PRIMETALS TECHNOLOGIES

# WSA - BREAKTHROUGH TECHNOLOGY CONFERENCE

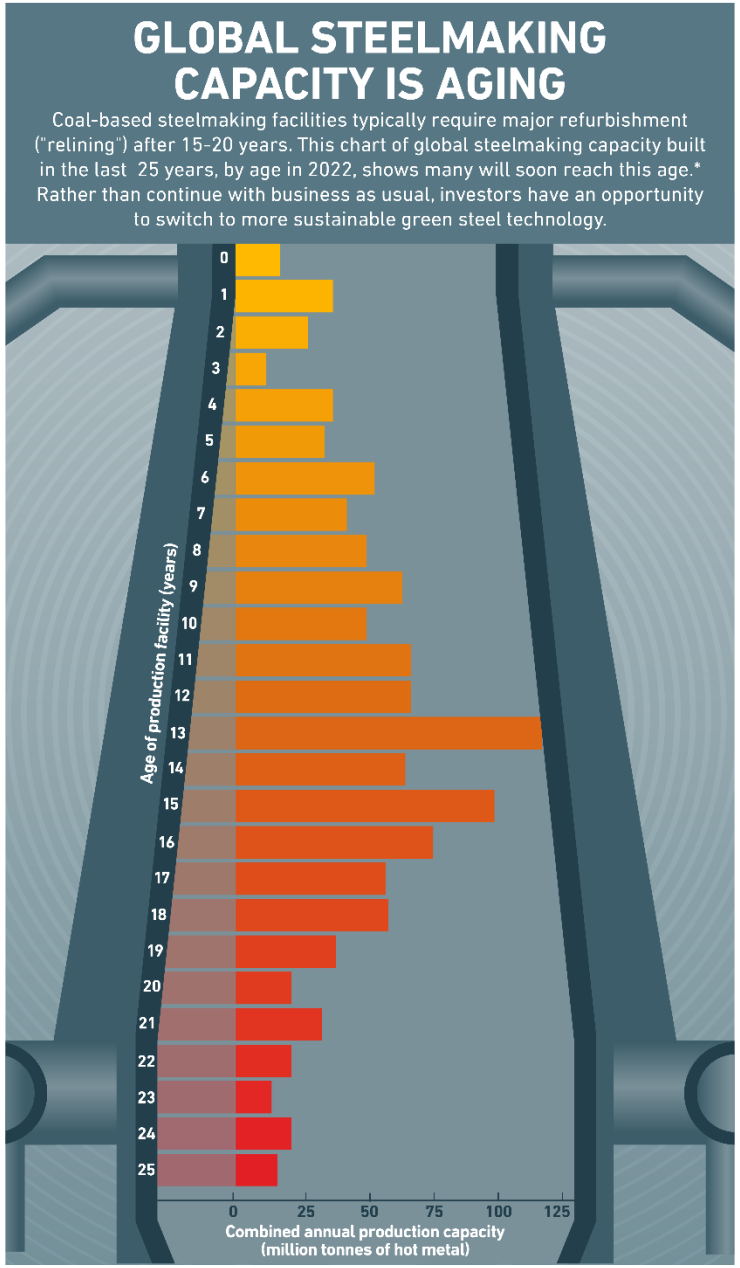
## DECEMBER 5-6, ABU DHABI

## GREEN STEEL IN MOTION – IRON FEEDSTOCK MEETS RENEWABLE ENERGY

Dr. Alexander Fleischanderl

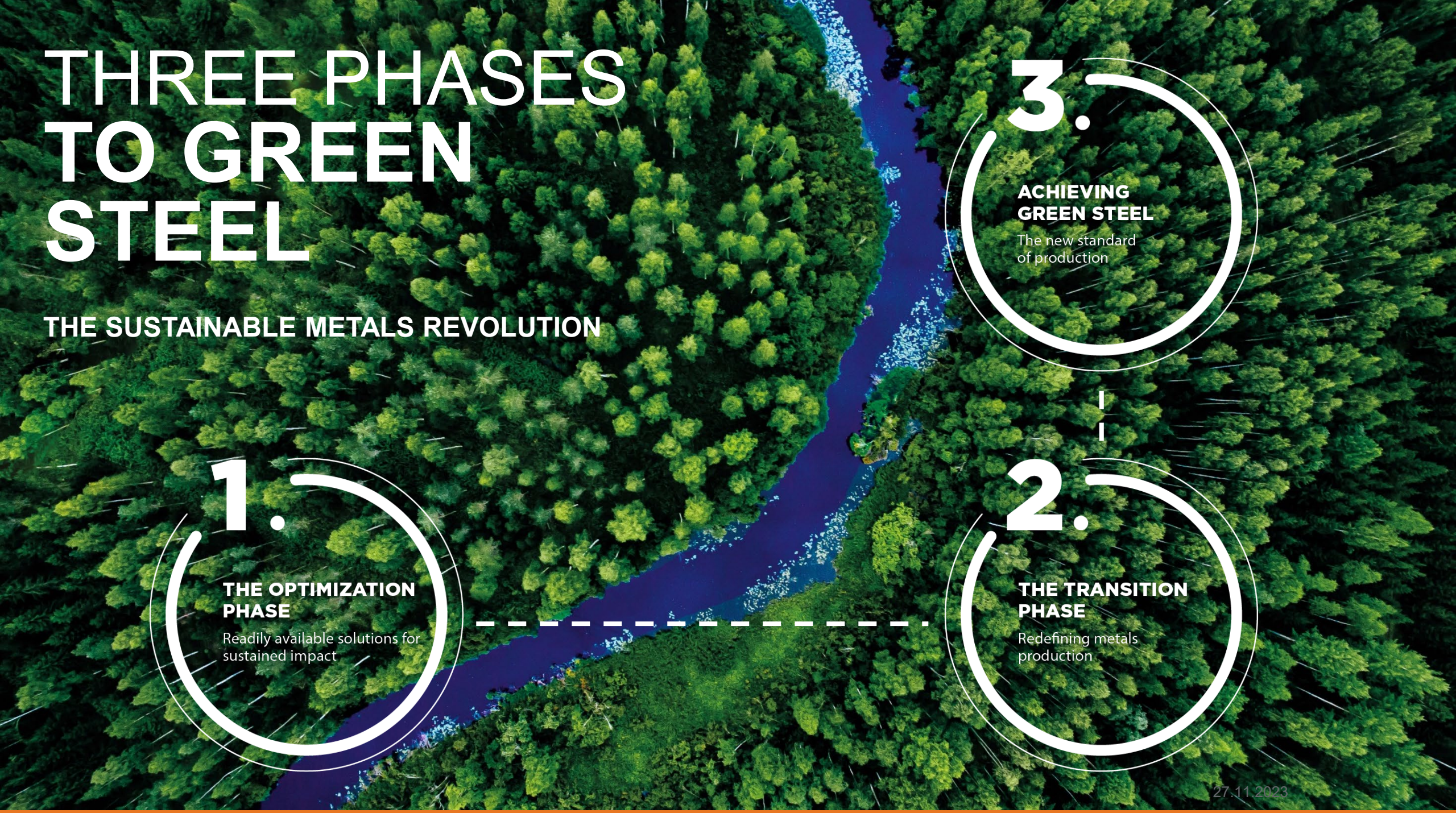
# Why this is a make-or-break decade

- 71% of blast furnaces will require major refurbishment ("relining") by 2030, according to International Renewable Energy Agency. The question is … what comes next?
- Investors must choose between refurbishing existing furnaces or switching to EAFs.
- Factors that determine to turn steel into the decade of green steel:
  - Penalties for $CO_2$: New ETS, CBAM
  - Renewable energy availability and price
  - Low-carbon hydrogen availability
  - Raw material quality, availability and price
  - Location (feasibility and skilled people)



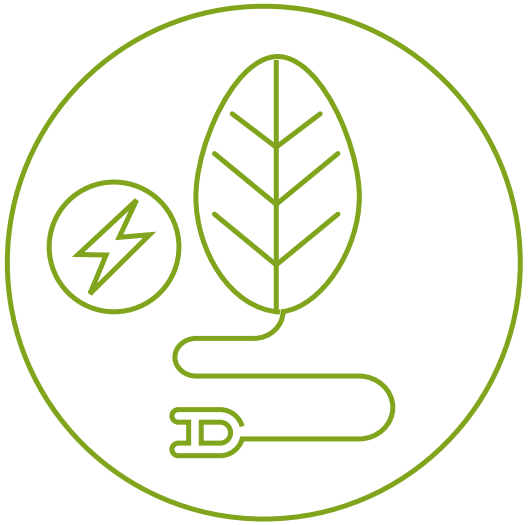
# THREE PHASES TO GREEN STEEL

## THE SUSTAINABLE METALS REVOLUTION



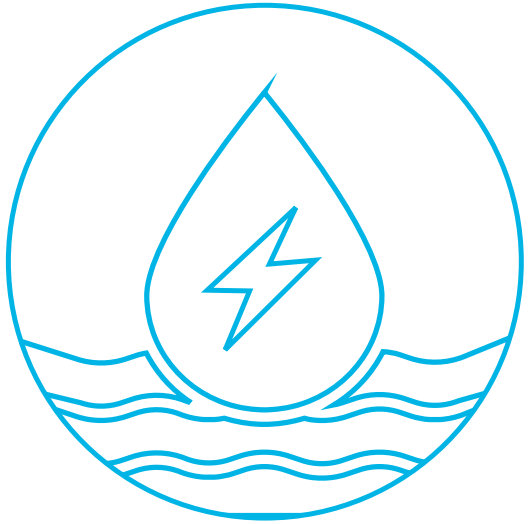

27.11.2023

# The pathways to achieve net-zero in the sector



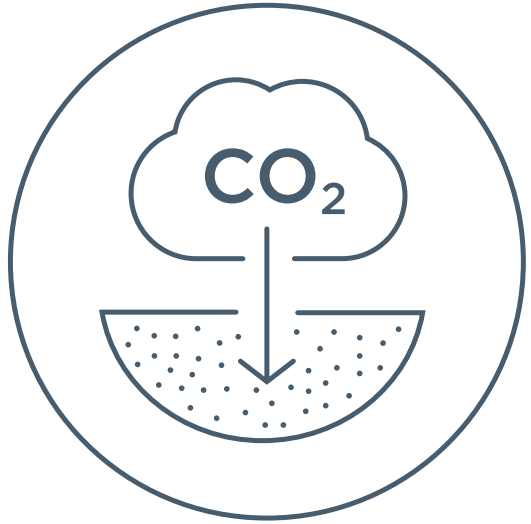
**Electrification of production**

- Expansion to clean, renewable energy to enable sustainable production processes
- Growing number of electric furnaces
- Produce the green hydrogen required to replace carbon-based reductants
- Direct electrolysis of steel, still in its infancy



