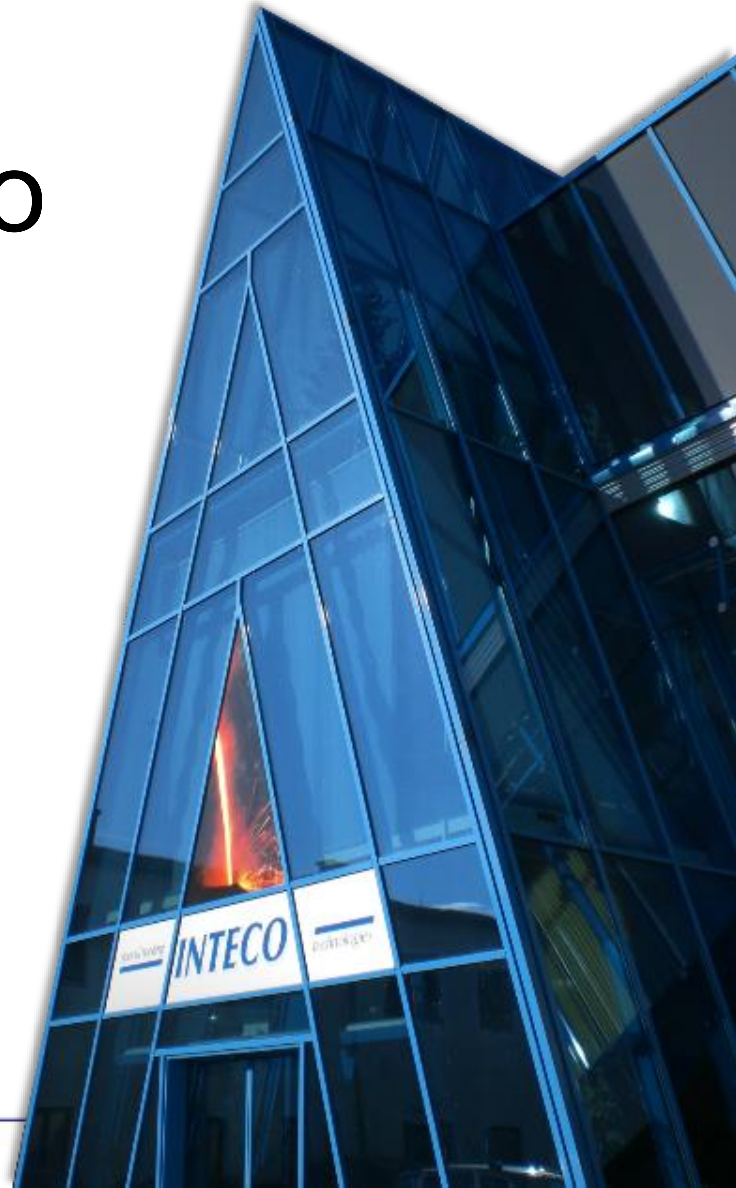
Zero-emission, low-cost hydrogen

via Methane pyrolysis as pathway to green steel

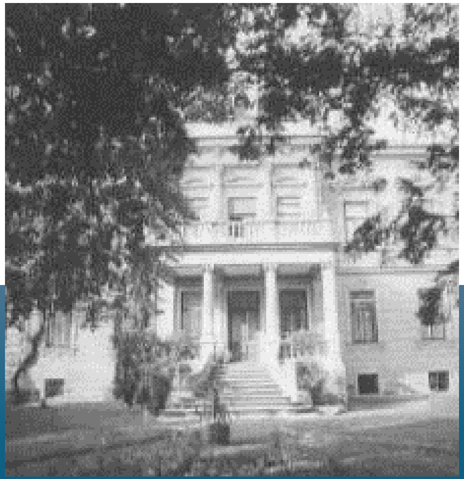
Harald Holzgruber
CEO Inteco Holding



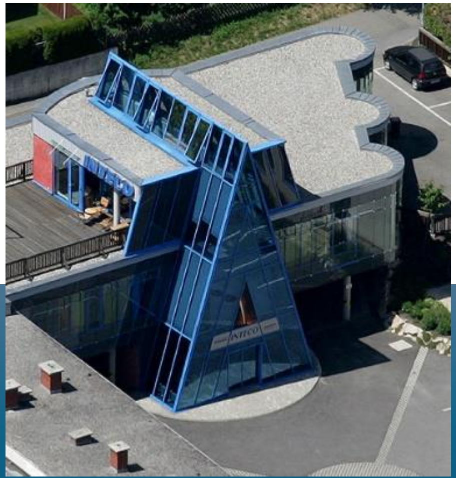
Family Business

Tradition over generations

1973



2025



Good to know...

