# Hy4Smelt

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

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29.10.2024


ESTEP 2024
Annual Event

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European Steel Technology Platform
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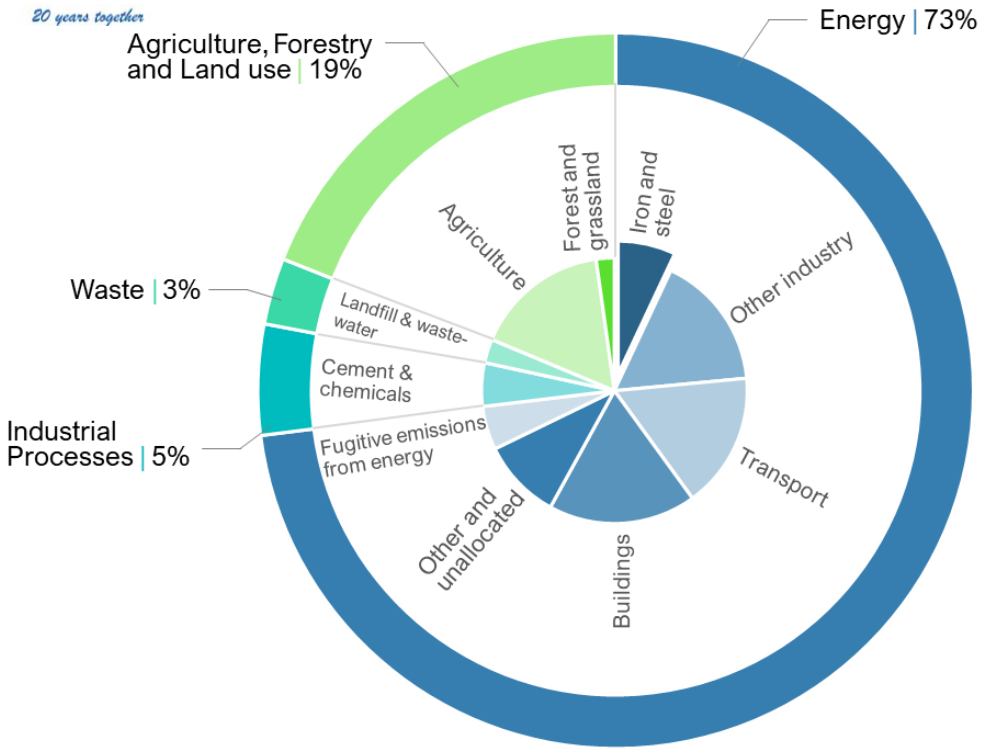
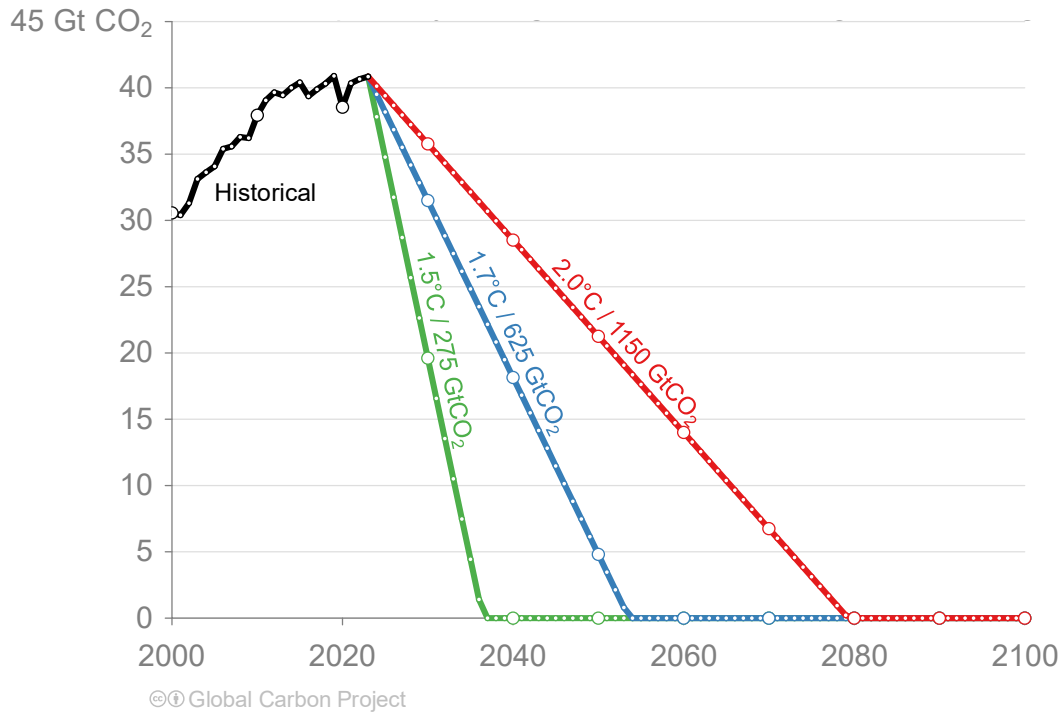
A CIRCULAR ECONOMY DRIVEN BY THE EUROPEAN STEEL

voestalpine
ONE STEP AHEAD.