**Carbon Direct Avoidance (CDA)**

- Stop the common practice of fossil-based reduction and move to hydrogen-based reduction
- Scaling-up and establishing a hydrogen eco-system

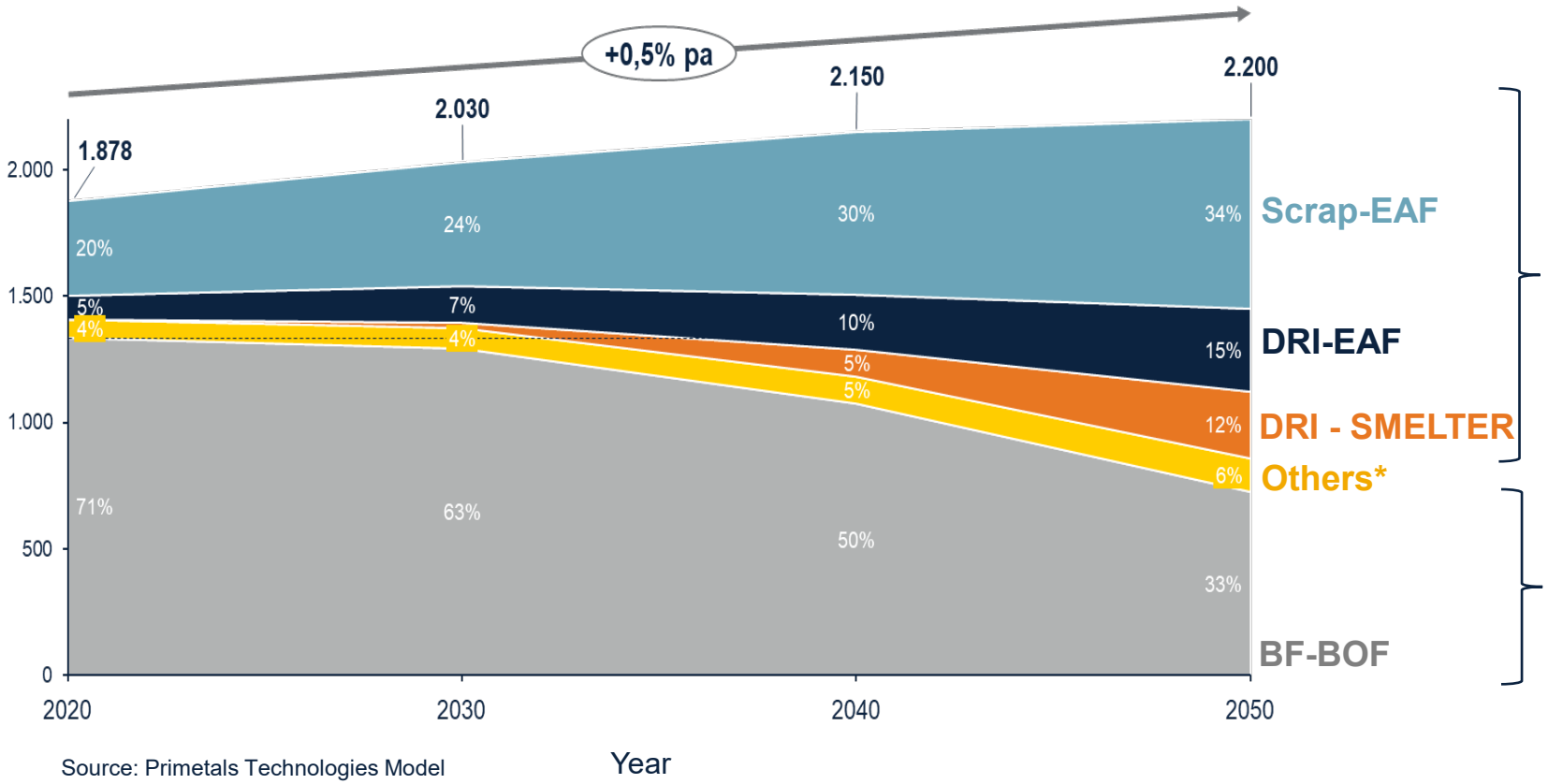



**Carbon Capture Usage & Storage (CCUS)**

- CCUS for long life-time assets in upstream ironmaking facilities in e.g., India, China
- Mitsubishi Heavy Industry's KM CDR amine scrubber-based capturing system: store or use
- LanzaTech Carbon Smart technology to lock-in carbon from industrial waste gasses

# The Scale for the Transition is Massive
# There is no technological silver bullet yet, but pathways are set

## Steel production [mtpy]



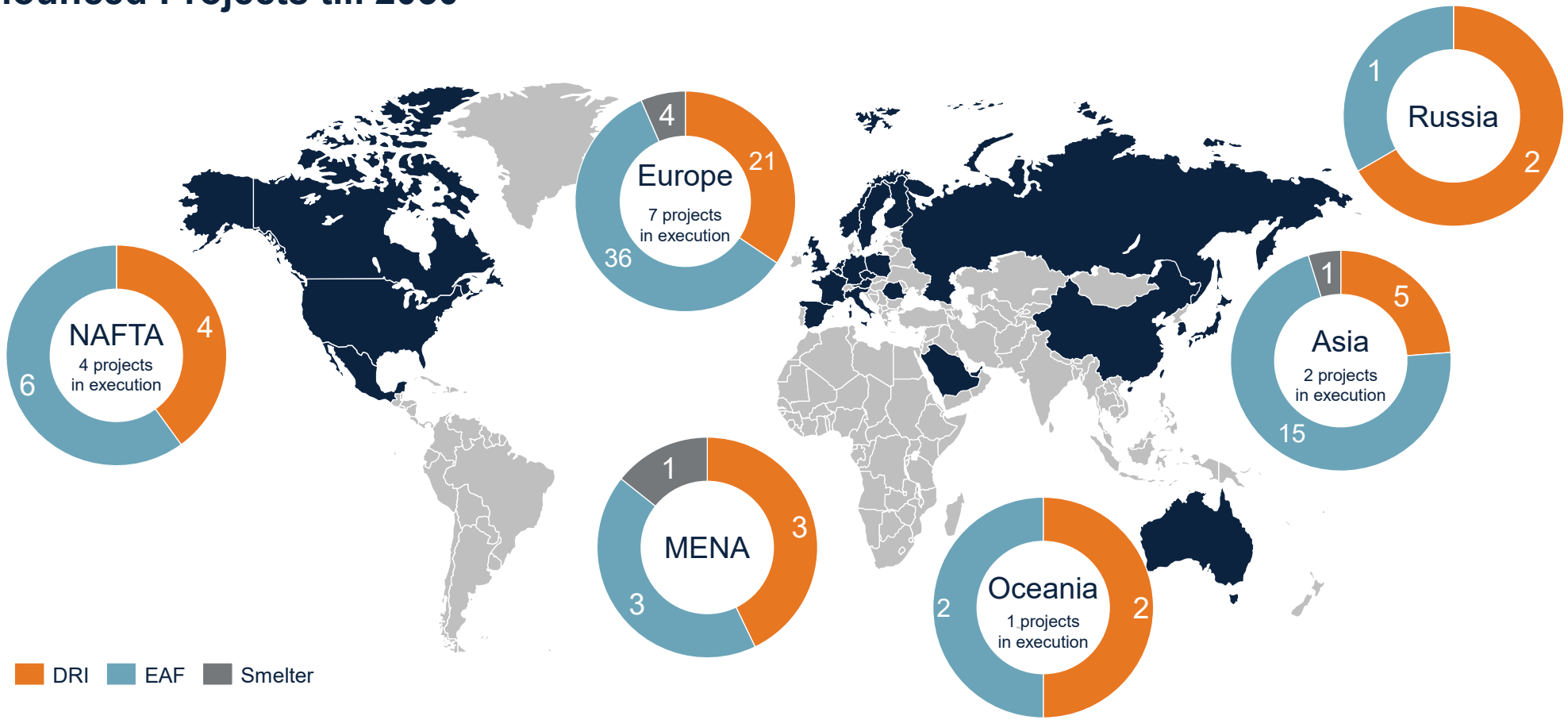

Source: Primetals Technologies Model

- Low Carbon technologies will more than double from currently 26% to over 60% of the total steel production by 2050.
- This represents over 850 million tons of additional low-carbon steel production by 2050.
- In addition to currently available technologies, new low carbon technologies will be required.
- BOF steel production will also be transformed away from coal-based BF technologies

- Steel produced from coal-based technologies will also be transformed by 2050 using CCS and other technologies such as hydrogen injection etc.

# Europe is most active in the industry transition based on DRI, EAF and Smelter. In total 37 DRI plants, 63 EAF and 6 Smelter are announced.