1973

Founded as **IN**ternational **TE**chnical **CO**nsulting

1000++ years of experience

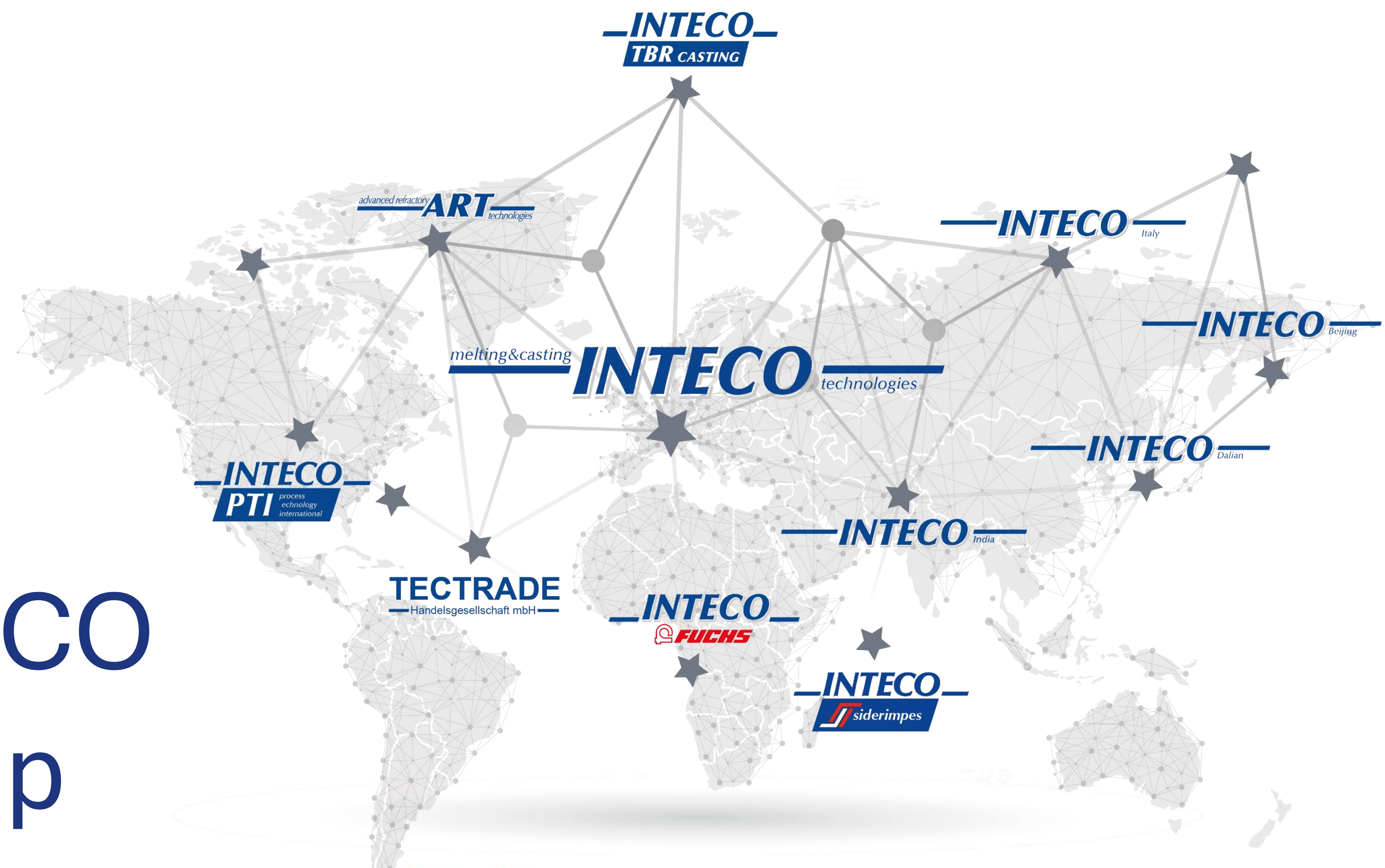
Headoffices in Bruck/Mur, AUSTRIA

Global presence: 10 subsidiaries

€

Turnover of ~ 100 Mio. € / year

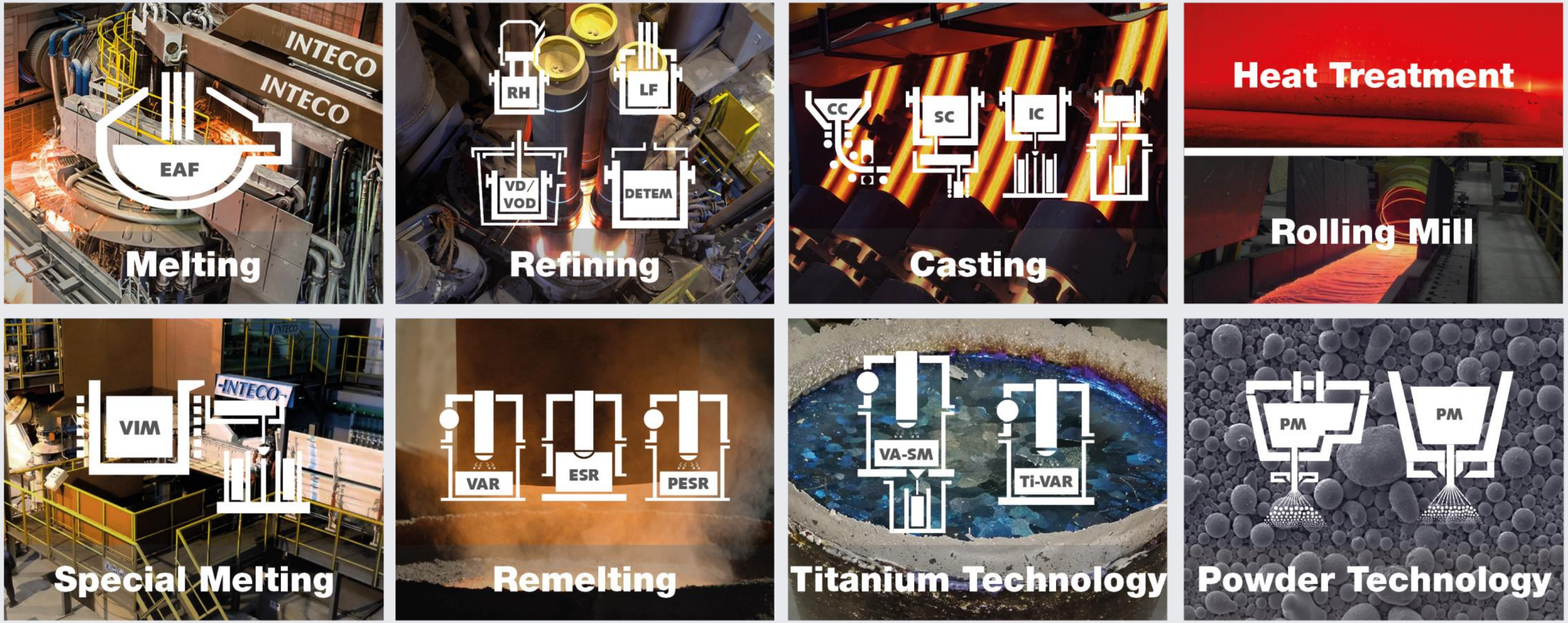
The INTECO Group



INTECO‘s Product Portfolio

