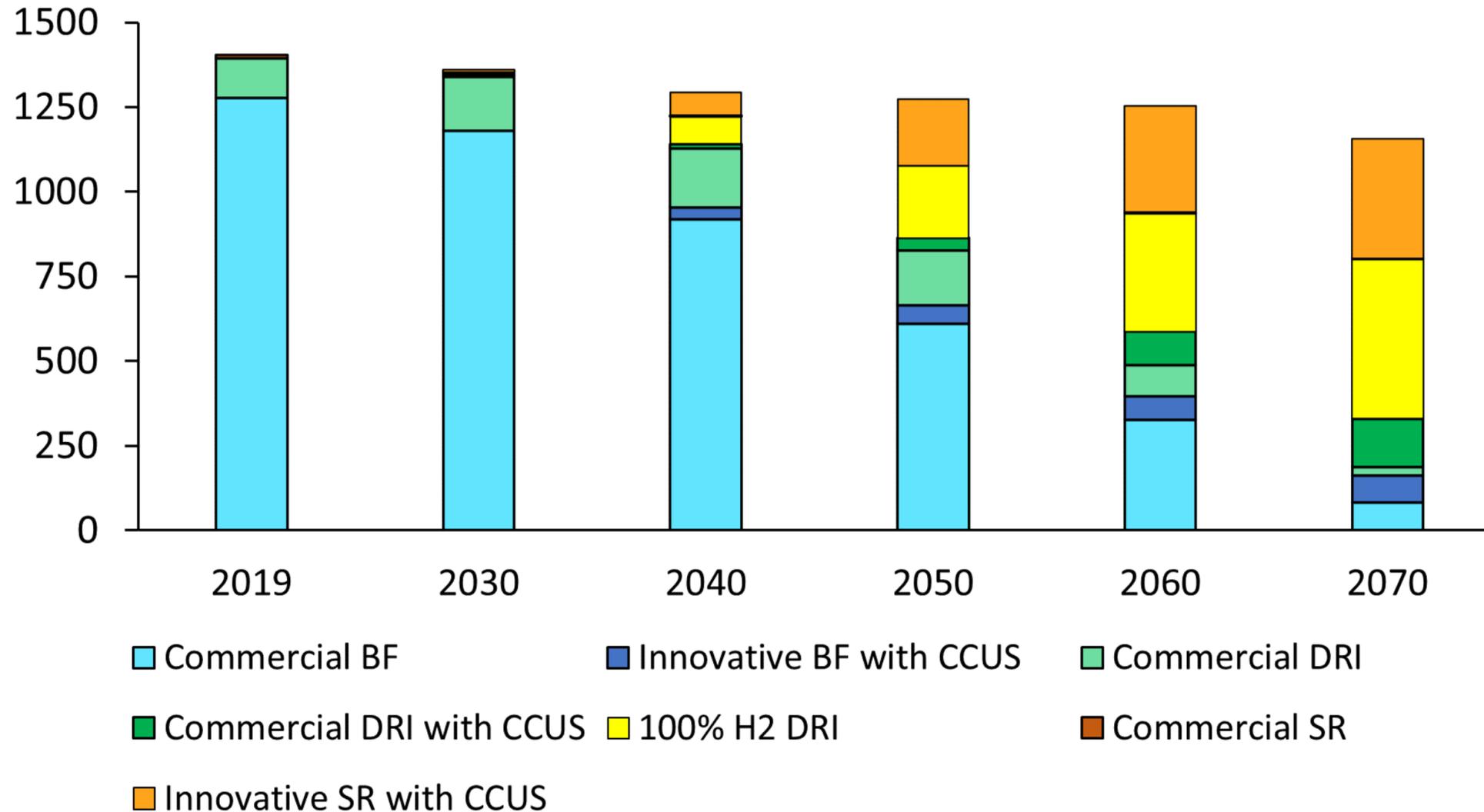


- **Crude steel** demand will be **30 % higher in 2050** than it is today
- Much of this **growth** will be in **emerging economies** with declining demand in China, Europe, Japan, and South Korea
- **Contribution of scrap** in the total steel charge will likely grow to **40 % in 2050** from 30 % than today
- Process technologies for **OBM (ore based metallics)** will have an **important role** in future CO<sub>2</sub> neutral steelmaking