PRIMETALS TECHNOLOGIES

# Climate goals - $CO_2$ emission scenarios



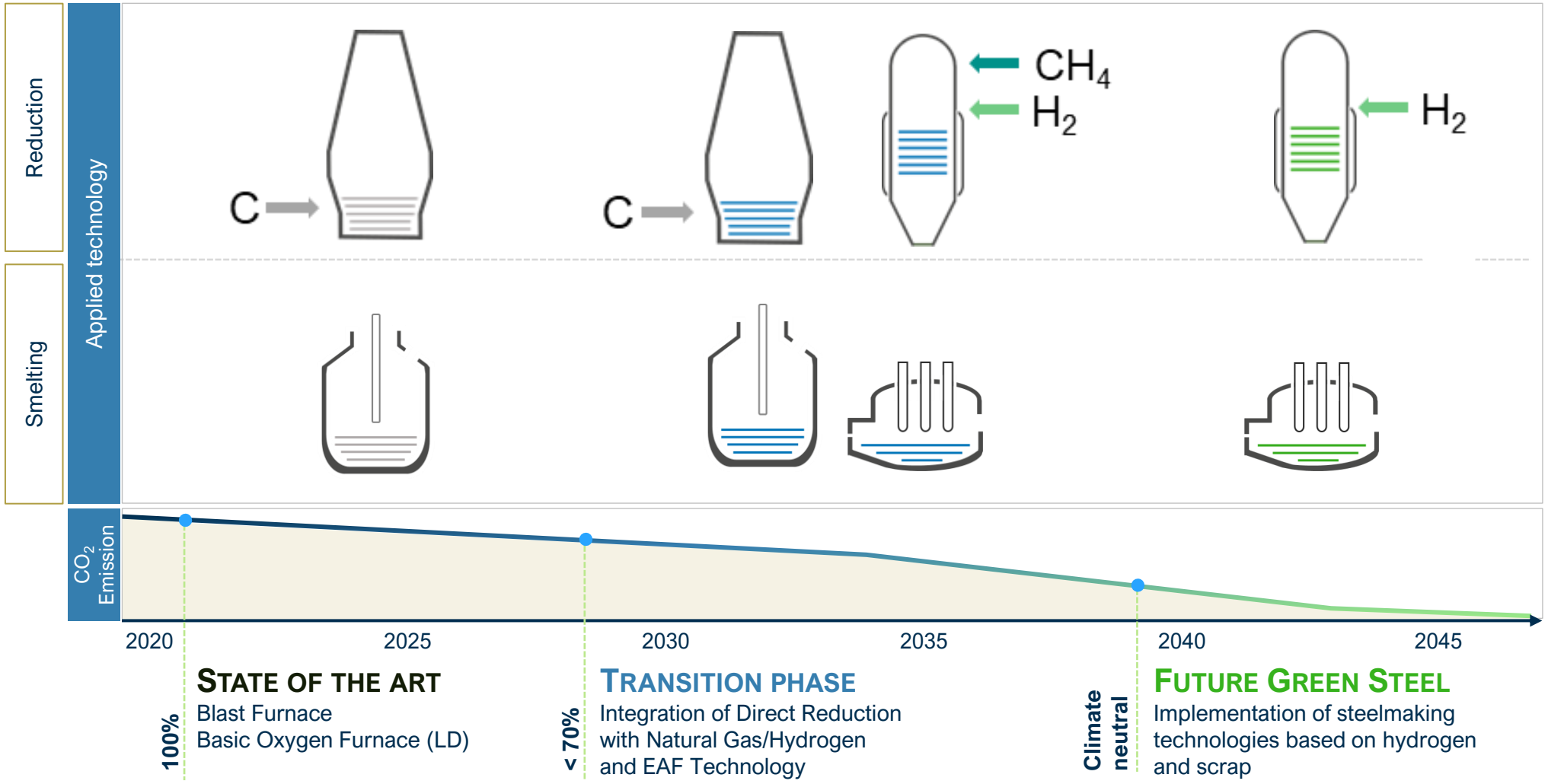

- **Iron and steel industry** accounts for approx. **7 % of global** anthropogenic **$CO_2$ emissions**
- Source of $CO_2$ in iron ore based steelmaking:

  **$Fe_2O_3 + 6CO = 2Fe + 3CO_2 + 3CO$**

  **$Fe_2O_3 + 6H_2 = 2Fe + 3H_2O + 3H_2$**

- **Global $CO_2$ reduction pathways** and **remaining carbon budgets** for achieving **COP 21 targets** (Paris 2015) at the end of the 21st century

# Transition process towards green steel



# Natural gas and hydrogen in steel production

- **HBI** from **DR plant** in Corpus Christi (TX) for the **first step of transformation** in voestalpine Linz (flat products) and voestalpine Donawitz (long products)

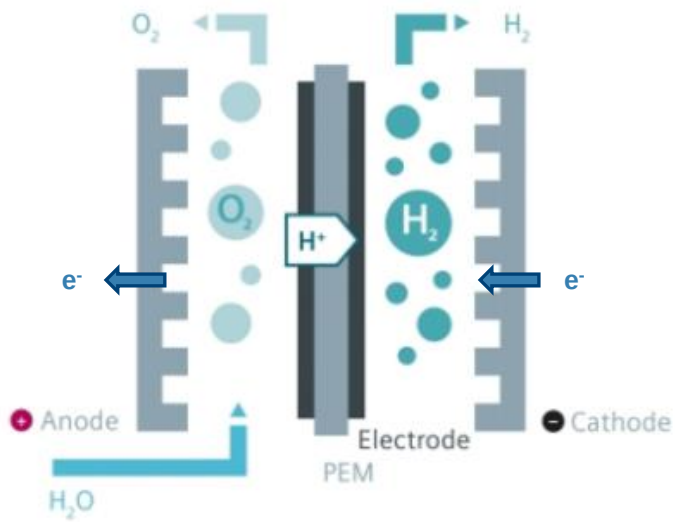
- 6 MW **PEM demonstration plant** for upscaling of electrolysis technology to **industrial production of green hydrogen** in Linz

# Climate neutral hydrogen production - H2Future

One of the biggest proton exchange membrane (PEM) electrolyser units in the world with 6 MW power and 1.200 $m^3/h$ $H_2$ production at voestalpine Stahl Linz site **for full scale demonstration of $H_2$ production and grid balancing**

- Ambitious efficiency targets at nominal power
- **$W_{el}$ = 48 - 51 kWh/kg**
- **$h_{System}$ = 82 % - 77 %**
- To demonstrate a **CAPEX of < 1.000 €/kW** for PEM technology

| | |
|---|---|
| Project Budget: | **17,8 M€** |
| Total EU Funding: | **12,0 M€ (70 % funding)** |
| Project Duration: | **5 years (2017-2021)** |