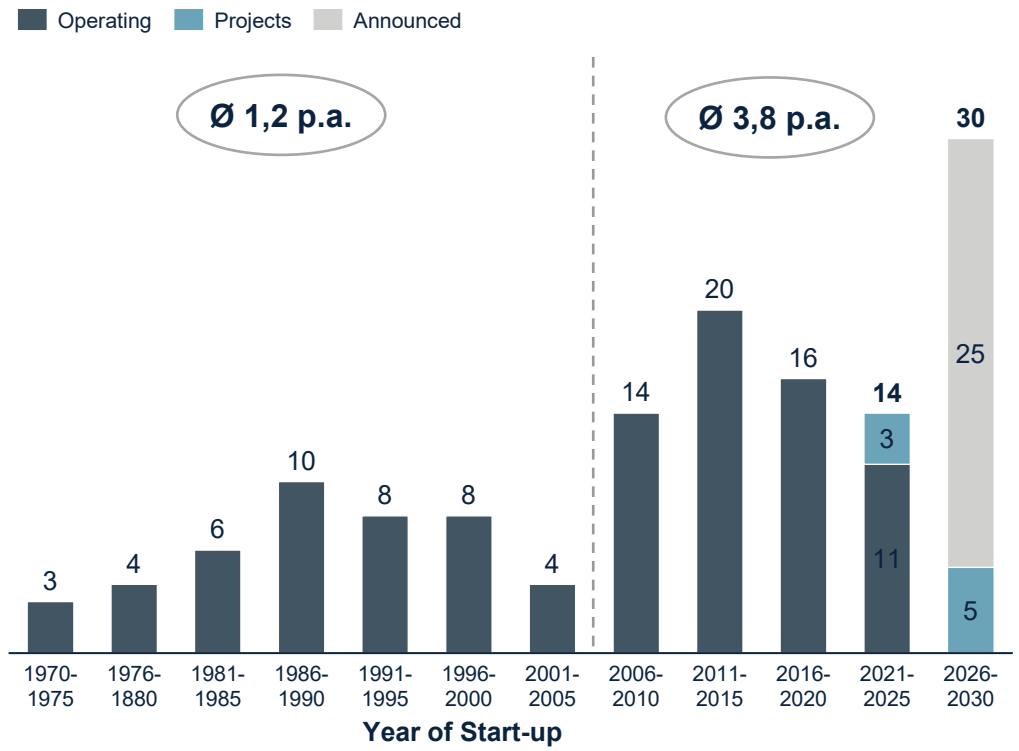
## Announced Projects till 2030



# Strong growth of DR plants are expected for the next 30-50 years

## Number of DR Plants operating and planned

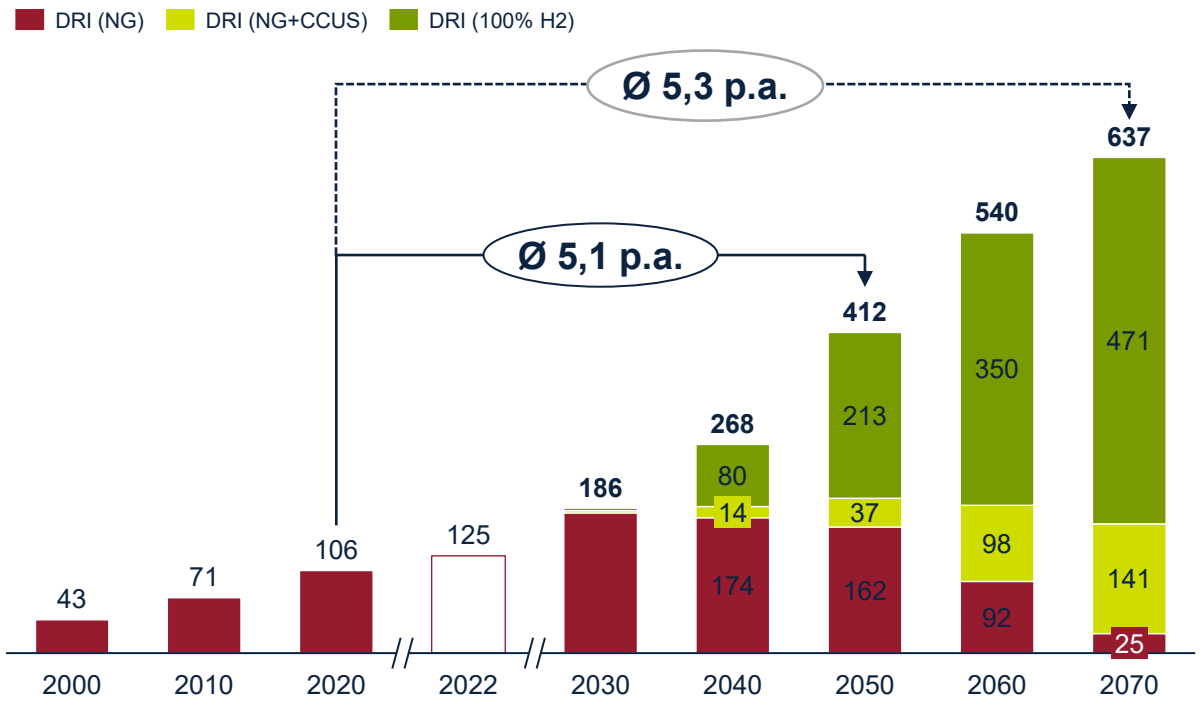
(Shaft Technology)




Source: BCG Plantfacts, PT

## DRI Production Forecast

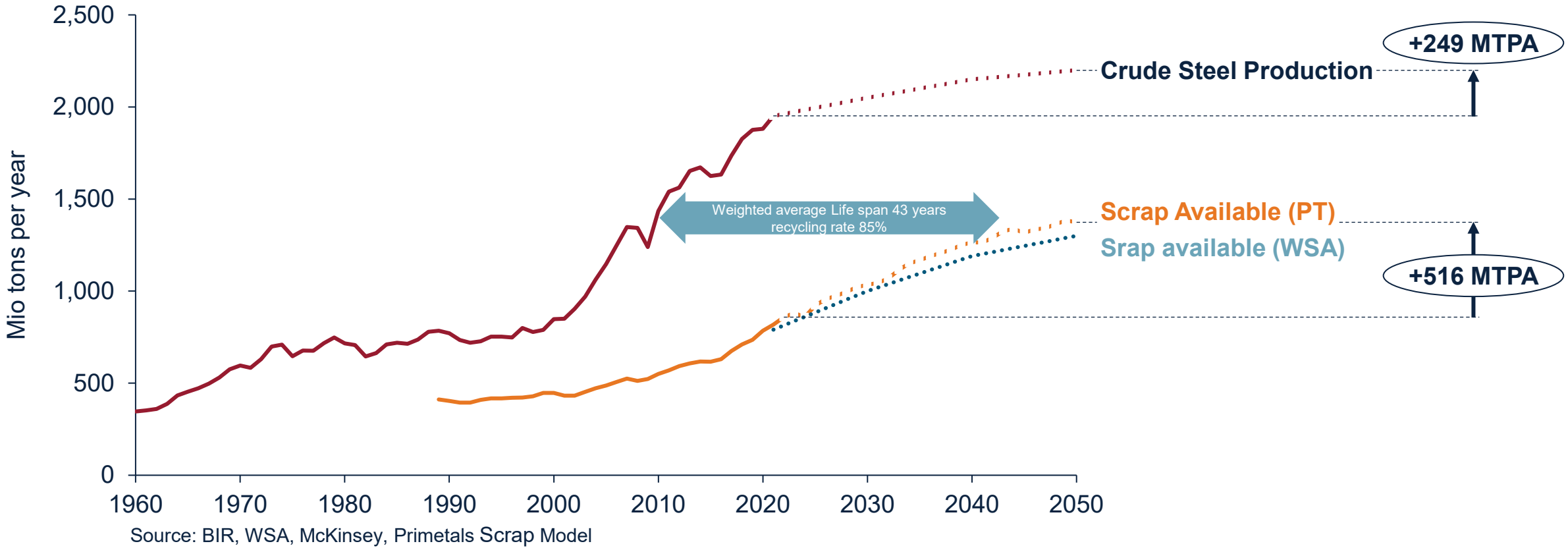
(mio ton DRI)




Source: iima - International Iron Metallics Association, PT

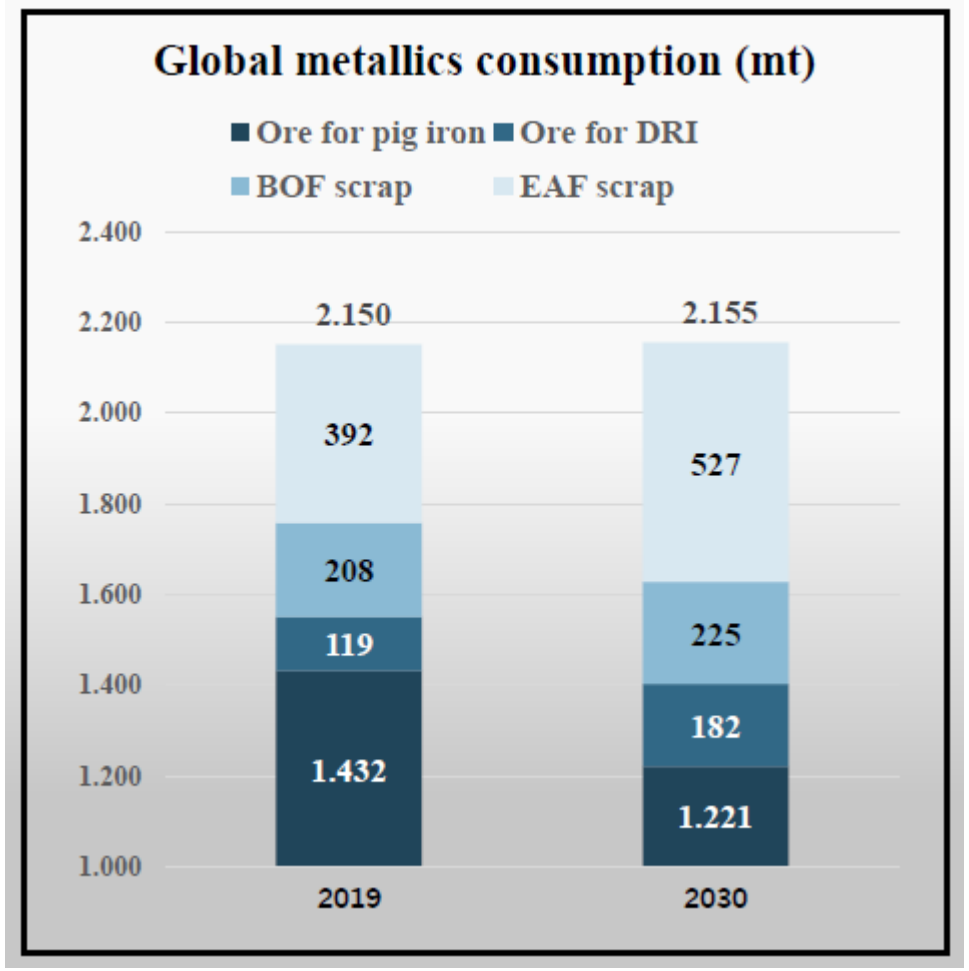
# Scrap Availability and it's Impact for De-Carbonization