Source: Worldsteel Association, Fact sheet scrap use in the steel industry, 2021

# Technological pathways for OBM production

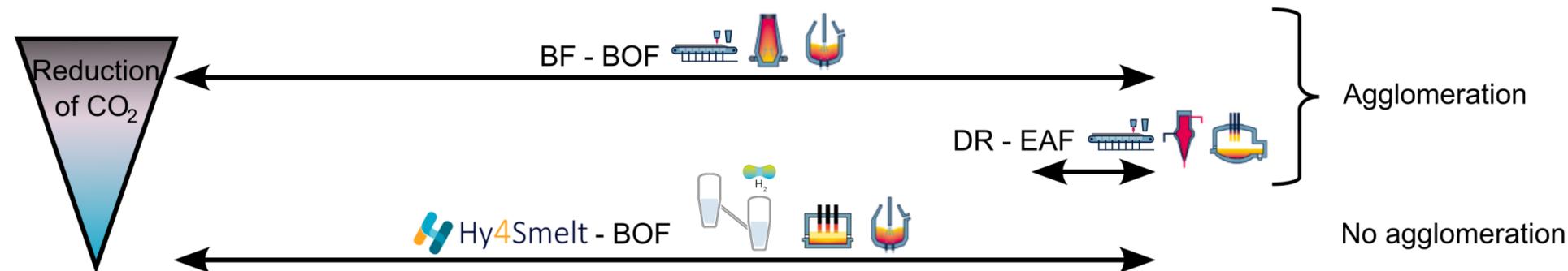
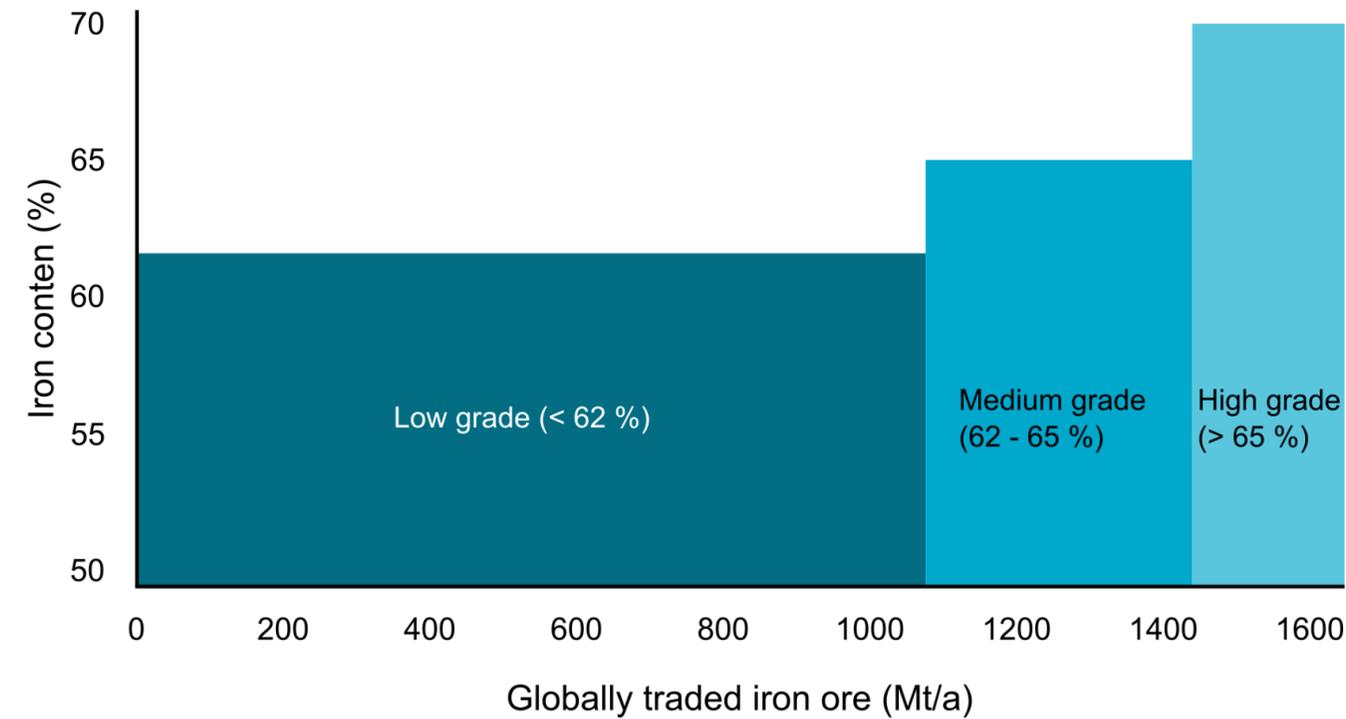
OBM million tpy



- **Decrease in hot metal production** and blast furnace/basic oxygen (BF/BOF) steelmaking
- **Increase in electric arc furnace (EAF) steelmaking** and scrap use
- **Increased use of direct reduction** producing direct reduced iron (DRI) and especially hot-briquetted iron (HBI)

Source: Global iron production by technology in the sustainable development scenario, International Energy Agency