**PEM reactions**

**Anode:** $H_2O = 2H^+ + 0,5O_2 + 2e^-$

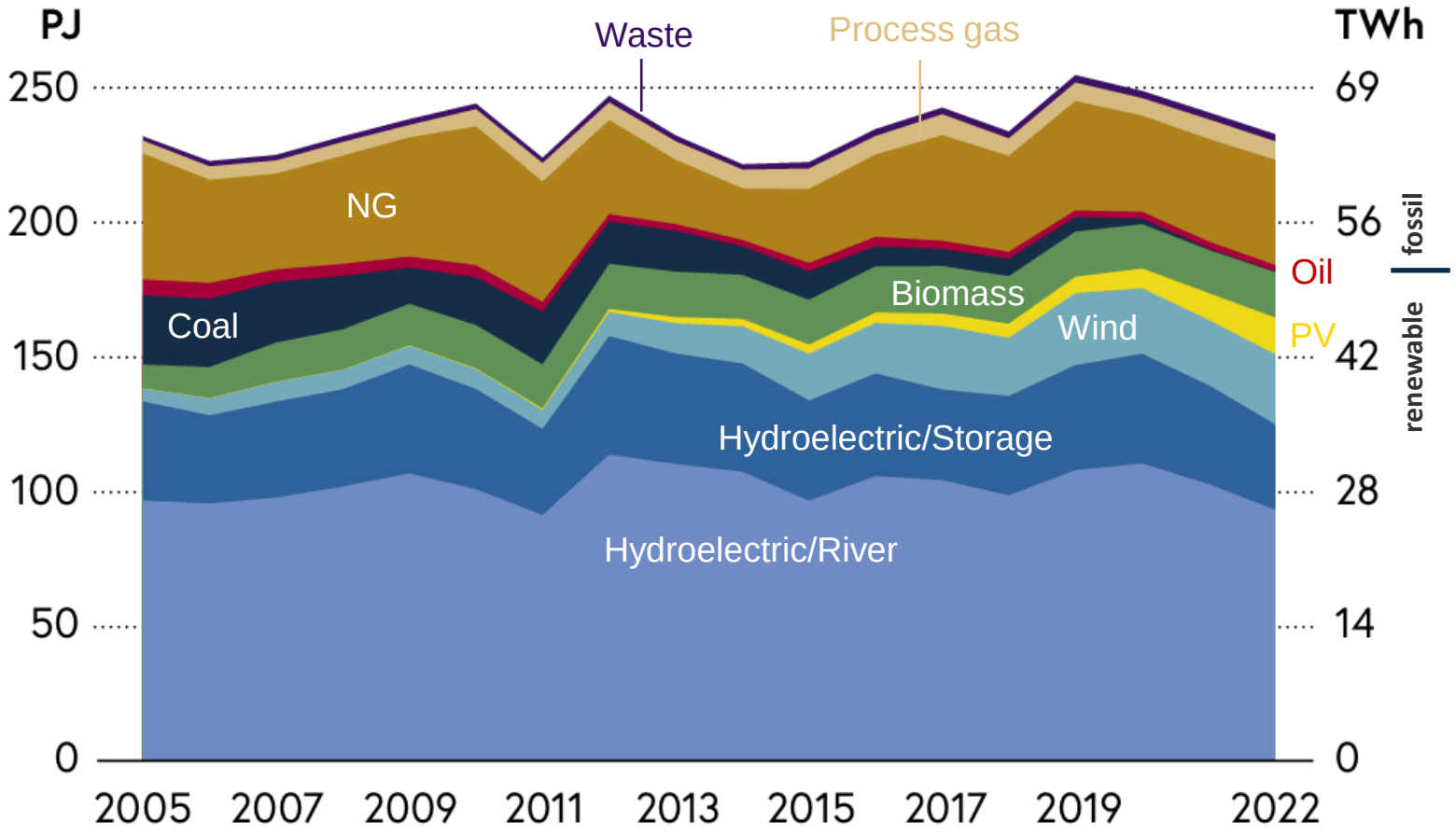
**Cathode:** $2H^+ + 2e^- = H_2$

# 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%**

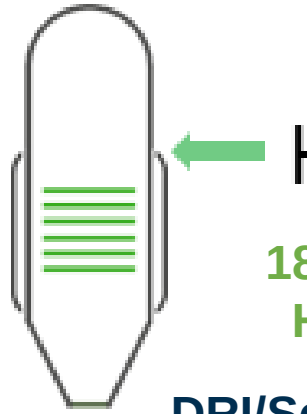
# Replacement of fossil energy - Climate neutral steelmaking