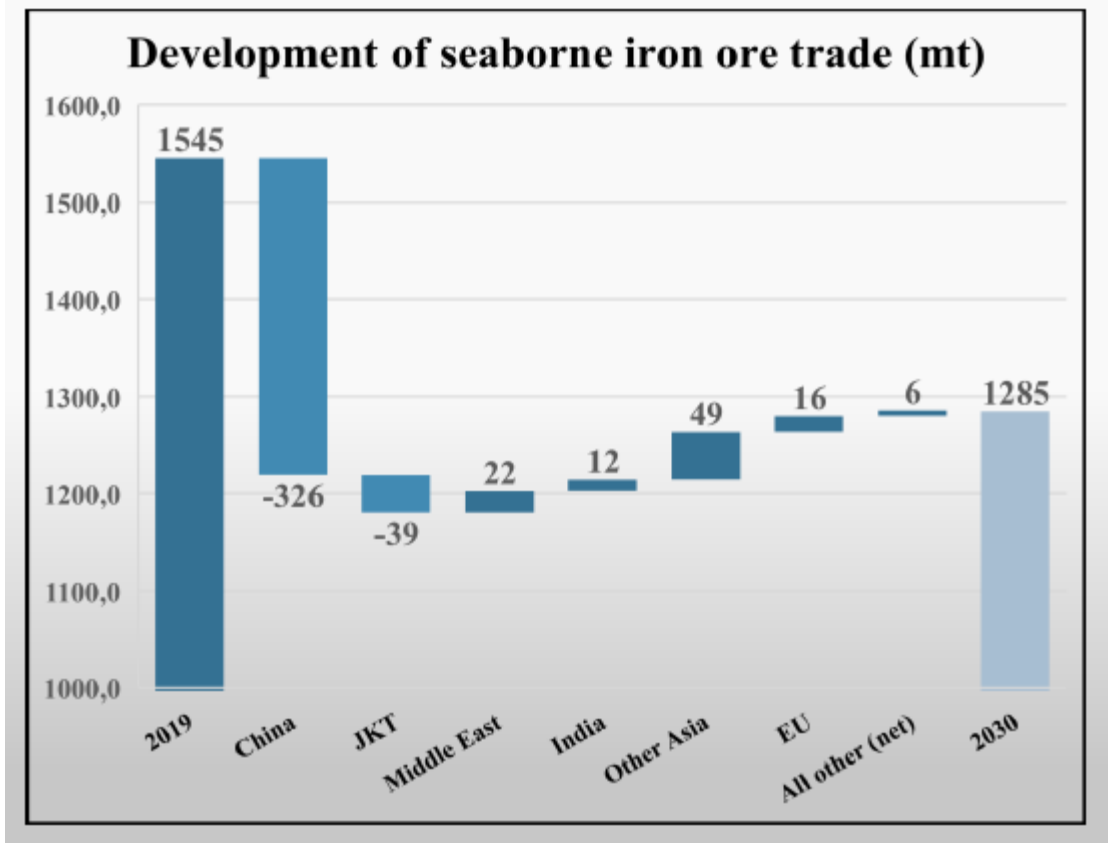
## Steel Production and Scrap Availability in MTPA