# Iron ore grades and process routes

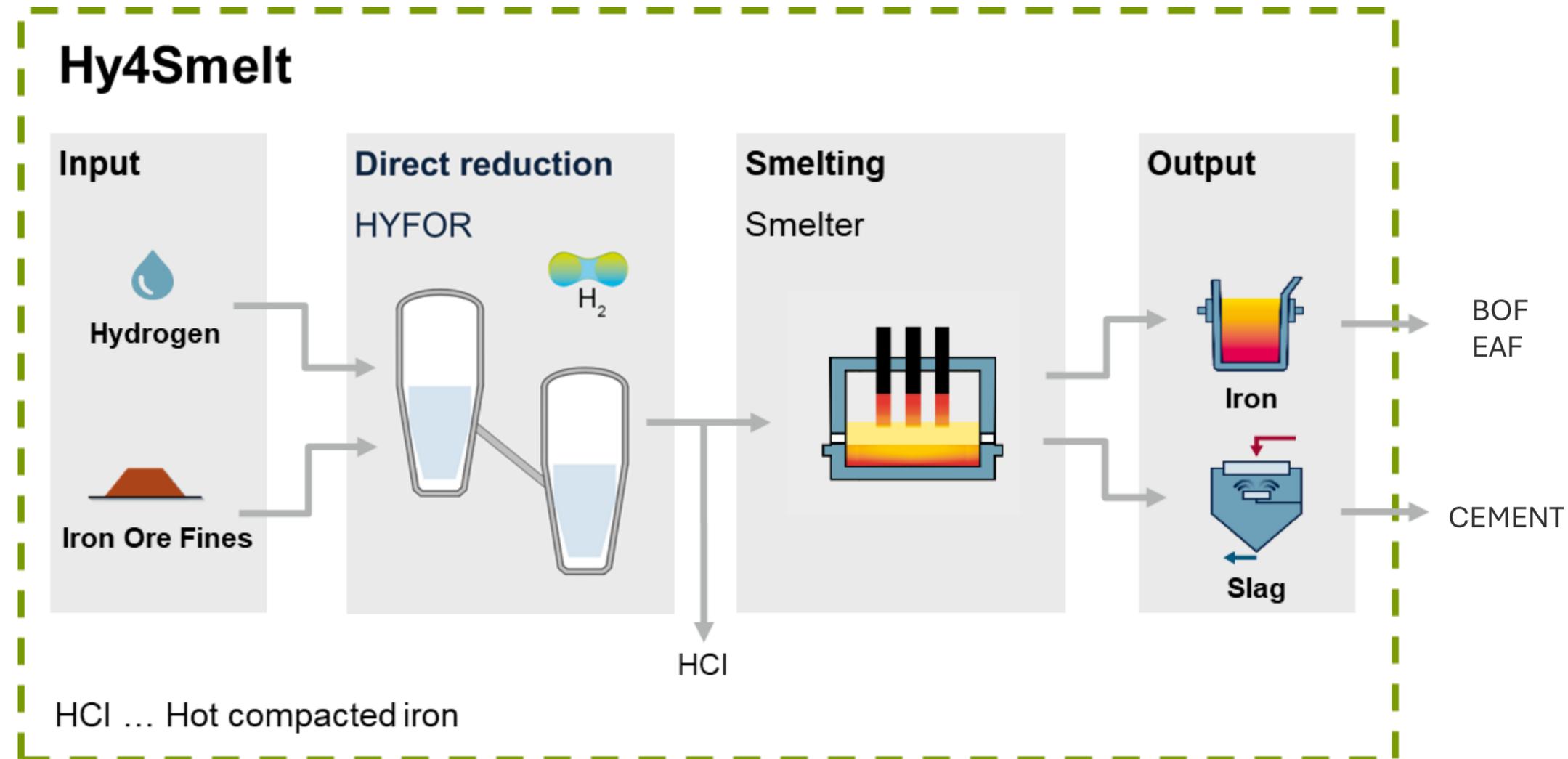


- **Majority of iron ores** for steel production are fine ores with **Fe < 65 %**
- **EAF** process is **not suitable** for melting DRI/HBI with **high slag quantities**
- **Iron ores with Fe > 65 %** will not be able to replace low/medium grade ores in the future
- **Electric smelting furnace (Smelter)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