## Electric energy production in Austria



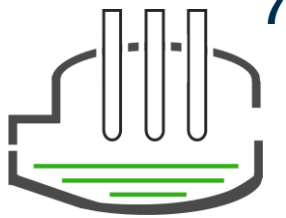

https://www.bmk.gv.at/themen/energie/publikationen/

## Electric energy demand for 6,0 million t steel per year




**18 $TWh_{el}$**
**$H_2$ DRI**

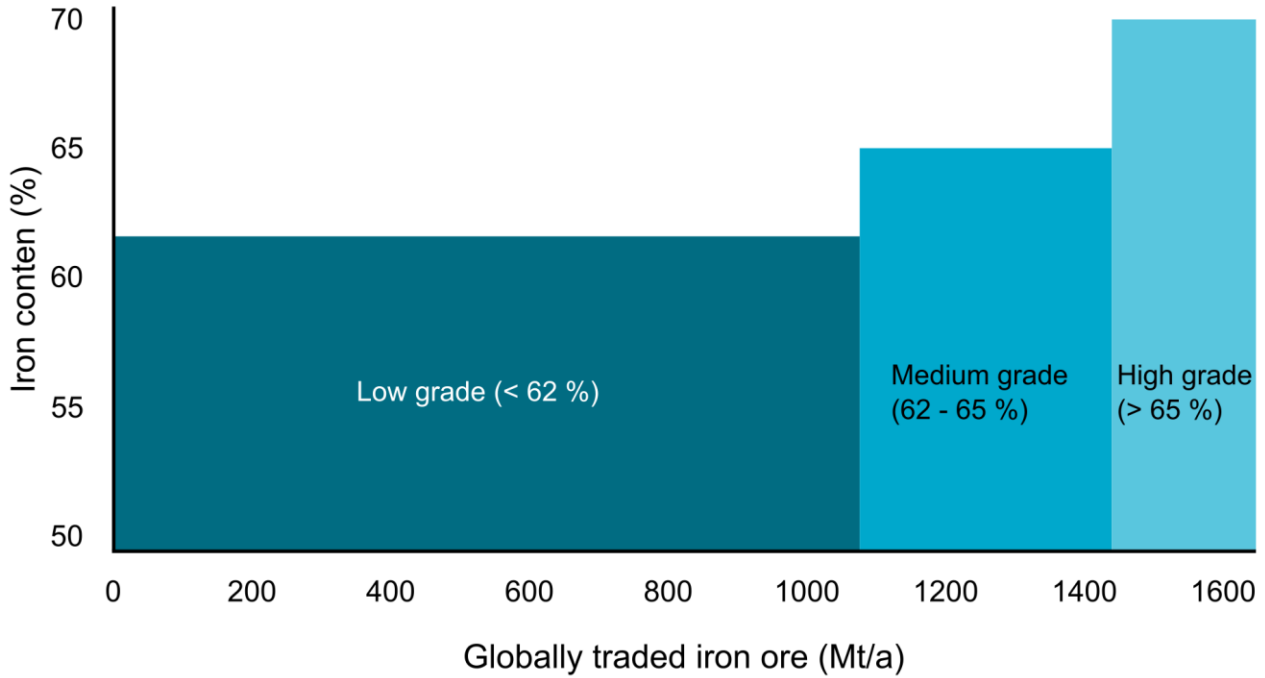
**DRI/Scrap 75/25**

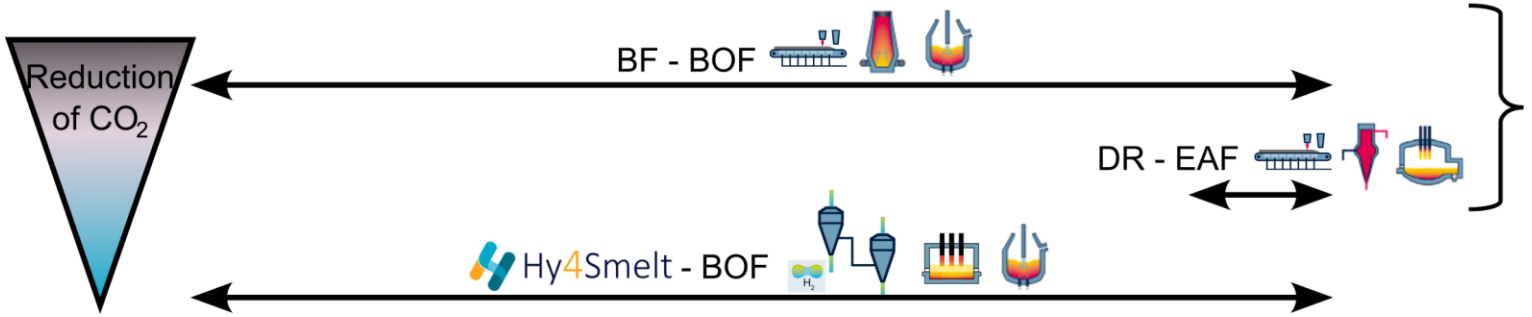


**2,5 $TWh_{el}$**
**75/25**

**7,5 $TWh_{el}$**
**Downstream processes**

# Availability of iron ore qualities on the world market



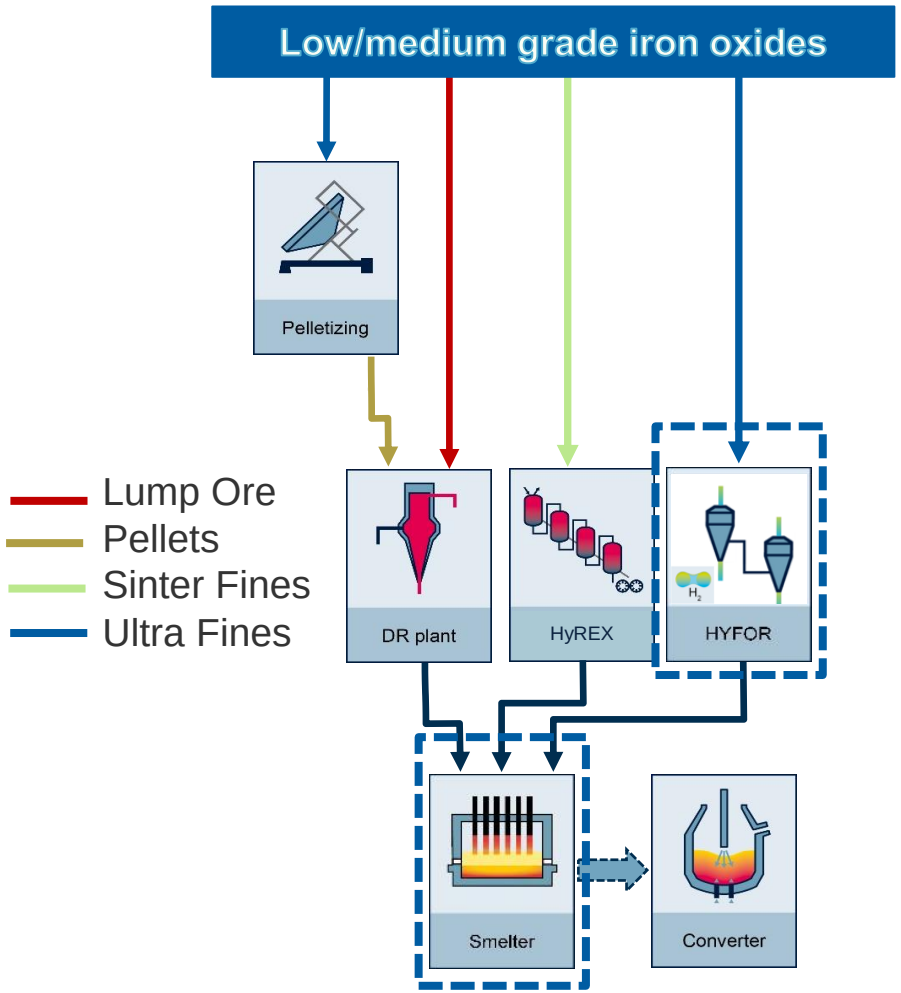




- **Majority of iron ores** available globally for steel production are fine ores with **Fe < 65 %**
- **EAF** process is **not suitable for** melting DRI/HBI with **high slag quantities** of up to 300 kg/t