Source: BIR, WSA, McKinsey, Primetals Scrap Model

# The Feedstock Playground

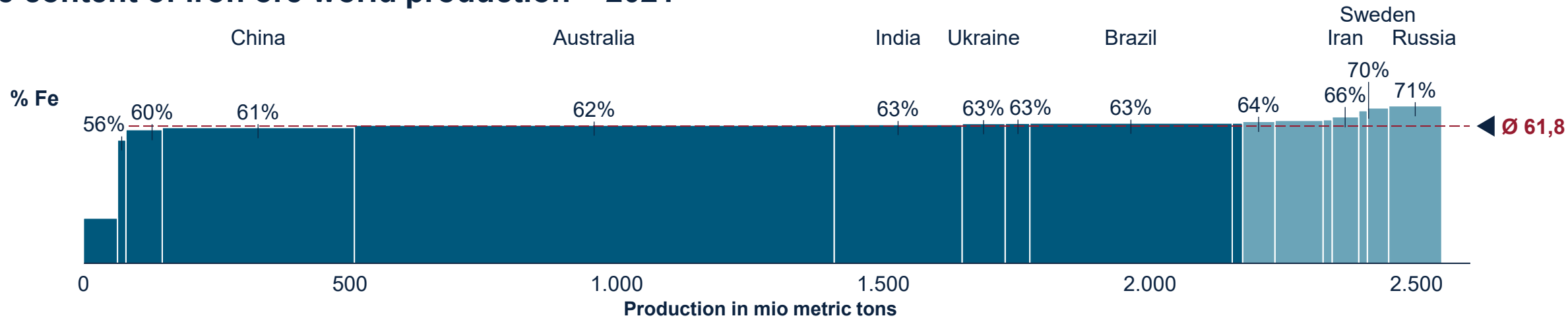


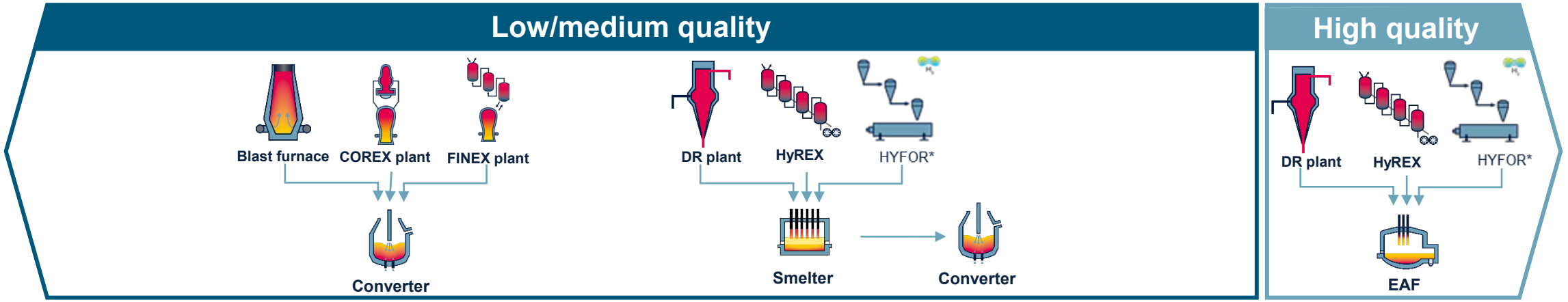




WSD WORLD STEEL DYNAMICS Source: WSD analysis

# The iron quality determines the process route

## Fe content of iron ore world production – 2021

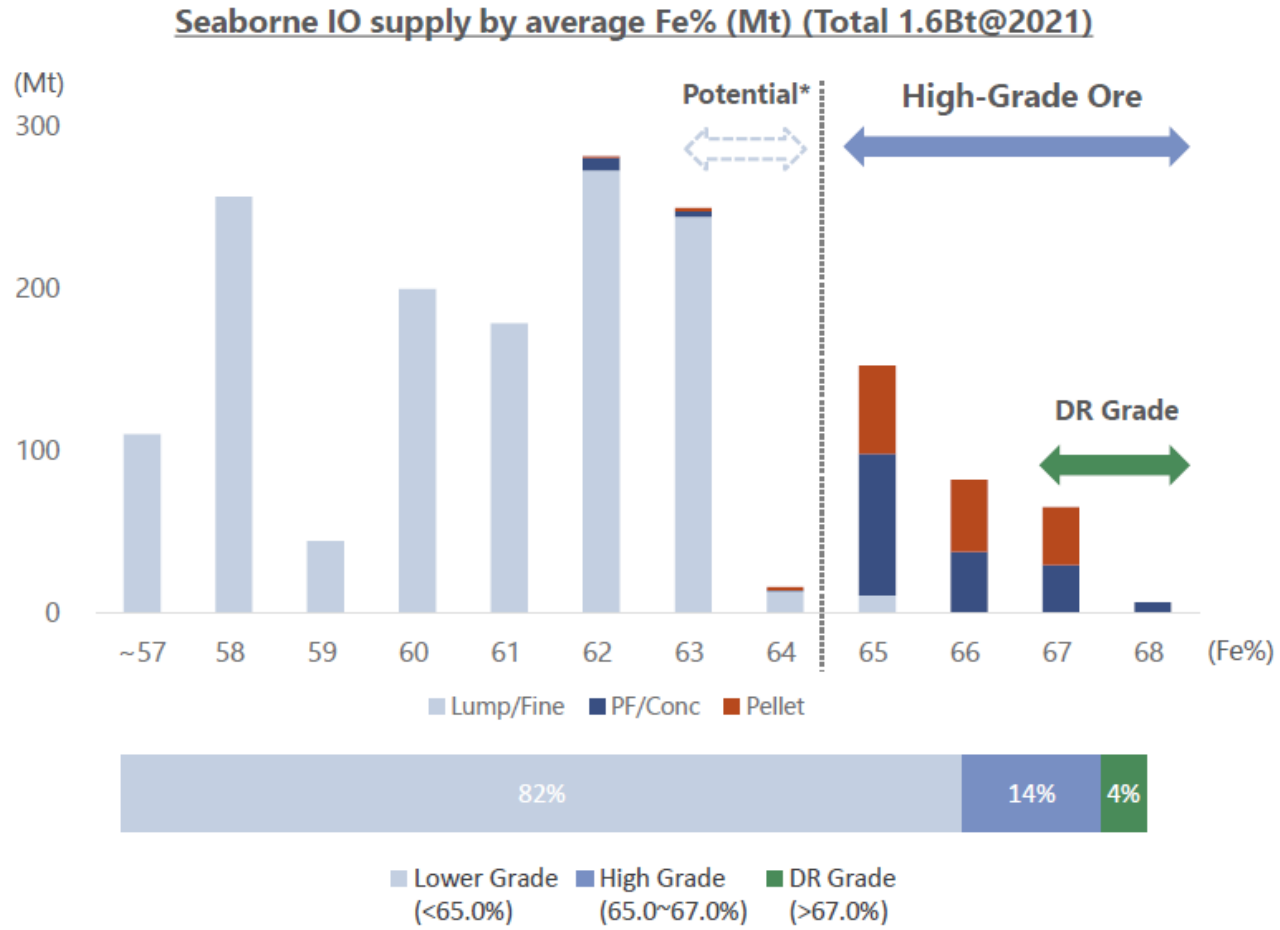



Source: National Minerals Information Center USA, Primetals

# Current Iron Ore Supply by Grade

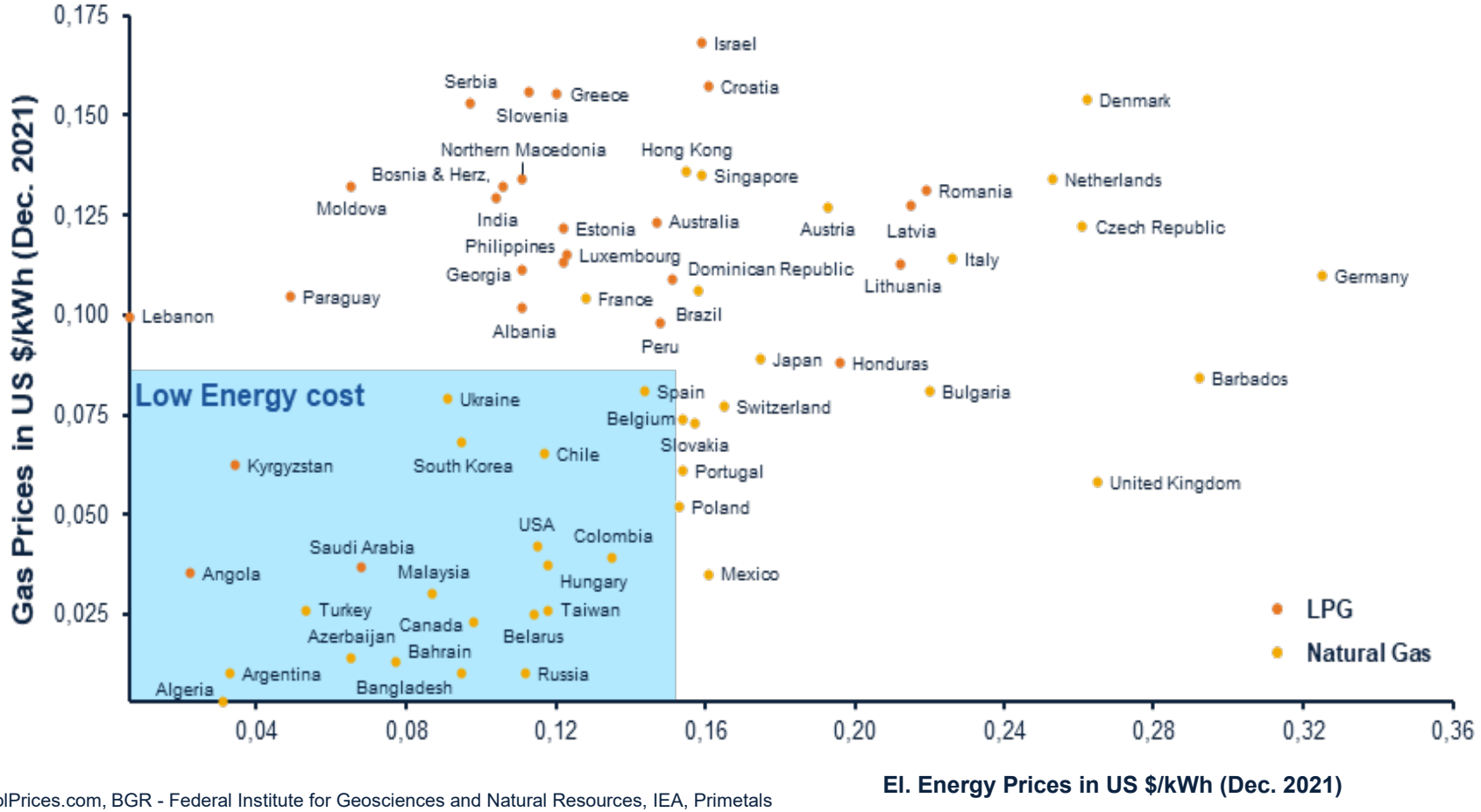
## Supply of DR Grade Ores is limited, accounting only for 4% of current seaborne grades




(Source : Woodmac and MC)

# Energy cost is the main driver for electrification and a hydrogen eco system

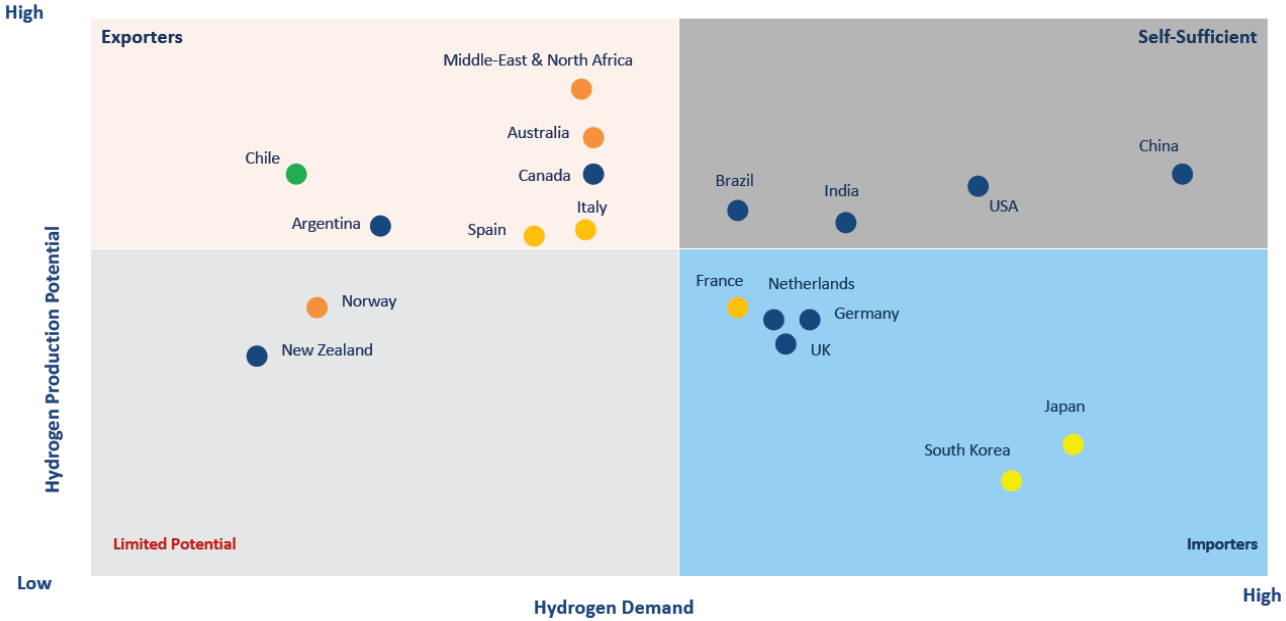
## Energy cost 12/2021 in US$/kWh




Source: GlobalPetrolPrices.com, BGR - Federal Institute for Geosciences and Natural Resources, IEA, Primetals

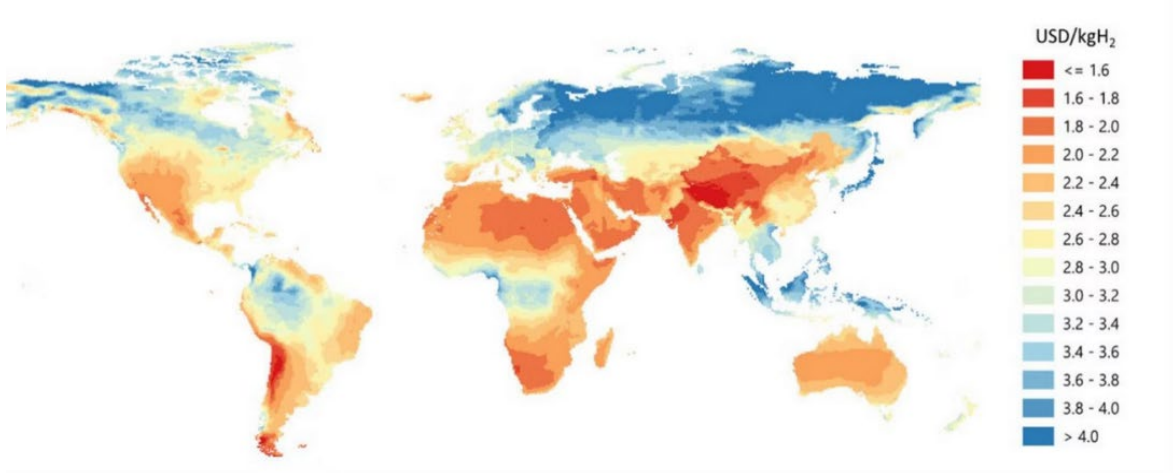
# Energy cost is the main driver for electrification and a hydrogen eco system

## Hydrogen Market Space after 2030




Source: Frost & Sullivan

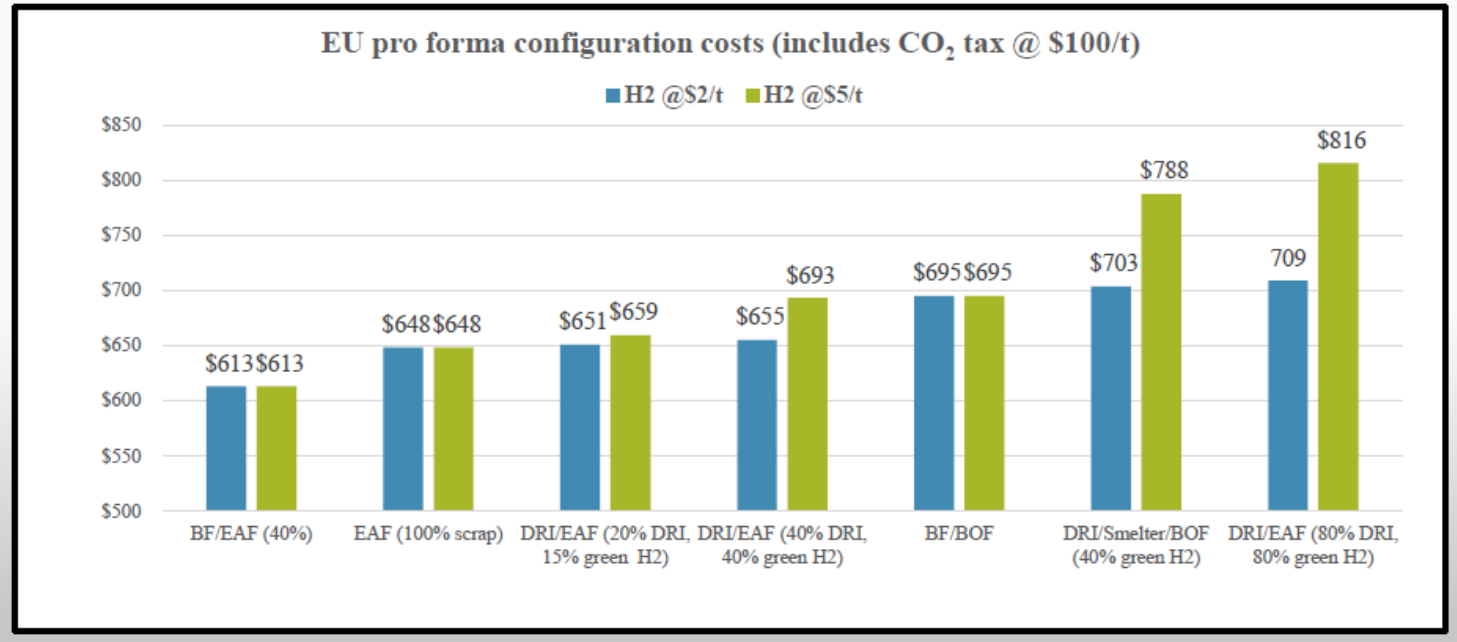
## Hydrogen cost from renewable energy long term



# Hydrogen Usage

## 2030 EU pro forma configuration $H_2$ cost scenarios

The BF/EAF configuration with a 40% hot metal charge is the lowest cost configuration; EAF operations with high percentages of green DRI have higher costs at $2/t $H_2$ and are extremely uncompetitive at $5/t.