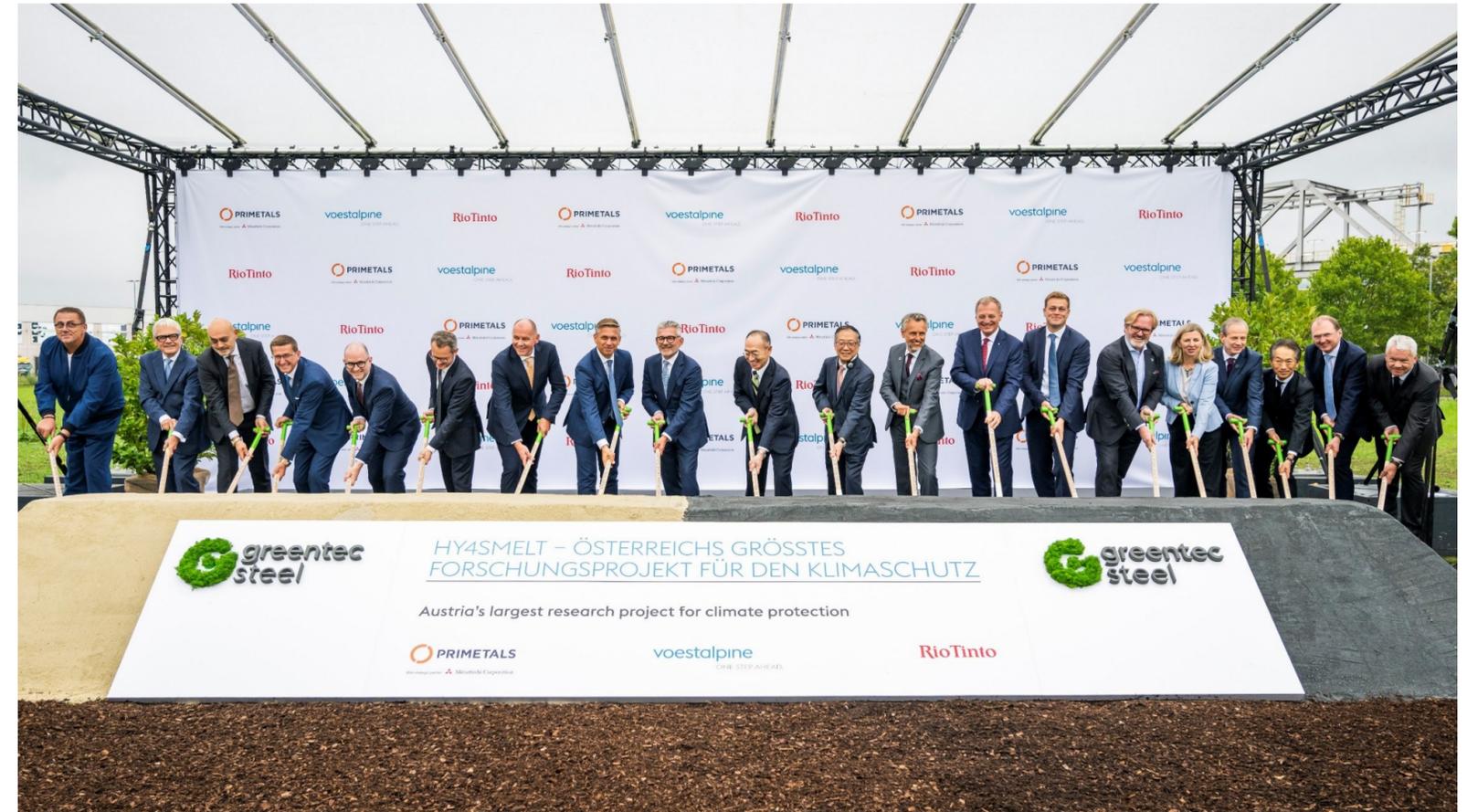
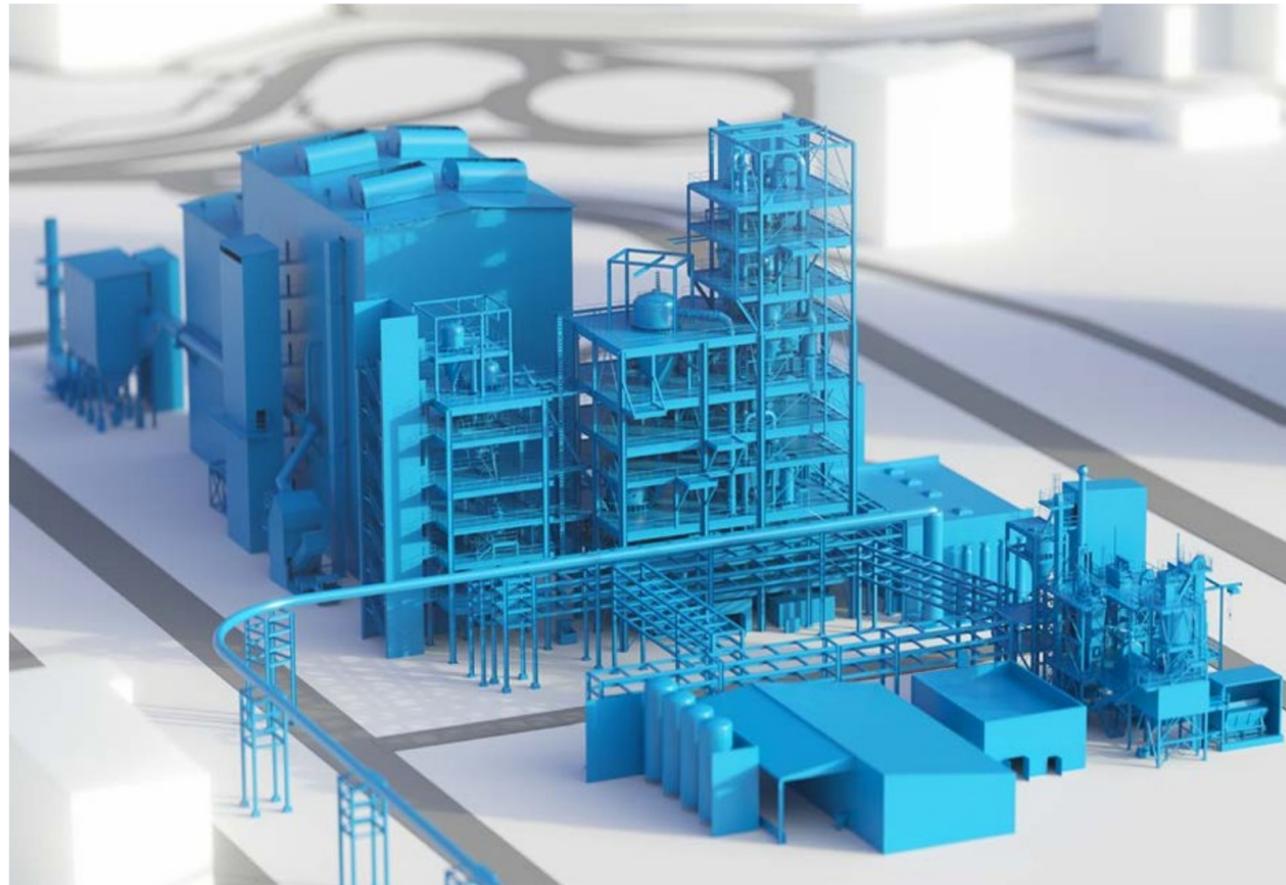
Source: Hy4Smelt Consortium, Mitsubishi Corporation

# Why Hy4Smelt?

- 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 metalics** for downstream EAF and BOF process by HCl, 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



# Demonstration plant for green hot metal



Iron ore **2 – 3 t/h**  
 Hydrogen **1.200 m<sup>3</sup>/h**  
 Hot metal **1.5 – 2.5 t/h**  
 Slag **< 1 t/h**

Location **voestalpine Linz site**

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

Groundbreaking Hy4Smelt 2025-09-25

 Federal Ministry Innovation, Mobility and Infrastructure Republic of Austria  Federal Ministry Economy, Energy and Tourism Republic of Austria