- **Iron ores with Fe > 65 %** will not be able to replace low/medium grade ores in the future
- **Smelter in combination with direct reduction** enables slag separation for **LD and EAF process** in a similar way to the BF process

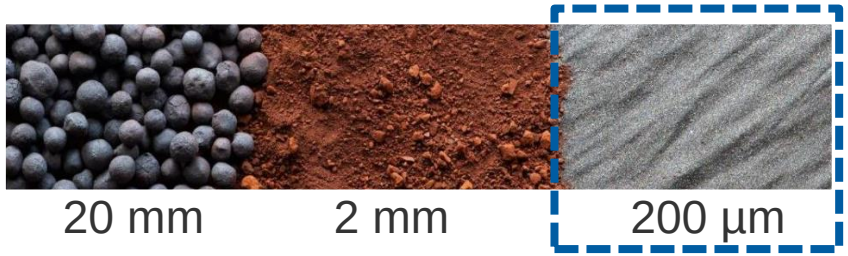
Agglomeration

No agglomeration

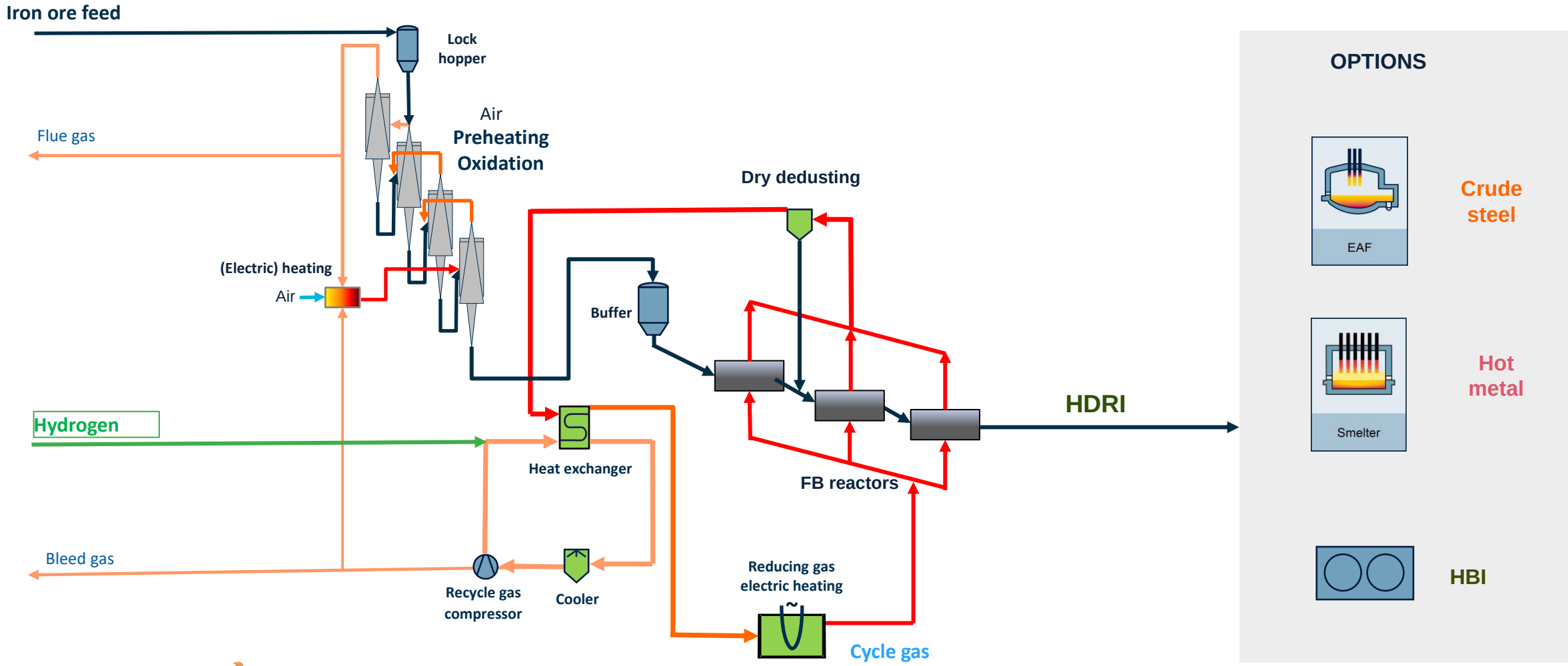
# Process routes for green hot metal




- **HYFOR** is the **world's first direct reduction process** for **ultrafine iron ores** that will not require any agglomeration steps like sintering or pelletizing
- A combination with the **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 **Hy4Smelt** produces **green hot metal** with **hydrogen** for the BOF steelmaking plant