The hydrogen price is assumed to be either a fully-loaded (with capital return) production cost or a purchased price based on a supply contract; assumes 0 free allowances although they will not be fully phased out until 2034; the configuration D with 100% scrap will not be able to produce the same high quality flat roll steels as the others; -included for illustrative purposes

Source: WSD analysis

WSD WORLD STEEL DYNAMICS

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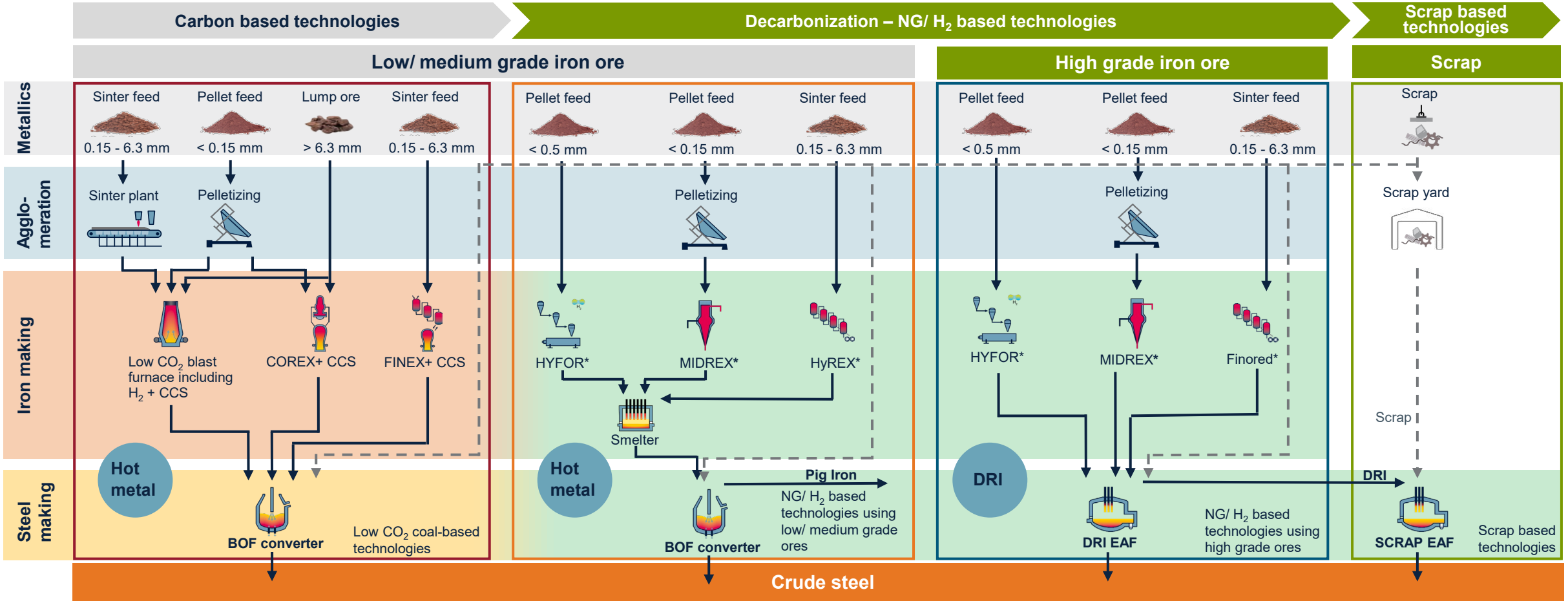
# Process Routes for Transitioning to Net-Zero




*MIDREX, HyREX and HYFOR are registered trademarks of Midrex Corporation, Posco and Primetals Technologies respectively

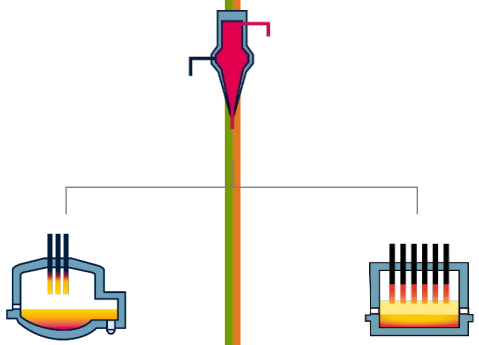
# Process Routes for Transitioning to Net-Zero

**Commercially available**

**Technologies in pilot phase**

## MIDREX

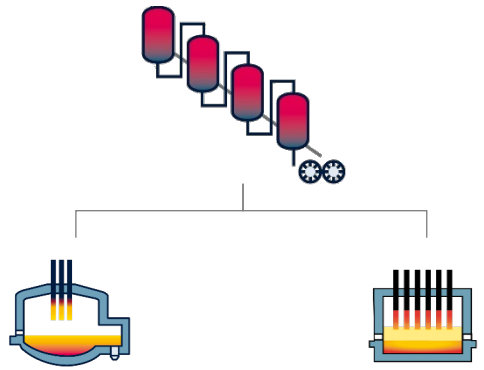
Natural Gas | Hydrogen | Pellets



High Grade | Low Grade

## Finored / HyREX

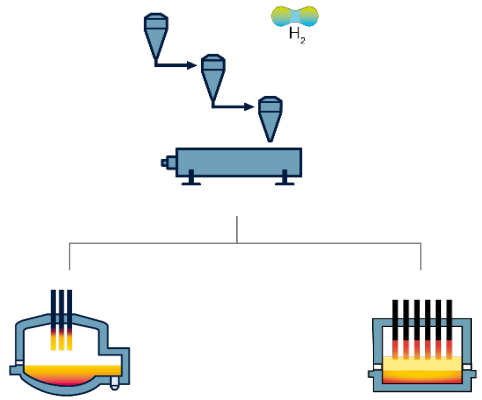
Natural Gas | Hydrogen | Sinter Feed



High Grade | Low Grade

## HYFOR

Hydrogen | Fines



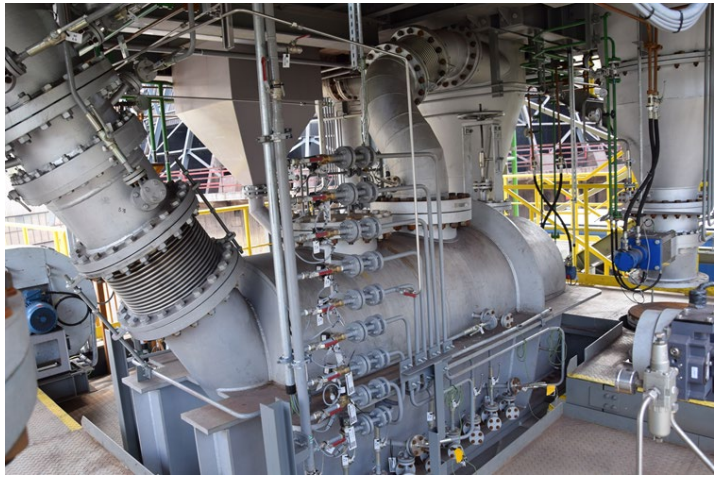

High Grade | Low Grade

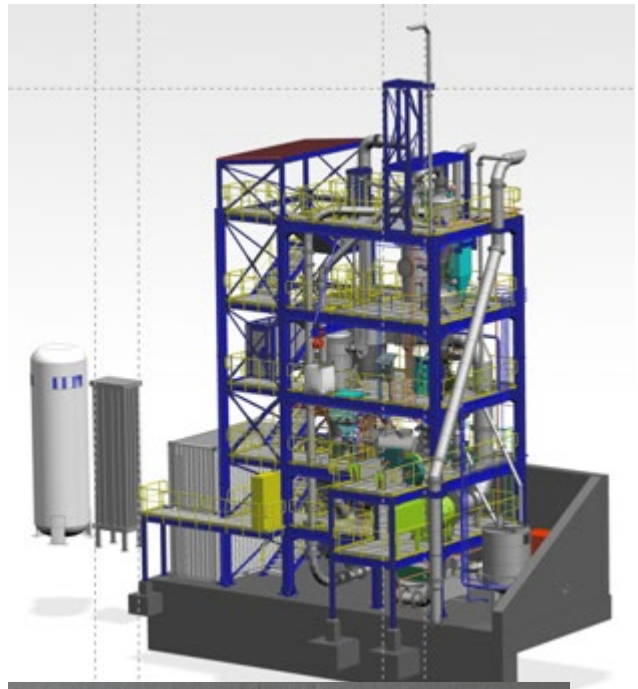
*High-grade ores: Electric arc furnaces (EAF)*

*Low-grade ores: "Smelter" for DRI melting and final reduction*

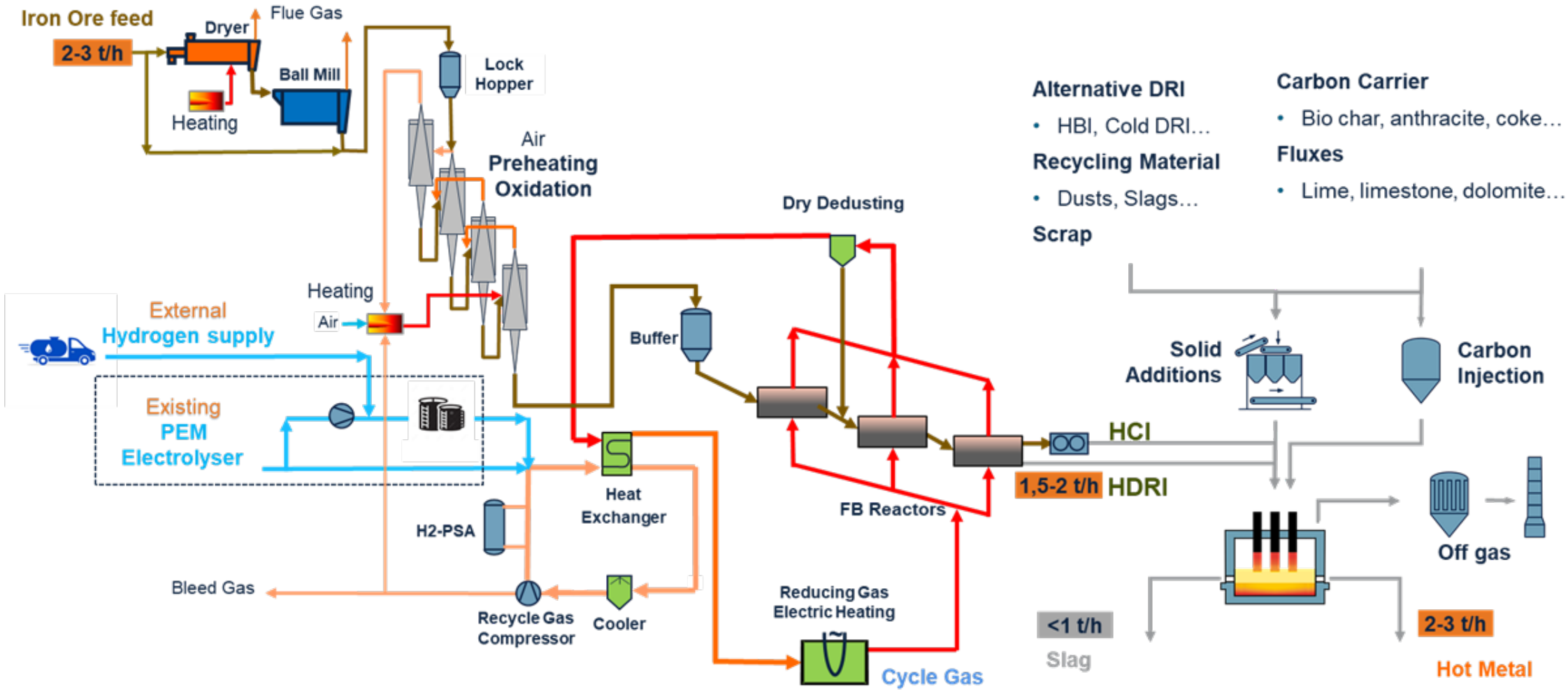
# HYFOR Pilot Plant

- No Pelletizing required – Fines Feed (any type of ore)
- Extremely high Yield (Low Temperature / Pressure Operation)
- Feed: ~ 1 t Iron Ore/Campaign
- Product: ~ 0.6 t DRI Fines/Campaign
- Hydrogen Supply by Truck
- CE – certified for high Temperature and Over-Pressure Operation with 100 % $H_2$
- Fully Equipped with State-of-the-Art Automation System