 Co-funded by the European Union

# Flow sheet demonstration plant

## Main process data

Productivity: 2 – 3 t/h Iron ore feed

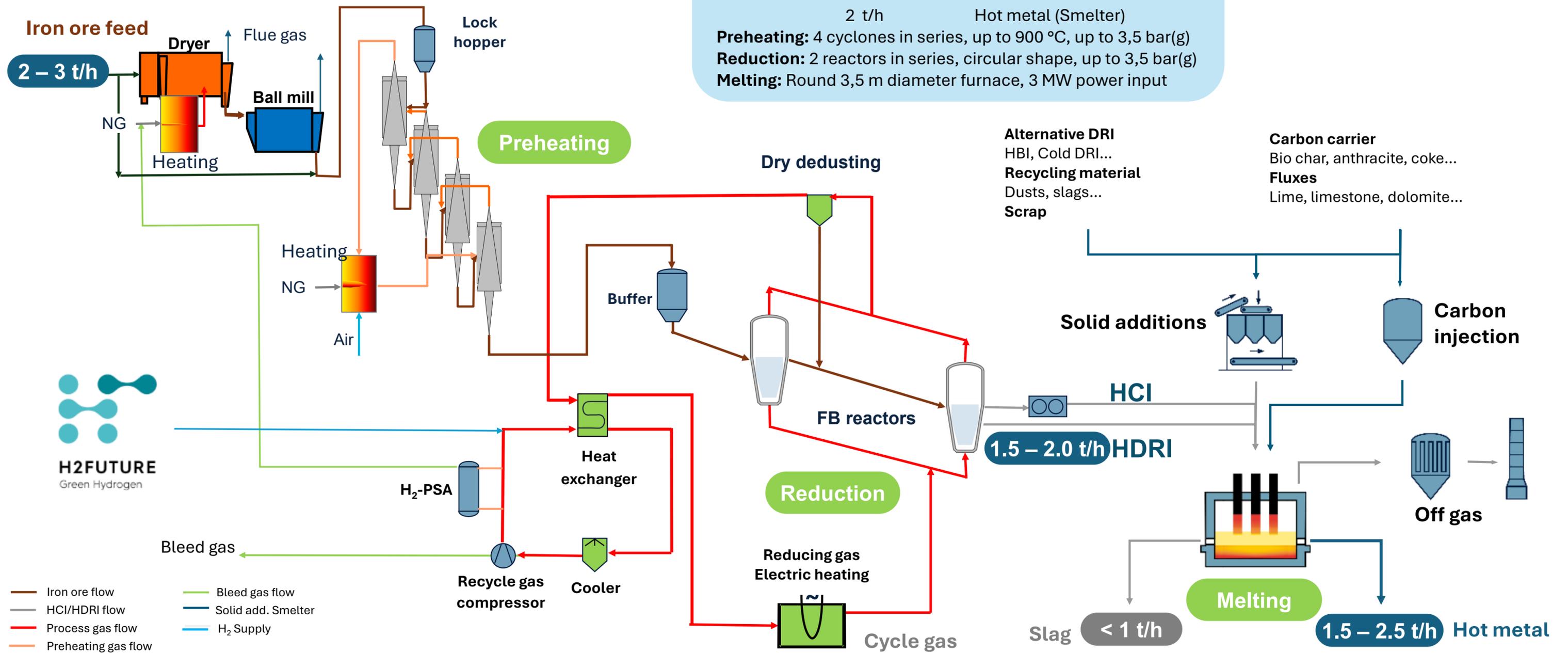
1.5 – 2 t/h DRI (HYFOR)

2 t/h Hot metal (Smelter)

**Preheating:** 4 cyclones in series, up to 900 °C, up to 3,5 bar(g)

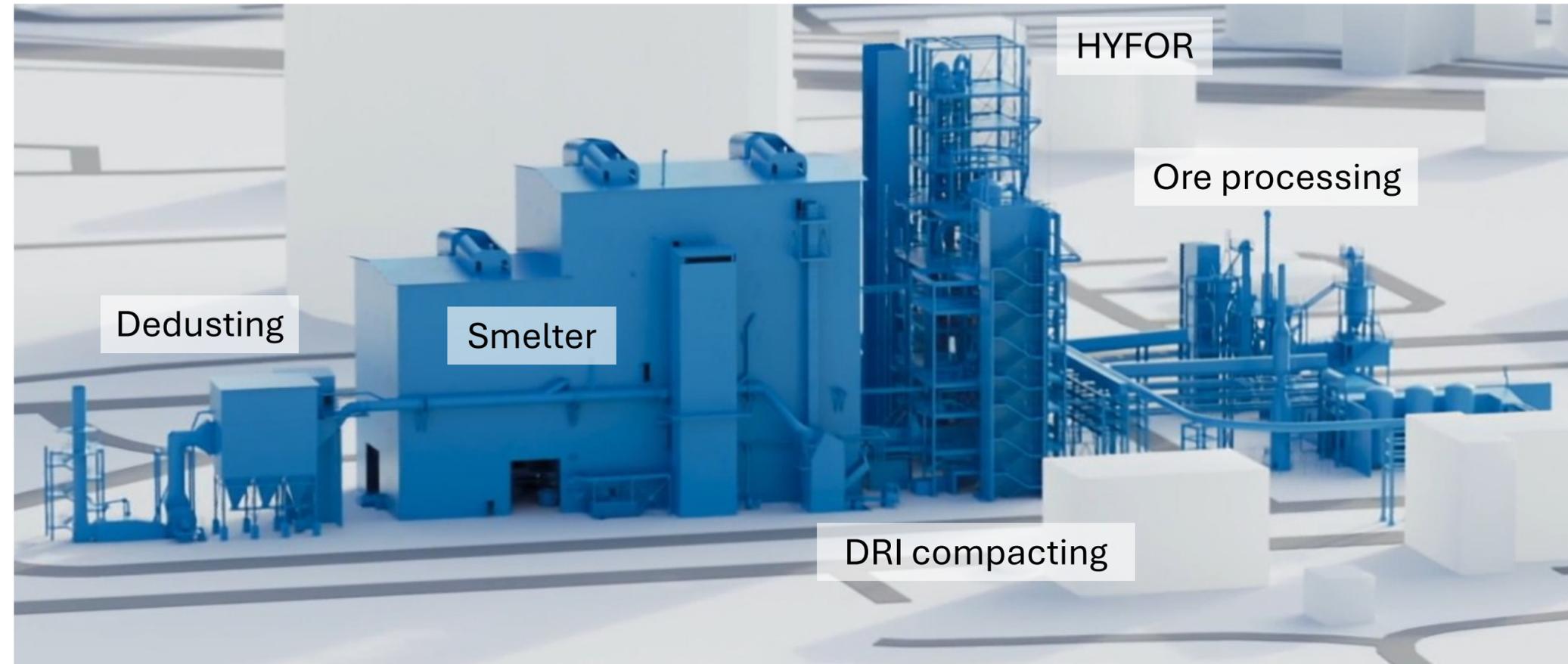
**Reduction:** 2 reactors in series, circular shape, up to 3,5 bar(g)