# Hyfor® - Fluidized Bed Direct Reduction Process



# HYFOR process development

2015 → 2023

## Cold static fluidization tests

## Hot static reduction tests

## Cold continuous fluidization tests

## Hot continuous reduction tests

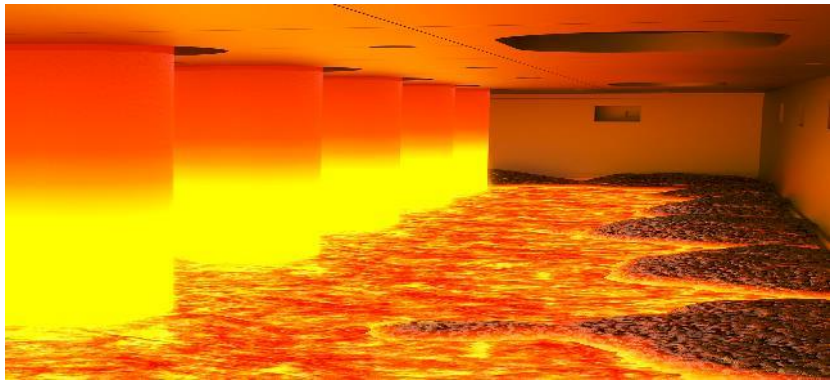
# HYFOR development – Pilot Plant at voestalpine Donawitz


- Test the performance of the **HYFOR reactor** and the **preheating/oxidation cyclone** under real operating conditions
- Direct reduction of **magnetite/hematite iron ore fines with $H_2$** in fluidized bed reactor at **700 °C** up to a **metallization degree of 97 %**
- Typical grain size: **100 % < 150 µm**
  Max. grain size: < 500 µm (up to 1 mm possible)
- **Batch operation** with 800 kg ultrafine iron ore is equal to **200 kg DRI per hour**
- **Pilot plant at voestalpine Donawitz site** as technical basis for next development phase

# Smelter process

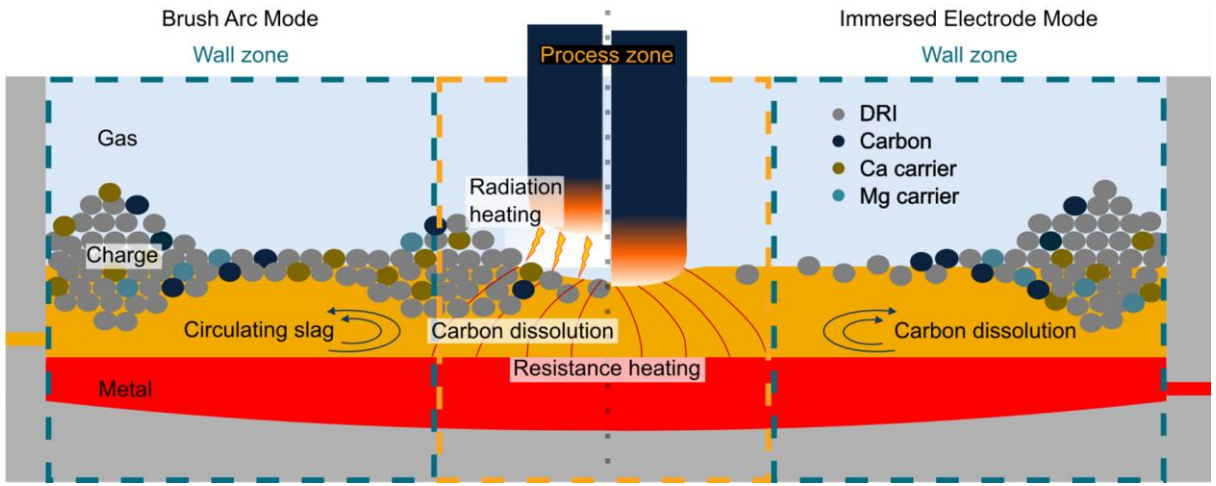
- **DRI is molten, final reduction takes place** and an adjustment of the iron (carbon level) and slag (basicity, MgO-level)
  - Iron from the Smelter go the steel plant
  - Slag is granulated and used in cement industry
  - High calorific off-gas as substitute for natural gas
- Due to the **reducing atmosphere inside the Smelter**, the Smelter is well designed to **process other iron oxide containing materials from steel production** such as dusts, mill scale or slags to improve the **circularity of the production process**
- For the **Smelter** in large scale ironmaking **no reference plants exists yet**; however, principles were tested and verified by simulations, in the laboratory and on a modified furnace in the hundred kg scale

Cross section of a Smelter



Inside a Smelter

# Metallurgical tasks for Smelter




**Targets for Smelter operation:**

- Hot metal from C-free DRI/scrap for direct use in BOF or EAF with flexibility in C-content up to 4,5 %
- Smelter slag comparable with granulated BF slag for cement sector with FeO-content < 1 %