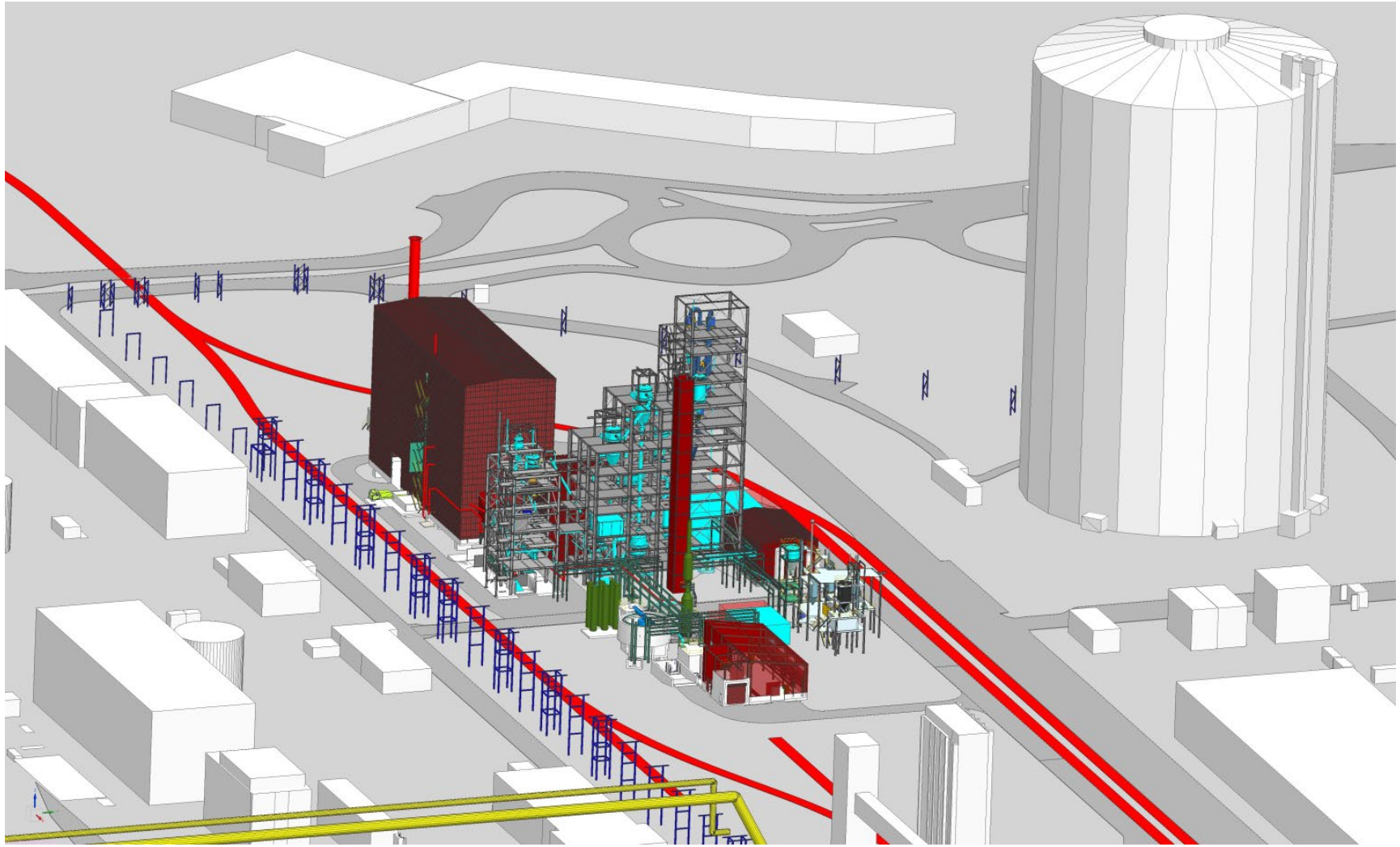


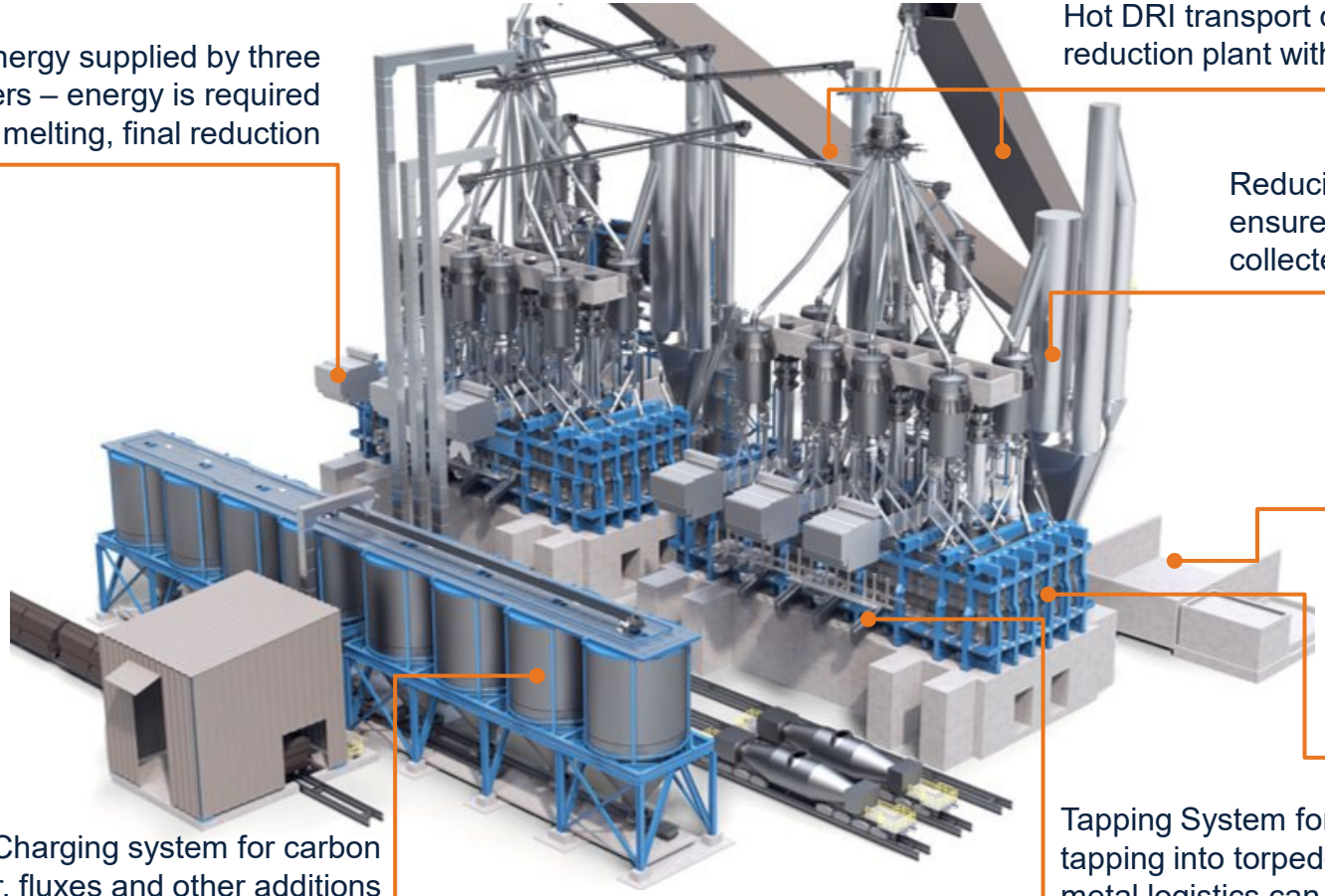
# Flowsheet Hy4Smelt



# 3D Model Hy4Smelt Project



# 2.5 MTPA Plant → 2x90 MW Smelter



Electrical energy supplied by three transformers – energy is required for melting, final reduction

Hot DRI transport connects direct reduction plant with Smelters

Reducing atmosphere in the furnace ensures CO rich off gas – off gas is collected and prepared for further usage.

Slag is adjusted to fit for application in cement industry. Slag is tapped on one side and granulated right after tapping.