**Melting:** Round 3,5 m diameter furnace, 3 MW power input

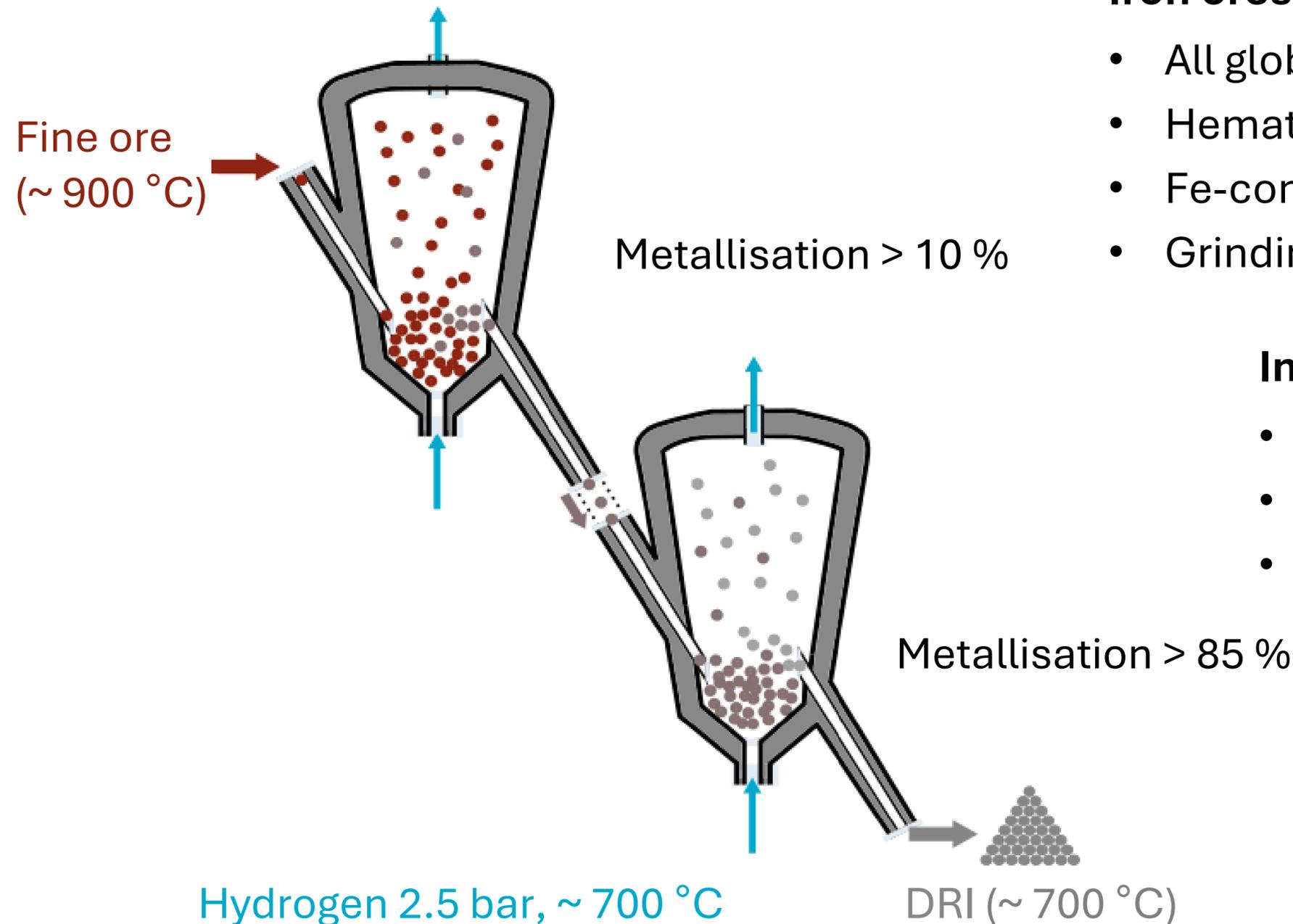


# Key performance indicators for demonstration plant

- Reduction with **100 % H<sub>2</sub>** at > 75 % H<sub>2</sub> utilization
- **Metallization up to 93 %** with solid losses < 0.1 %
- Demonstration of up to **100 %** replacement of fossil carbon with **biochar**
- **Hot metal carburization of > 3 %** with < 1 % FeO remaining in slag
- **Glass content** of granulated slag > 85 %
- Demonstration of **reduction of scope 1 CO<sub>2</sub> emission** of > 90 %