**Influence factors to reach quality targets:**

- Addition of C-carriers, slag formers, electrode position and power input

**Ways for addition of components:**

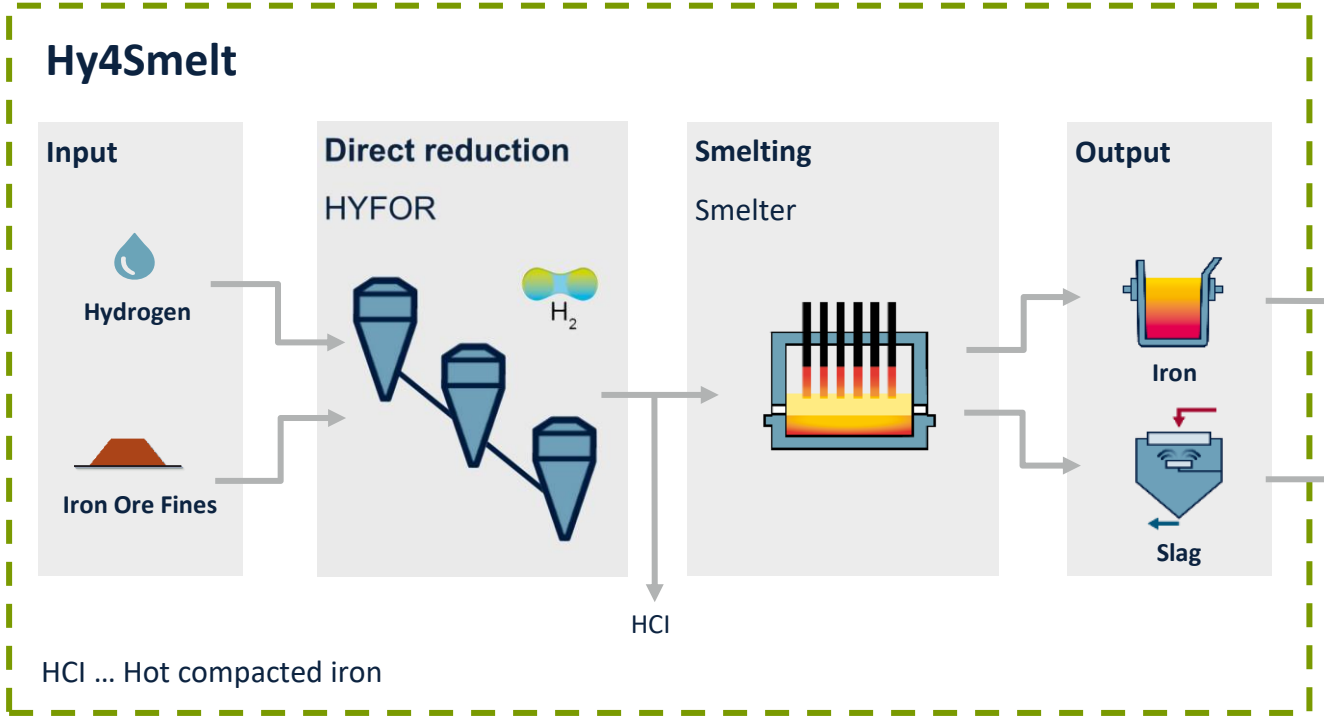
- Charging HCI conveyor (C/slag formers)
- Separate bin directly to the smelter (C)
- Direct injection smelter bath with lance (C)
- Option via DRI-feed bin before briquetting (C)

**Trial program:**

- Basic trials at ARP Leoben by K1-MET project, final confirmation by Hy4Smelt demonstration plant

# Hy4Smelt – Process Principles

- Hy4Smelt is a **groundbreaking new process** combining direct reduction (HYFOR) and electrified smelting under reducing conditions (Smelter)
  - In the **direct reduction step** the iron oxide in the fine iron ore is reduced to metallic iron using only green hydrogen
  - In the **smelting step** the direct reduced iron is smelted using green electricity, the melt is adjusted, and metal and slag are tapped separately from the furnace
- Hy4Smelt plant is capable to process a **wide range of iron ore fines** coming from different mines worldwide
- Green energy and bio-carbon in Hy4Smelt allows **for carbon neutral iron production**

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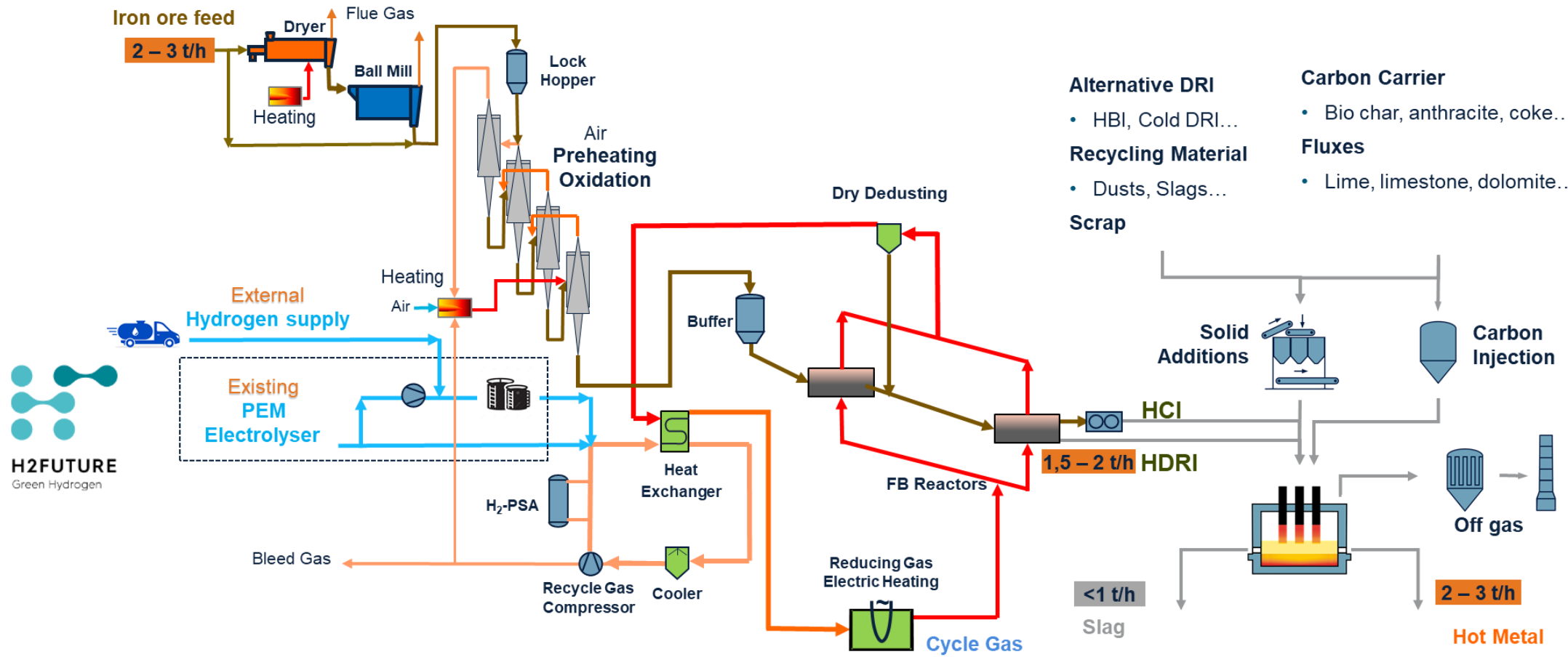
# Hy4Smelt Demonstration Plant – Overall Flowsheet