PROCESS KNOW-HOW & CONSULTING

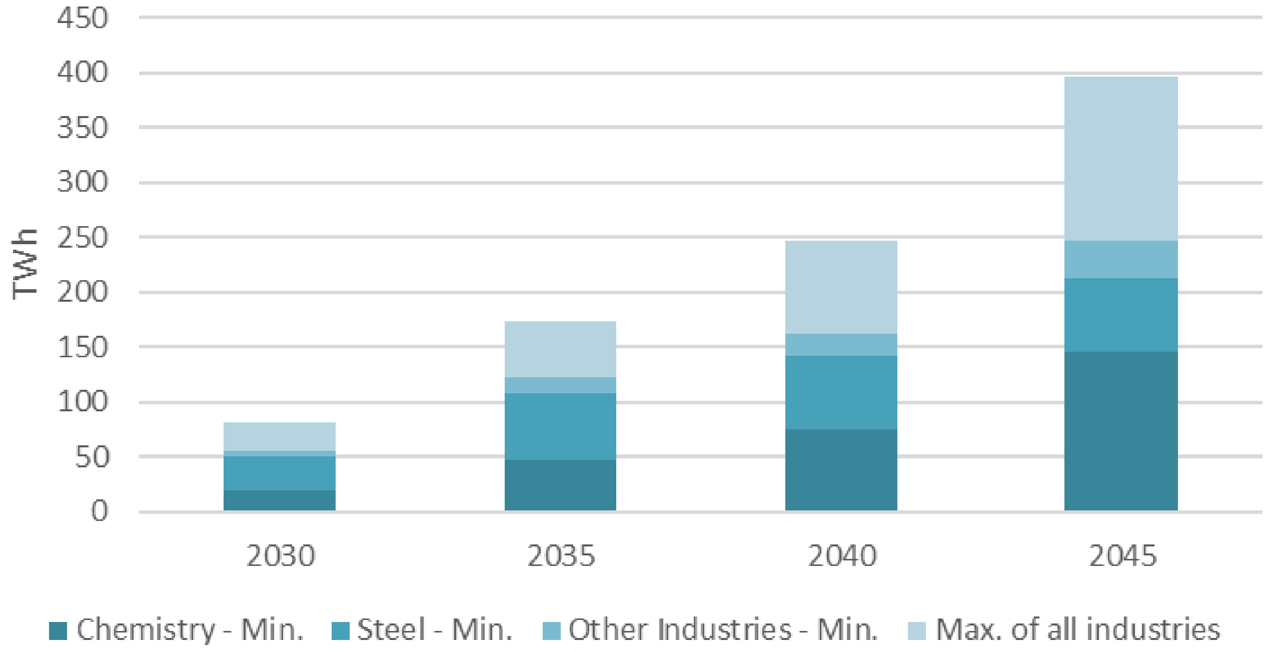
DIGITAL SOLUTION &
INDUSTRIE 4.0



DIGITAL SOLUTIONS &
INDUSTRIE 4.0

PROCESS KNOW-HOW & CONSULTING

H_2 demand for steel industy

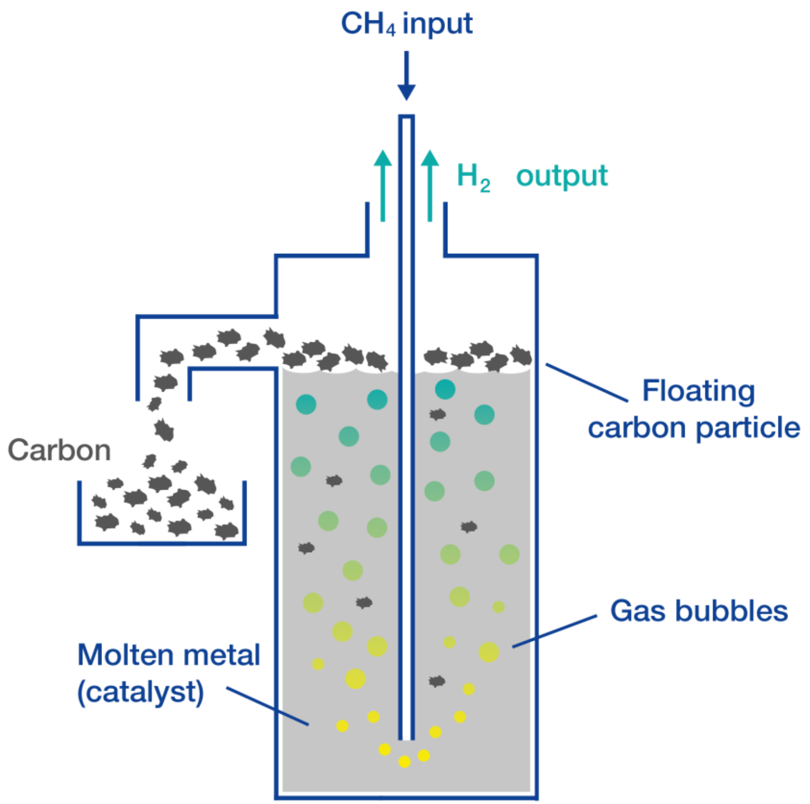


Forecast hydrogen demand of German industry – *Nationaler Wasserstoffrat* (May 2024)