# Process design HYFOR reactor cascade



## Iron ores

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

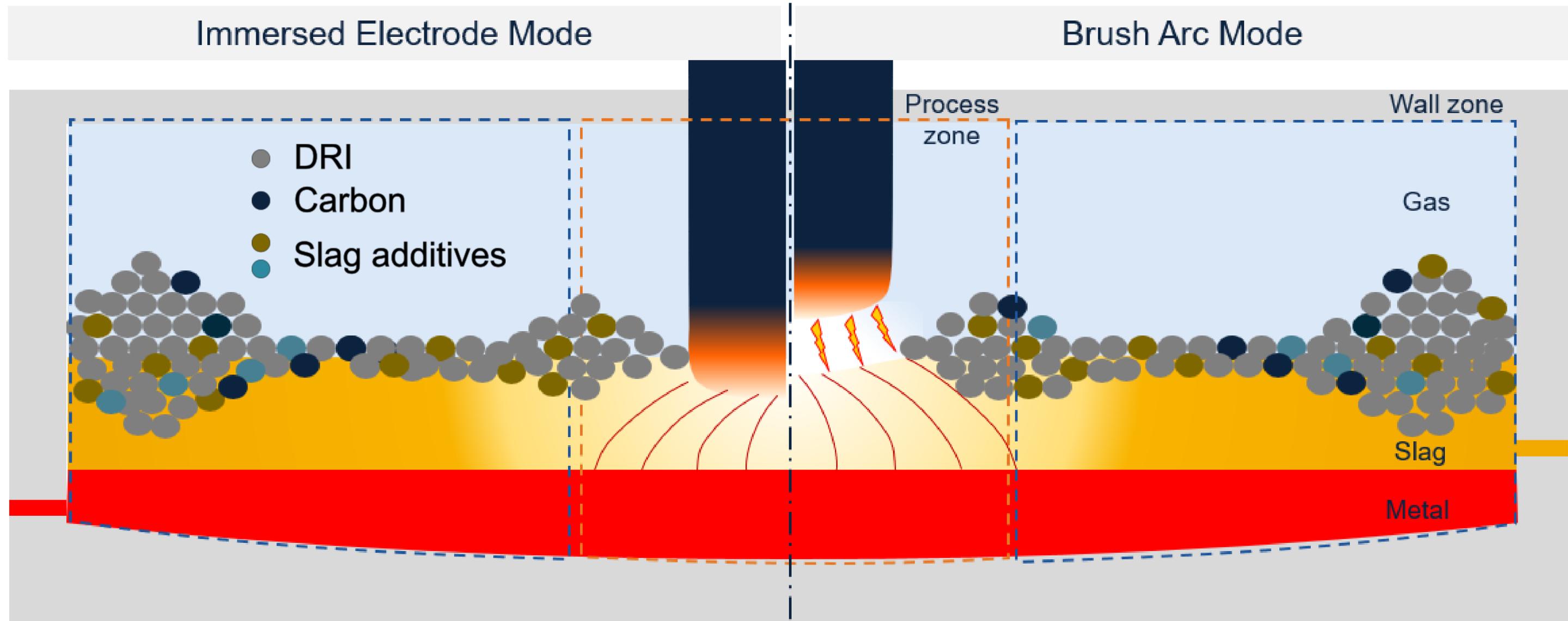
## Input design parameters

- Ultrafine iron ores < 500  $\mu\text{m}$ : 2.3 – 3.8  $\text{t h}^{-1}$
- Calcined/oxidised to  $\text{FeO}/\text{Fe}_2\text{O}_3$
- Hydrogen: 1200 – 1500  $\text{Nm}^3\text{h}^{-1}$