Large furnace ensure big surface between slag and metal and good slag reduction, big hot heel to buffer hot metal before tapping as well as long refractory lifetime

Tapping System for hot metal tapping into torpedo car. Existing hot metal logistics can be reused

Charging system for carbon carrier, fluxes and other additions (e.g. recycling materials, scrap)

# Break-Through Innovations
# HYFOR & Smelter for low-grade DRI processing

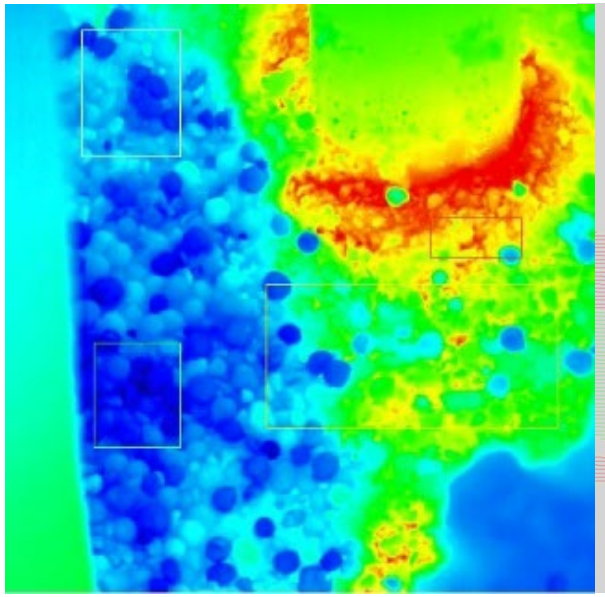
**Pilot testing**

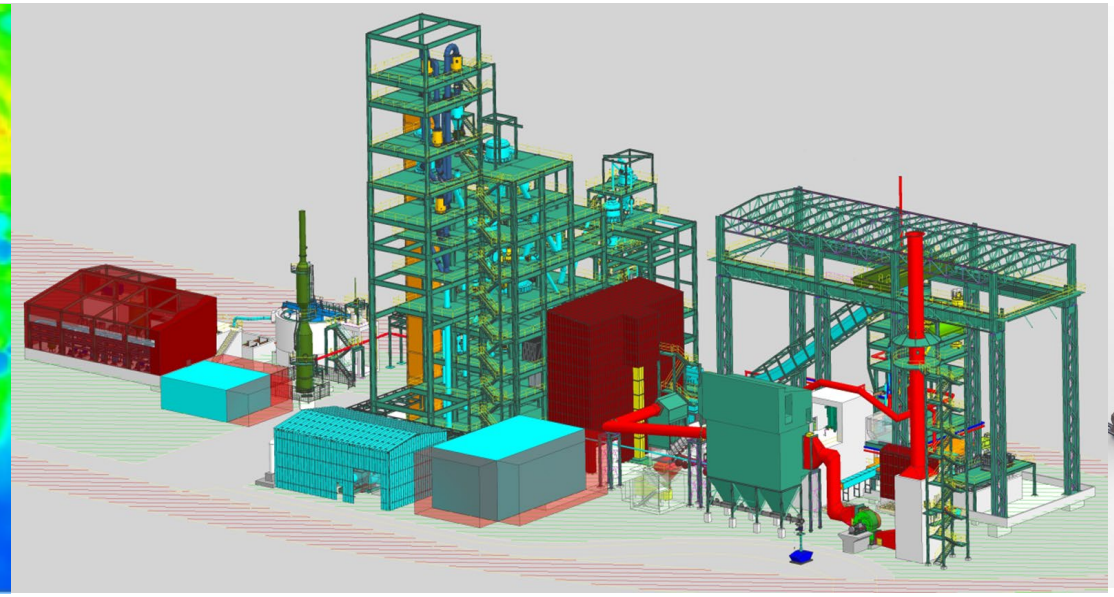
**Hy4SmeIt – Industrial Prototype, 3 t/h**

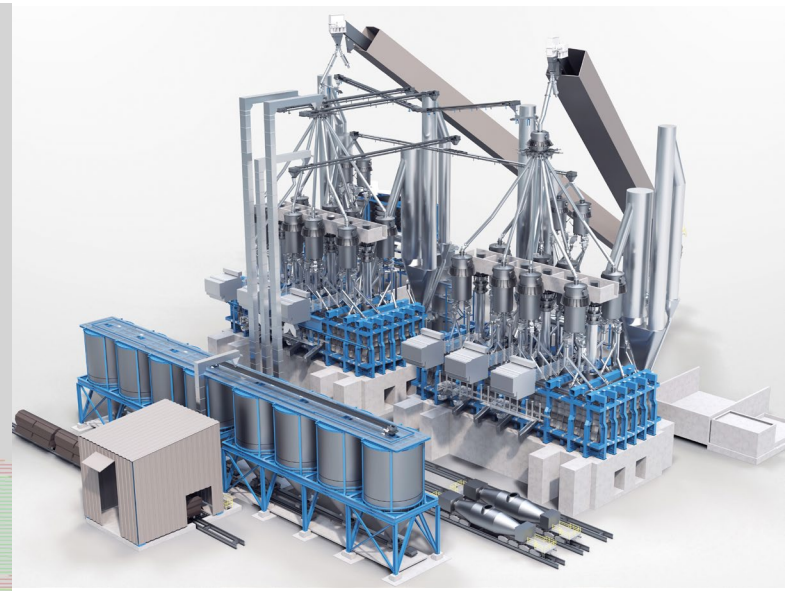
**HyREX - Industrial Demonstrator**

**Commercial plant**

**2022** **2023** **2024** **2025** **2026** **2027** **2028**



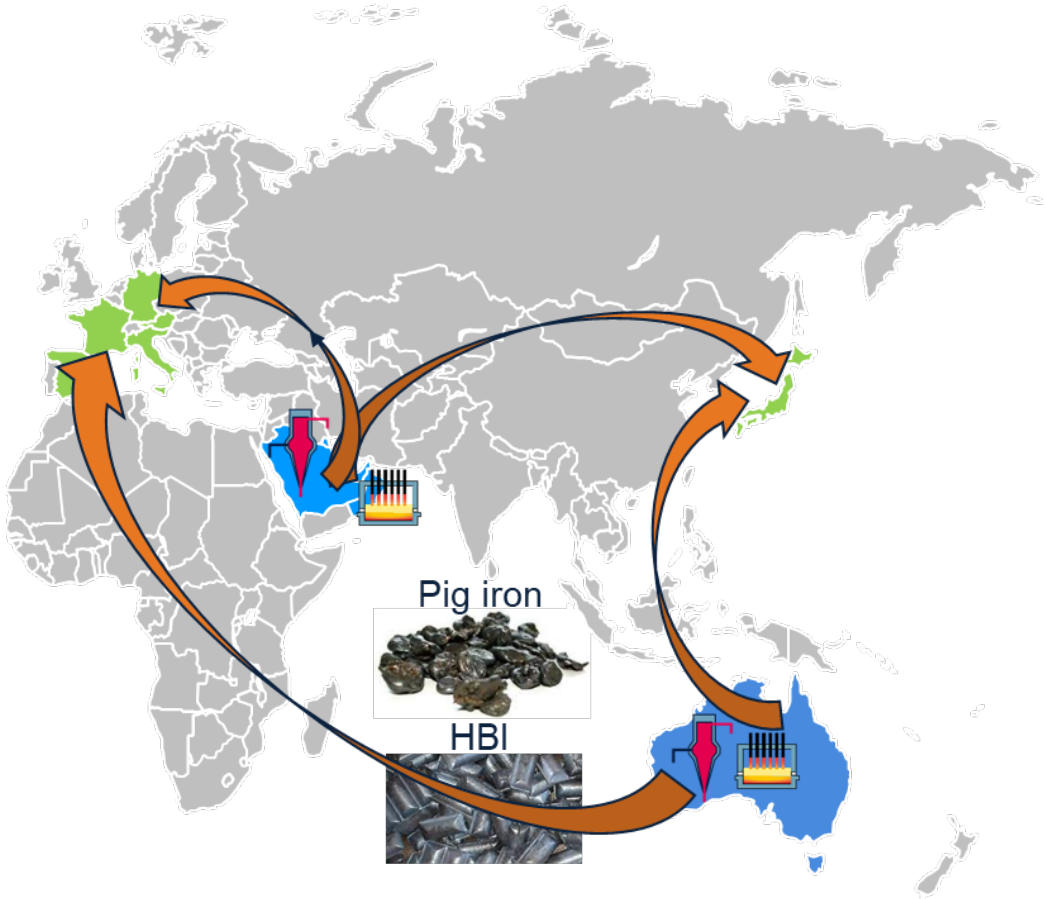




# Protectionism for local steel

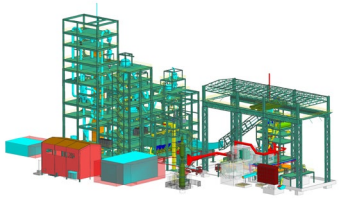
**Trade flows & Green Steel pace are impacted by:**

- Raw material supply chain (scrap protectionism)
  Backwards integration of scrap processors
  (i.e. Arcellor Mittal, SDI)
- Scrap availability and quality (crafted scrap)
- DR-grade ores become an undersupply – DRPs will have to use lower ore grade feedstock plus Smelter
- Cheap energy might drive a decoupling of iron- and steelmaking (MENA, Australia, US or Brazil)
- Green metallics will become an undersupply (high premium of 300-500 $ per ton after 2025 expected), but regionally different – import into EU, Japan, Korea?
- New steel players & business models become visible
  - Salzgitter - Orsted (circularity/synergy)
  - H2GS – Automotive sector
  - GravitHy (VALE, cross-industry approach)




Source: partly from McKinsey & Company: The resilience of steel

# Decarbonization Highlights (announced or in execution)



## Hy4Smelt, Austria

- Strategic Partners
- HYFOR & Smelter
- 1st continuous industrial prototype green metal plant based on 100% green H2
- Start-up 2026
- 95% $CO_2$ reduction

## SALCOS, Germany

- Steelmaker investment
- Transformation of an integrated 6 mtpy steel plant to an $H_2$-DRI- EAF
- 1.7 bn€ investment to produce 1.9 mtpy green steel
- Start-up 2025
- 95% $CO_2$ reduction

## GravitHy, France, Finland

- Strategic investors
- Planning to build, own and operate its first green iron and steel plant in France
- 2.2 bn€ investment to produce 2 mtpy green DRI
- Start-up 2027
- 95% $CO_2$ reduction


## CCS, AM Gent Belgium

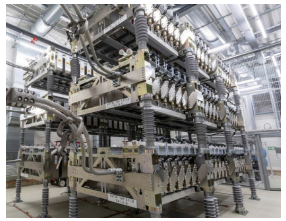
- KM CDR amine-based CCS pilot plant
- De-risk CCS application at BF, later at Reheating Furnace and DRP
- Data acquisition and scale-up


## HyREX, POSCO, Korea

- Strategic Partnership
- Fluidized Bed DRP incl. Smelter
- Demonstrator plant 40 TPH, 300.000 TPA
- Start-up 2026
- 90% $CO_2$ reduction

## Steelanol, Belgium

- Stratecic investment
- LanzaTechs uniqu bio-fermentation smart carbon technology
- 100.000 m³/h BF waste gas feed stock into 80.000 m³ per year bio-ethanol
- Start-up 2023



## Active Power Feeder, Germany

- Grid friendly power supply solution
- Connects EAF to power grid on MV MCC basis highest power quality
- Industrial Prototype at50 t EAF at BGH Edelstahl

**Dr. Alexander Fleischanderl**
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Global Head of Innovation & Information Technology

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# THANK YOU