- Minimum demand of 67 TWh (**2 Mio ton**) by 2045 only for <u>Germany steel industry</u>
- Up to 400 TWh for entire German industry by 2045
- Applications:
  - Reduction agent (DRI)
  - Energy carrier for high temperature processes such as:
  - EAF burner systems
  - Industrial furnaces

Methane pyrolysis - Principle

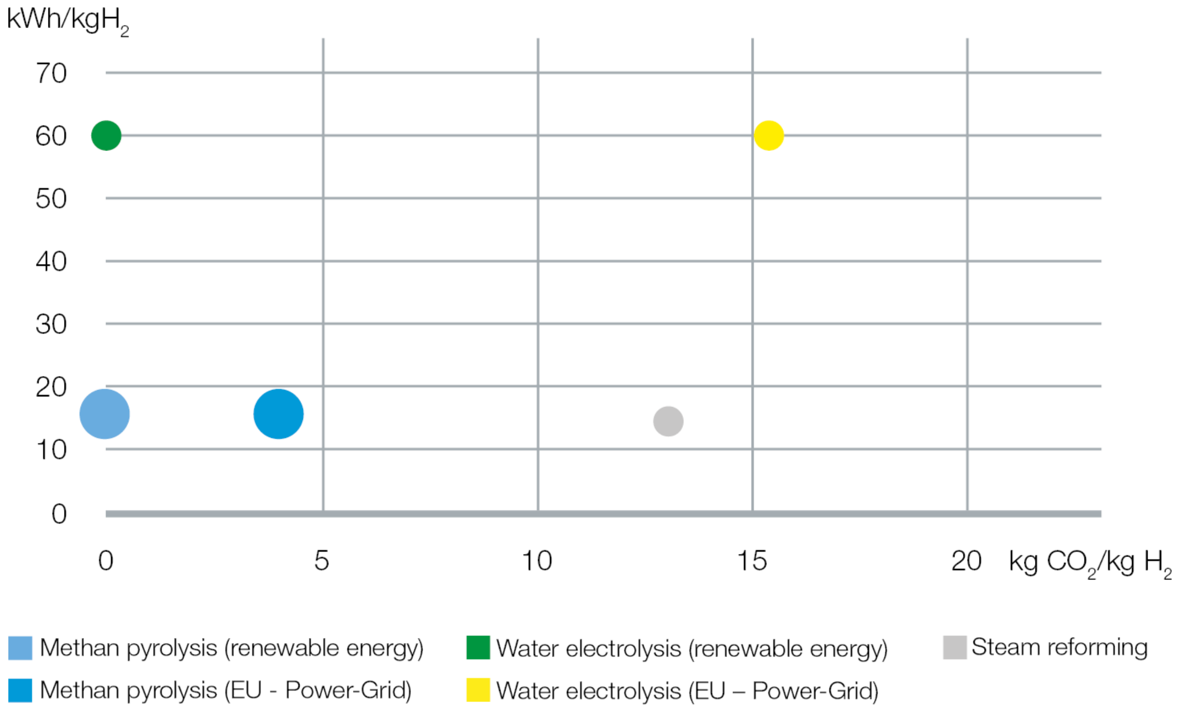
Liquid metal bubble column reactor

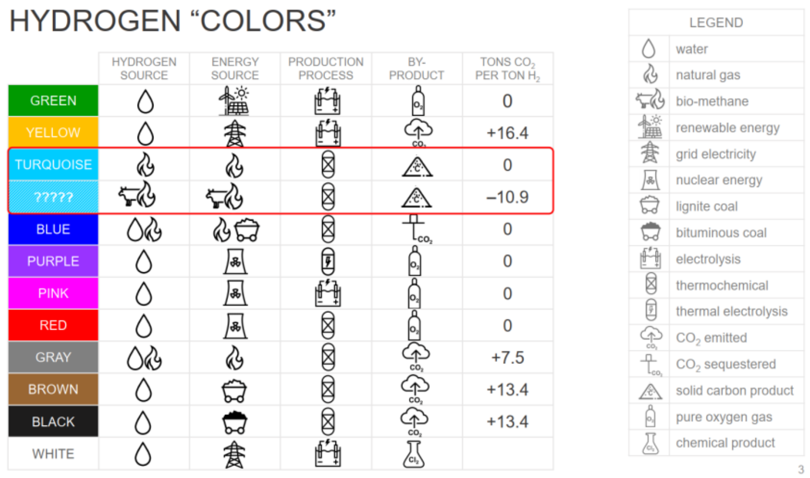


- Thermo(-catalytic) cracking
- $CH_4 \rightarrow H_2 + C_{solid}$
- Conversion rate > 70 %
  - Perfect suitable for most relevant applications in the steel industry

Why methane pyrolysis?