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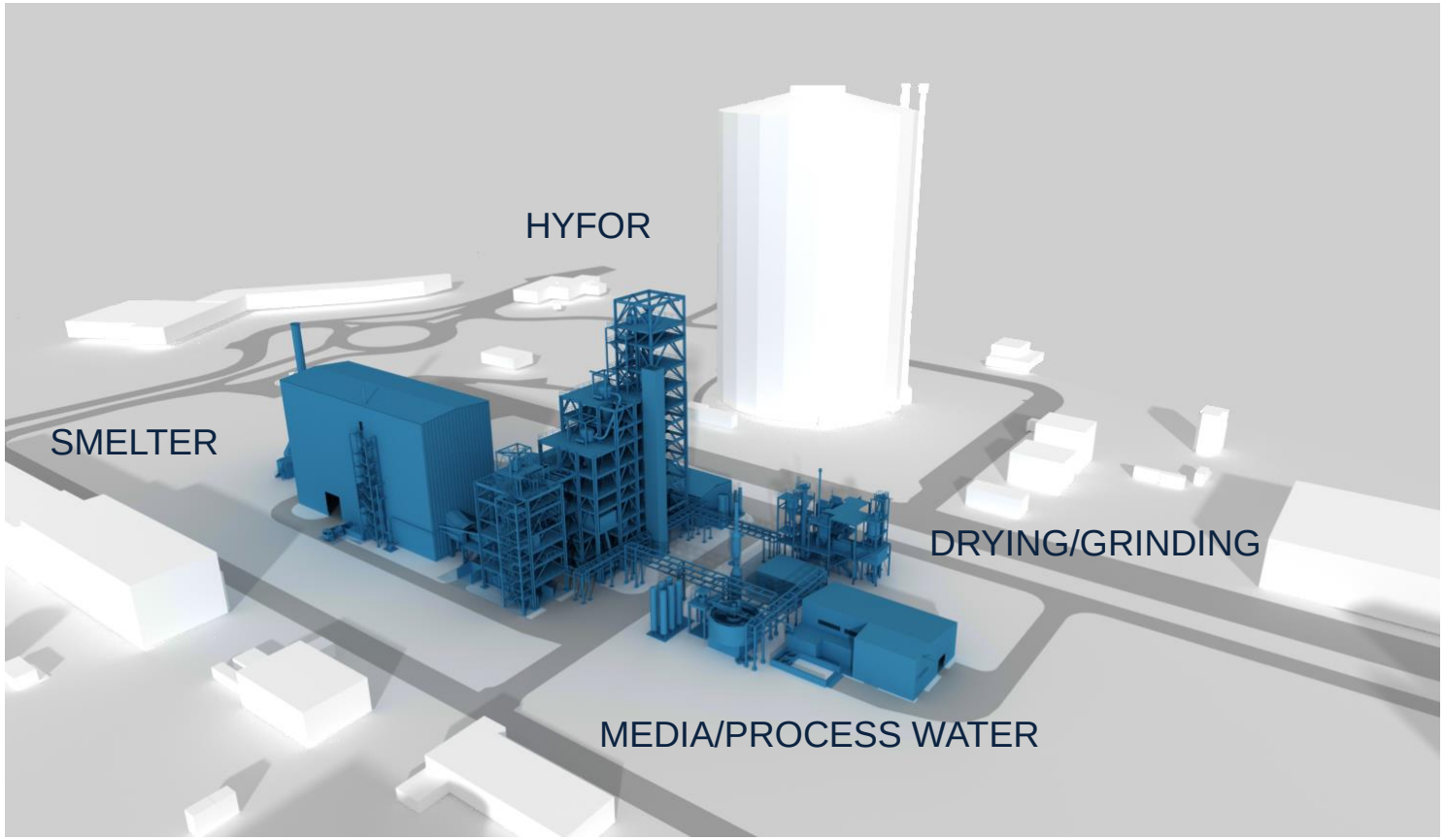
# Hy4Smelt - Basic design demonstration plant

## Hy4Smelt - demonstration plant

- Installation of **HYFOR, Smelter** and all required auxiliary facilities
- Designed for a maximum capacity of **3 t hot metal and 1 t slag per hour**
- **Continuous operation** from preheating iron ores to hot metal and slag
- **Flexible ore basis** – Utilization of multiple iron ore qualities (low- to high-grades, hematite to magnetite) **up to 3 t per hour**
- **Green metallics** – Reduction fully based on **green $H_2$ 1.500 $m^3$/h** and heating fully electrified
- **Carbon addition** – Based on biochar and other carbon carriers
- **Different feed mixes to Smelter** – DRI, HCI, HBI, scrap, and by-products
- **Autonomous** operation of **Smelter** part




Model of Hy4Smelt at voestalpine steel plant

# Funding Strategy Hy4Smelt Demonstration Plant

CAPEX Smelter-Part confirmed by KPC „Transformation of Industry“

CAPEX HYFOR-Part confirmed by „Twin Transition“

R&D-OPEX confirmed by RFCS/CSP Big tickets for Steel

H2 FOR GREEN STEEL

3rd INTERNATIONAL CONFERENCE

*meets*

A CIRCULAR ECONOMY DRIVEN BY THE EUROPEAN STEEL

ESTEP

# Hy4Smelt

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