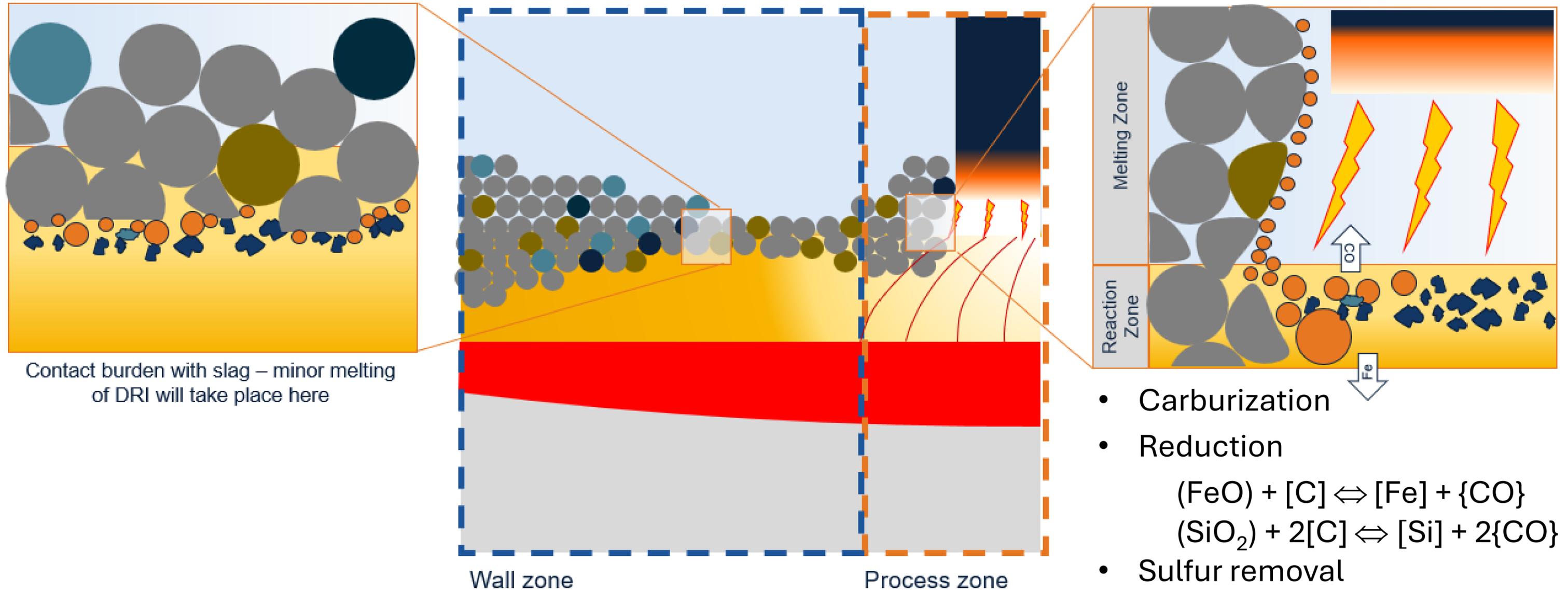
## Output design parameters

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

# Operation modes Smelter



# Simplified melting & reduction model Smelter



- Carburization
- Reduction
  - $(\text{FeO}) + [\text{C}] \rightleftharpoons [\text{Fe}] + \{\text{CO}\}$
  - $(\text{SiO}_2) + 2[\text{C}] \rightleftharpoons [\text{Si}] + 2\{\text{CO}\}$
- Sulfur removal
  - $[\text{S}] + (\text{CaO}) + [\text{C}] \rightleftharpoons (\text{CaS}) + \{\text{CO}\}$

Selected properties of investigated carbon carriers				
Property	Wood chips biochar	Wood coal pellets	Anthracite	Coke
Volatile matter VM <sup>db</sup> [wt.-%]	5.26	17.33	2.16	1.42
Ash A <sup>db</sup> [wt.-%]	2.72	1.78	4.96	10.88
Total sulphur S <sub>t</sub> <sup>db</sup> [wt.-%]	n.d.	0.01	0.22	0.77
Fixed carbon C <sub>fix</sub> <sup>db</sup> [wt.-%] **	92.02	80.89	92.88	87.70
Specific surface area (SSA) by N <sub>2</sub> -BET [m <sup>2</sup> /g]	273.21	1.23	9.07	2.54

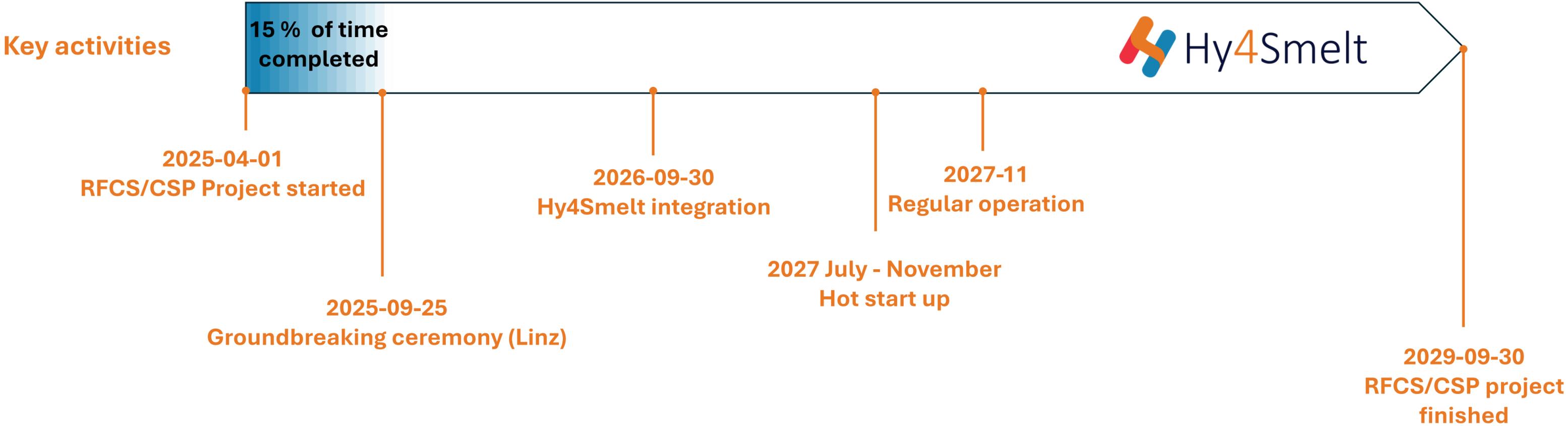
db .... dry basis; n.d.....not detected; \*\* calculated by equation,  $C_{fix}^{db} [wt.-%] = 100 - (VM - A)$

- Ongoing investigation of **reduction and carburisation behaviour**
- **Biochar** as promising **alternative to fossil carbon**
- Structural properties of **coke not required** in Smelter
- **Biochar demand** Smelter is **not comparable with BF** process (< 20 %)
- **Market for biochar is not yet developed** in Europe in large scale

# Hy4Smelt - Where are we now and what comes next?



Calendar year	2025			2026				2027				2028				2029		
	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3



Source: Hy4Smelt Grant Agreement (proposal)

# RFCS/CSP Project consortium



Media supply  
Trial operation



Slag treatment for cement and construction sector



Hy4Smelt slag for replacement of granulated BF slag in cement



Reduction technology of iron ores



Engineering Hy4Smelt  
Trial operation



Grinding parameters slag



Process evaluation  
Trial operation



LCA modelling Hy4Smelt



Dissemination

# Funding strategy as a unique combination of Austrian and EU programs



**Funding in million EUR**

**CAPEX HYFOR-Part** funded by aws „Twin Transition“



22

Federal Ministry Innovation, Mobility and Infrastructure Republic of Austria

**CAPEX Smelter-Part** funded by KPC „Transformation of Industry“



30

Federal Ministry Economy, Energy and Tourism Republic of Austria

**R&D OPEX** funded by the European Union (RFCS Big Tickets)



18



**R&D Deployment** funded by EU Clean Hydrogen Partnership „HI2Valley“



1.4



# Construction site Linz (AT) 2025-10-28, 10:00 h



## Link to Hy4Smelt Video



- [Net-Zero CO2-Emissionen bis 2050 - greentec steel](#)

**Thank you for your attention!**  
**Questions?**