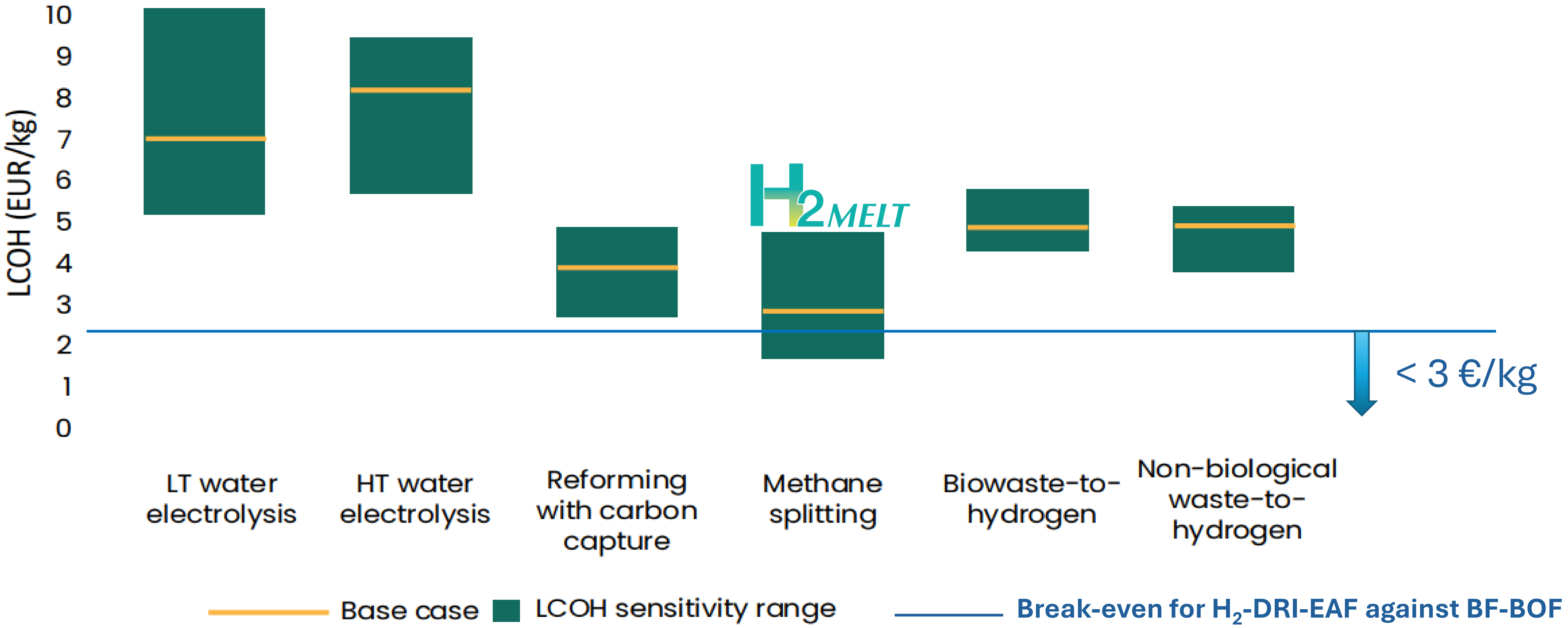
- Very low energy input
- Low CO_2 emissions
  - Potentially, zero emissions, if only renewables are utilized





Source:Boysen, D.: Hydrogen Earthshot Summit, 2021

Competitive cost advantage



Unique technology benefits

- Attractive production cost
  - Hydrogen delivery cost < 3 Euro/kg
- Large scale potential
  - Feed stock & infrastructure already available
- Zero direct emissions
  - Even a CO_2 sink when operation with bio-methane
- Supply of solid carbon as valuable by product

Carbon - Valuable product

$4\ kg\ CH_4 \rightarrow 3\ kg\ C + 1\ kg\ H_2$

- Additional revenues
- Multiple large volume applications:
  - Carbon black
  - Asphalt
  - Refractories, casting powder, ...
  - Agriculture
- Super-flexible production as carbon properties can be adjusted widely

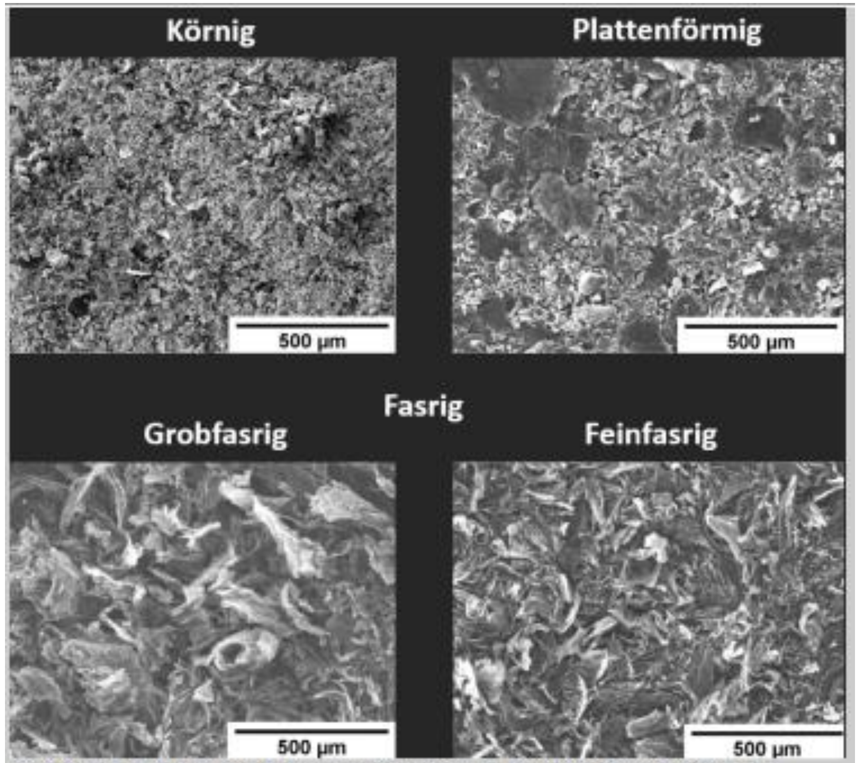
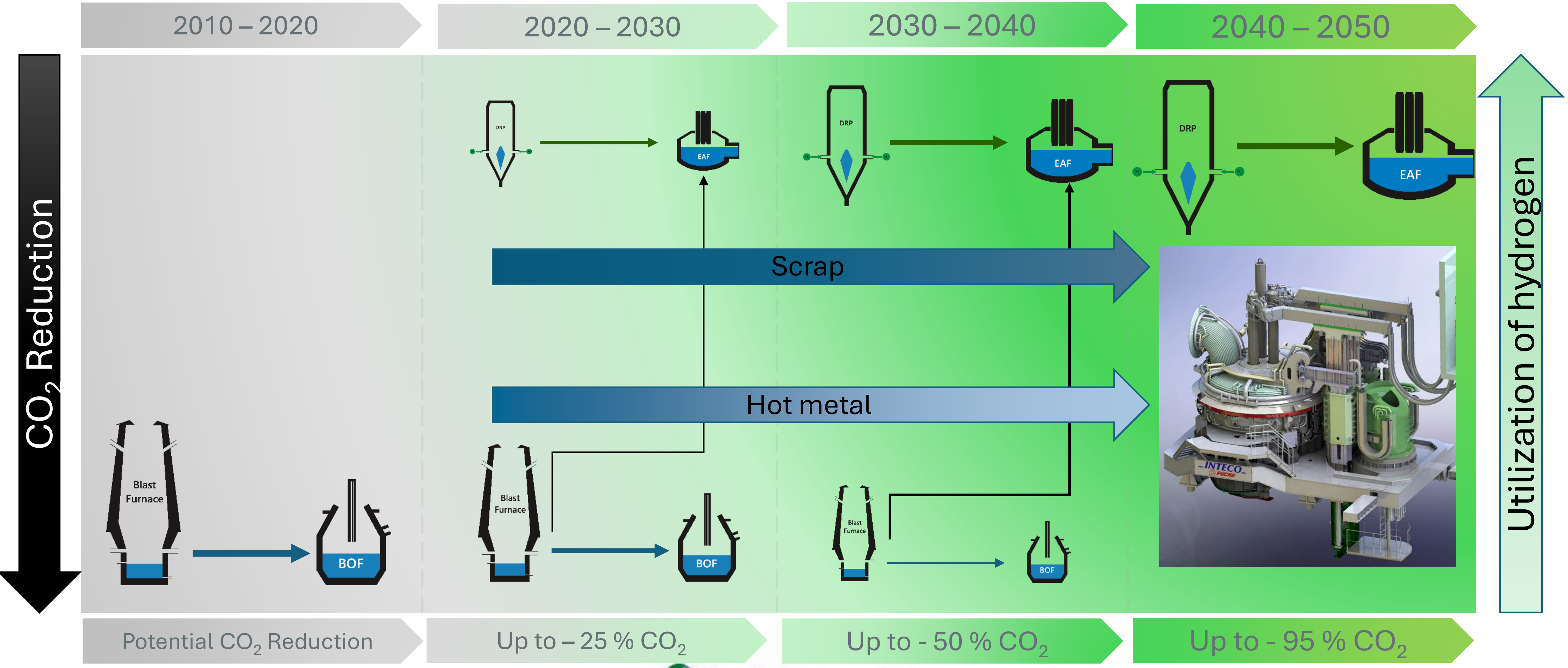


Abbildung 4: Kohlenstoff aus der Pyrolyse von Methan in verschiedenen flüssigen Metallbädern: Bi-Ni-Legierung (oben links), Ni-In-Legierung (oben rechts), Sn-Ni-Legierung (unten links) sowie Cu-In-Legierung (unten rechts)

EAF as future core unit



H-based direct reduction

Basically, all processes (Midrex, Energiron, Circored, ...) can operate with a quite wide range of natural gas/hydrogen mixtures.

A certain carbon content in the DRI is required (typically ~ 1.5 %) and can be reached by proper selection of natural gas / hydrogen mix.

Typically, ~ 55 – 60 kg H_2 / t DRI are necessary.

Pyrolysis-hydrogen for DRI plants

- Mixgas (H_2/ residual CH_4) beneficial for C-content in DRI
  - „Electrolysis quality“ by far not required for the process

- Temperature of H_2 gas well suited for DRI
  - Process temperature starting from 650 °C

- High pressure process → reduced need for gas compression
  - DRI-Process pressure ~ 4 bar

- Much lower energy consumption compared to H_2 generated by electrolysis

Some transformation projects

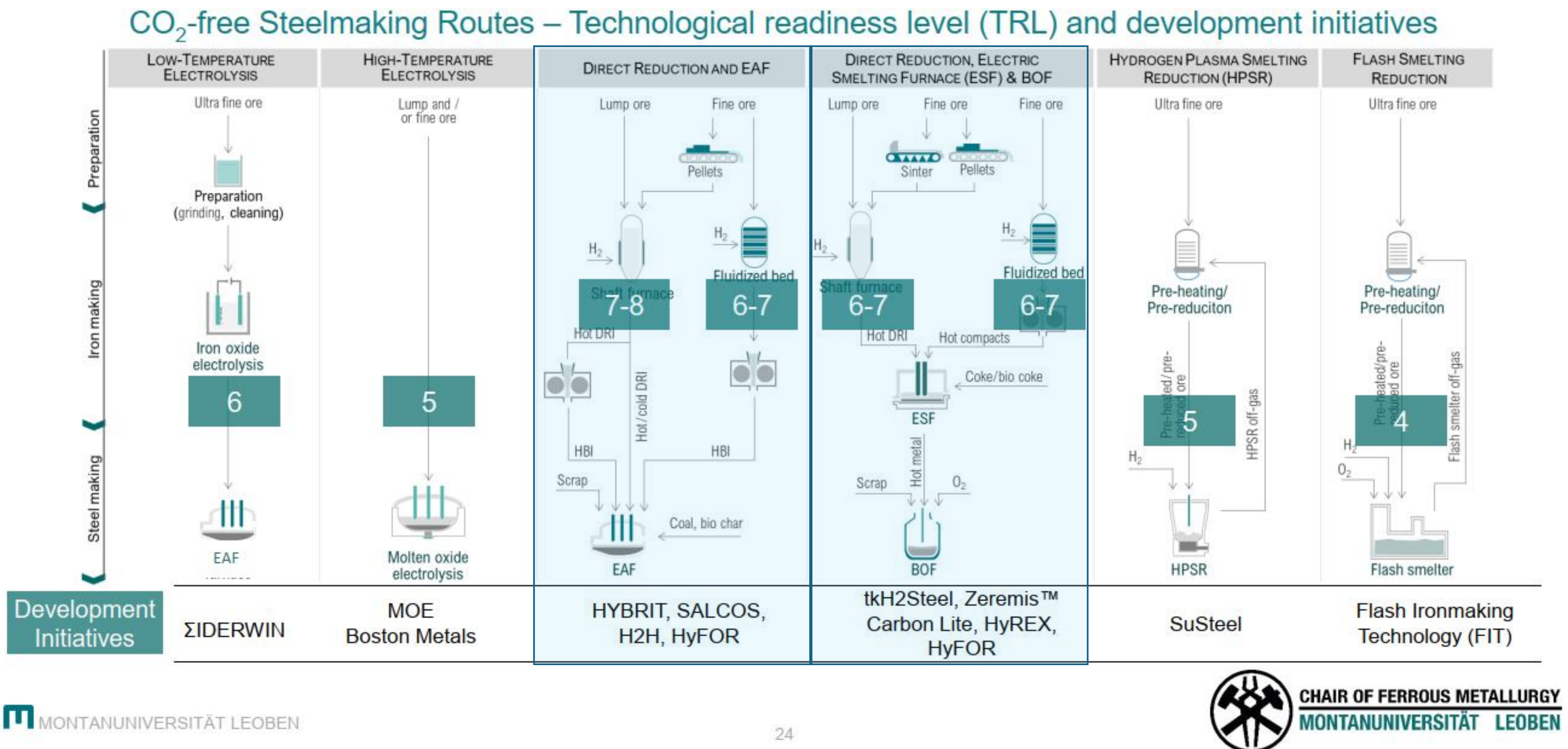
Plant	DRI Capacity (Mtpa)	Reducing Gas	Commission Year	Notes
H2 Green Steel	2.1	H_2	2025	First Phase (Electrolyser capacity of more than 700MW, Midrex technology)
SSAB, HYBRIT (Demonstration Plant)	1.3	H_2	2025	
Salzgitter	2	Mixed NG and H2	2026	First Phase (100MW electrolyser, Energiron ZR)
Thyssenkrupp	2.5	NG⟶H_2	2026	Midrex technology
ArcelorMittal Canada (Dofasco)	2.5	NG⟶H_2	2026	Energiron ZR
ArcelorMittal France (Dunkirk)	2.5	H_2 (NG)	2027	It is not clear whether the plan is to start with hydrogen or initially utilise gas, aligning with the approach seen in other ArcelorMittal operations in the EU.
ArcelorMittal Belgium (Ghent)	2.5	NG⟶H_2	Prior to 2030	
ArcelorMittal Spain (Asturias)	2.3	NG⟶H_2	2025	Supply both Asturias and Sestao plant

Plant	DRI Capacity (Mtpa)	Reducing Gas	Commission Year	Notes
ArcelorMittal Germany Bremen and Eisenhüttenstadt)	~2 in Bremen	NG⟶H_2	2030	Additional H_2 required in Eisenhüttenstadt will be generated from gas with the help of a pyrolysis plant
Liberty Steel Group (Whyalla, Australia)	1.8	Mixed NG and H_2	2025	
Liberty Steel Group (Dunkirk, France)	2	Mixed NG and H_2	--	1GW H_2
Liberty Steel Group (Galati, Romania)	2.5	NG⟶H_2	2027-2030	
Tata Steel Netherlands	--	--	Before 2030	Energiron ZR
Vulcan Green Steel (Oman)	2.5 first phase	NG⟶H_2	2026	Energiron ZR
Baosteel Zhanjiang Iron & Steel Co	1	Mixed NG, H_2 and Coke Oven Gas (COG)	Commenced on 1 January 2024	The new Energiron plant will mainly use H_2 as reducing gas, with the possibility to mix it with NG and COG
OMK (Russia)	2.5	NG	2025	It might be adapted to use hydrogen

POSCO 0.3 mio tpy
Hyrex plant

- DRI plants between 1 – 2.5 mio tpy
- Most projects will start with natural gas or mix gas

High TRL processes available



Case study: 1 mio tpy DRI

	CASE 1	CASE 2	CASE 3	CASE „INTECO“
	DR Plant based on NG (BASE CASE)	DR Plant with H_2 addition (30% H_2 share on reduction work)	H_2 DR Plant (100% H_2 share on reduction work)	DR Plant with **75 % H_2**
H_2 used (Nm³/h) (kg/h)	0 0	24,000 2,200	81,250 7,300	5.5 ton H_2 per hour
Energy input: - Hydrogen (H_2) (mmBTU) - Natural gas (mmBTU) - Total (mmBTU) - H_2 energy/total energy	 0.0 9.9 9.9 0% H_2	 2.0 7.7 9.7 20.2 % H_2	 6.6 2.5**) 9.1 72.8 % H_2	
Carbon content in DRI*)	2.5 wt%	~2 wt%	~0 wt%	~ 1.3 wt %

*) in case required, the carbon content of the DRI for Case 1 could also be increased to > 3.5%

**) used for heating of the reducing gas

MIDREX H_2 – The Road to CO2-free Direct Reduction

Robert Millner [1], Johannes Rothberger [1], Barbara Rammer [1], Christian Boehm[1], Wolfgang Sterrer[1], Hanspeter Ofner[1], Vincent Chevrier[2]

Material demands

75 % H_2 in process gas

	[t/h]	[tpy]	
DRI	125	1 000 000	Based on 8 000 hours / year
Pellets	177	1 420 000	
Hydrogen	5.5	44 000	Based on 75 % H_2 content
Carbon product	16.5	132 000	Density only 0.05!
Slag (steel plant)		150 000	100 – 150 kg/t liquid steel

Energy demand

1 Mio t DRI@1.3 % C (1.5 – 3 Mio t liquid steel)

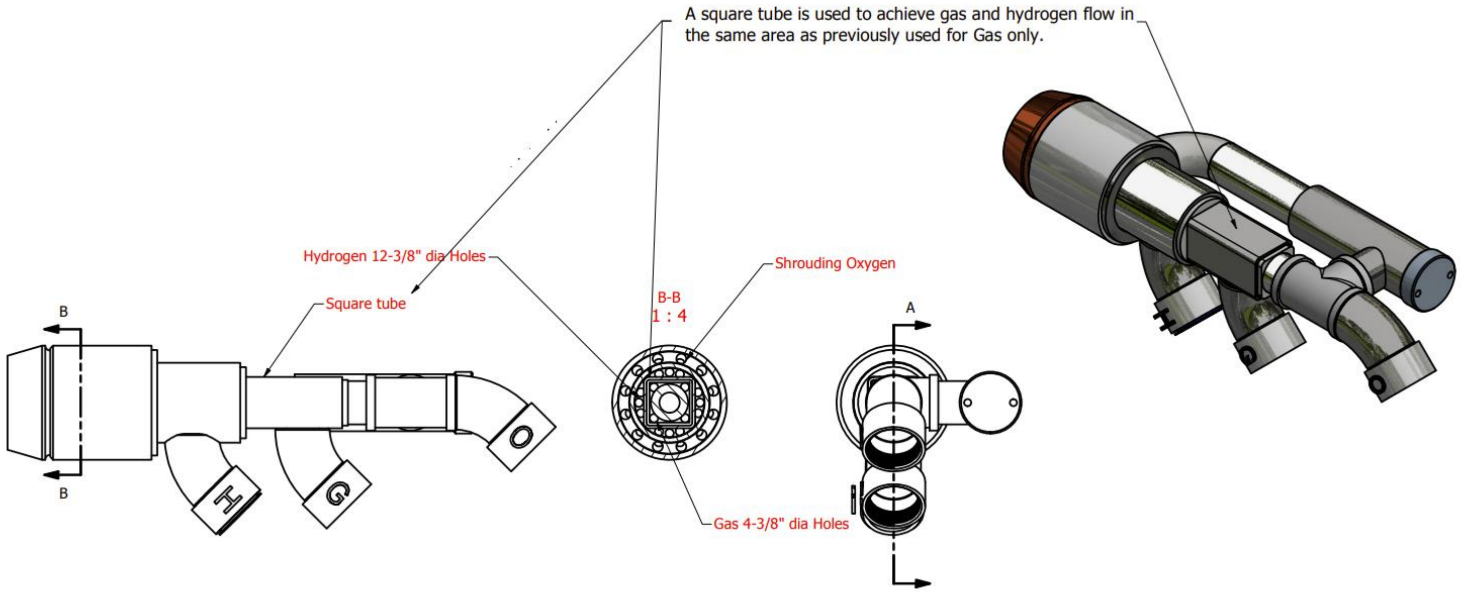
	Pyrolysis	
Specific energy	16.5 kWh/kg	
Hydrogen demand	44 000 tpy	75 % H_2 content in process gas
Annual energy demand	~ 726 000 MWh	
Power requirement	90 MW	Based on 8000 hpy

Note: Power requirement for 1 Mio tpy EAF is also in the range of 90 MW

INTECO PTI Hybrid burner

Ready to operate with any available H_2/NG mixture

- Replace/reduce need of natural gas
- Seamless integration into JetBOx & SwingDoor



A game changer

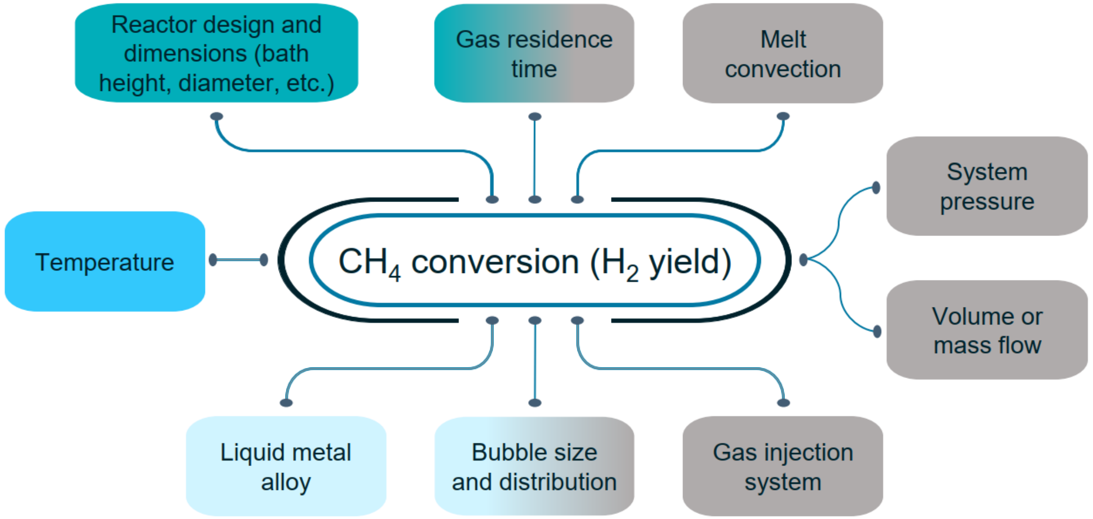
Enables economic green steel production

- Super-flexible hydrogen and carbon production
- Attractive hydrogen delivery cost
- Scalable range of H_2 & CH_4 in product gas
  - Tailored to process requirement
- Infrastructure and feedstock available

Unique demonstration plant

Research center for Hydrogen and CarbonUnique

- Tailored optimization of process parameter

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