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DRI Technology: Status, Trends and hydrogen use

Metal Consulting

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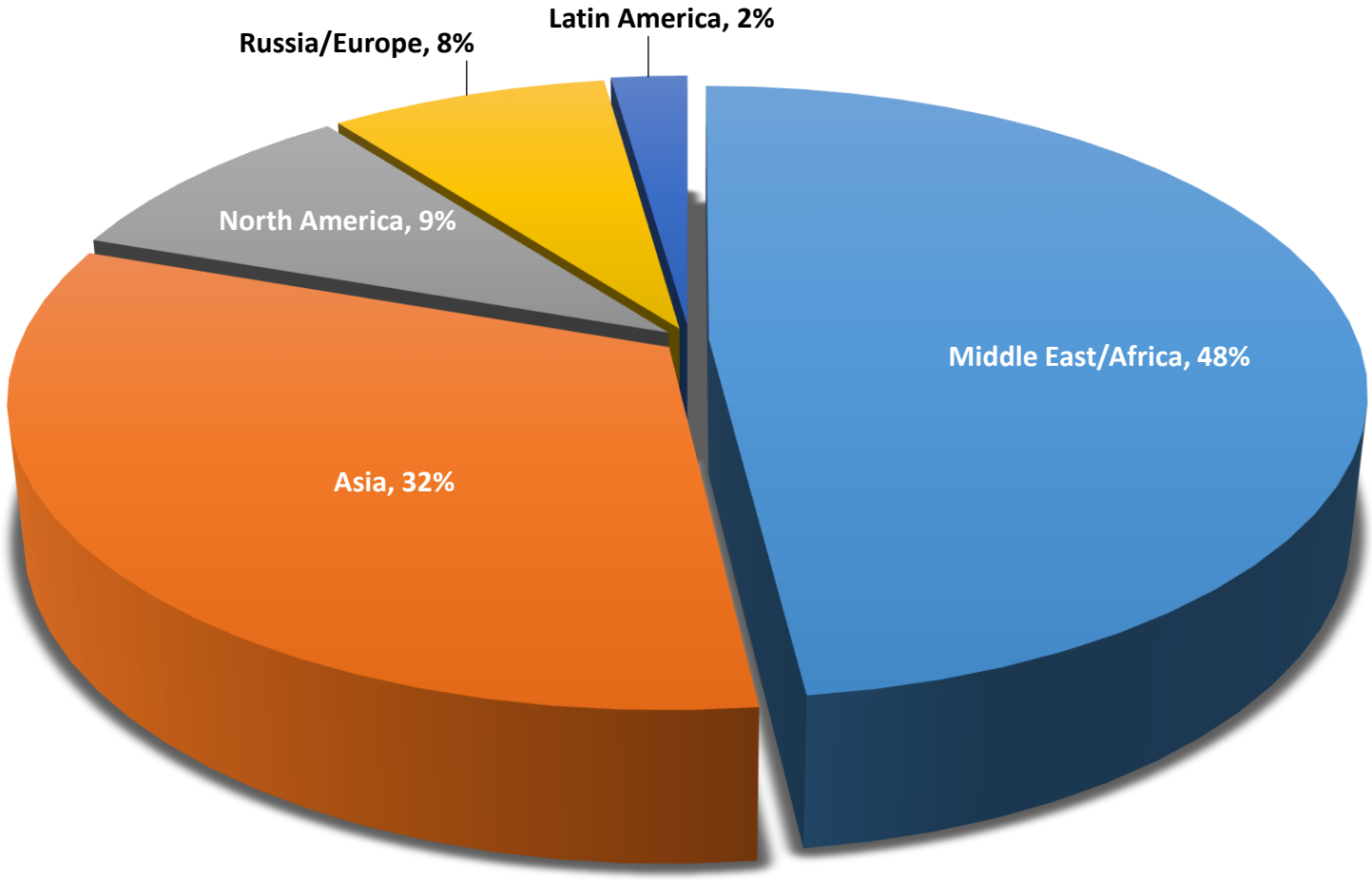
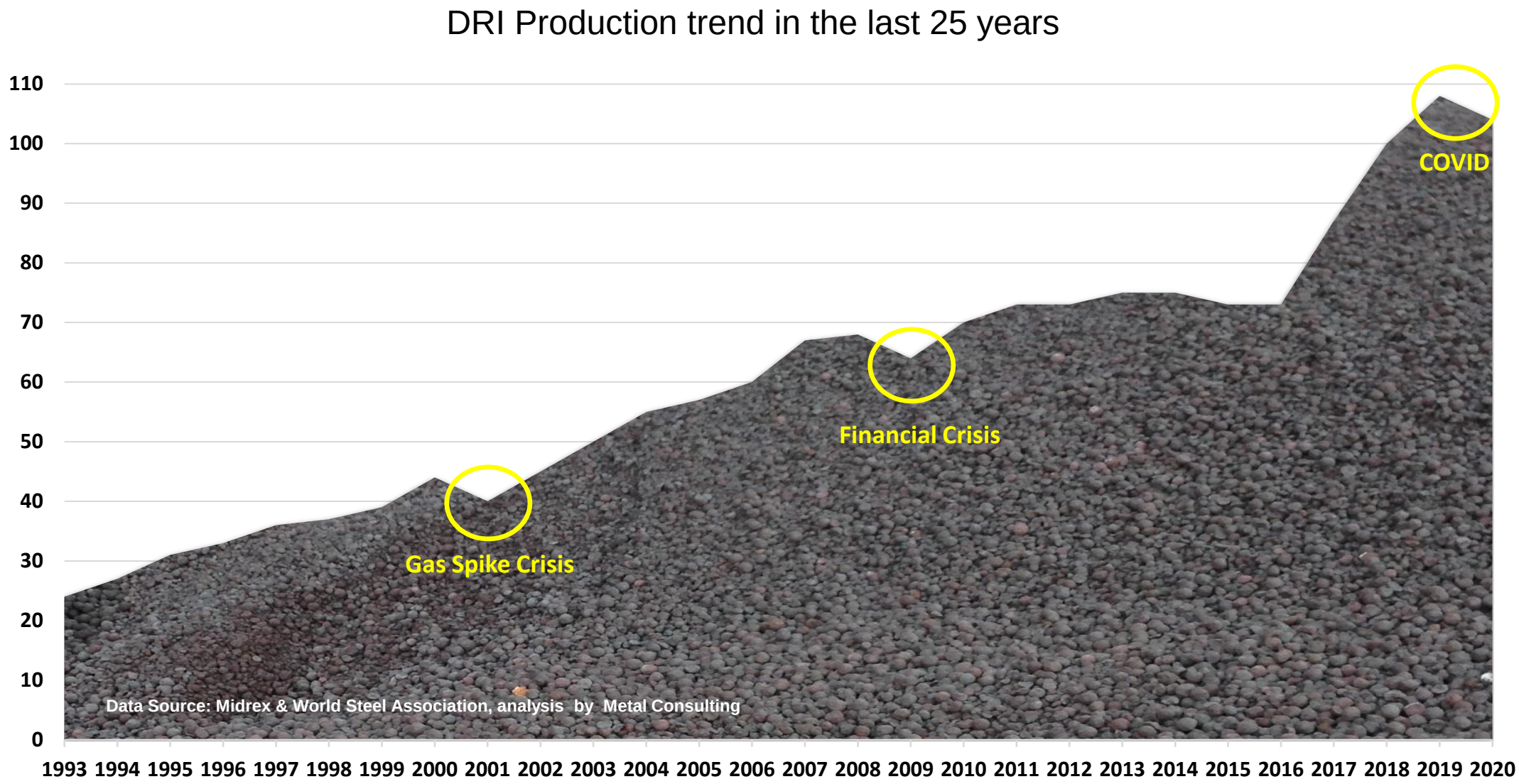
WHERE DRI/HBI IS PRODUCED?

The production of DRI and HBI in the world is around 104 million ton/year



2020 Data Source: World Steel Association, Midrex and SIMA analysis Metal Consulting

DRI/HBI PRODUCTION WORLDWIDE - HISTORICAL TREND

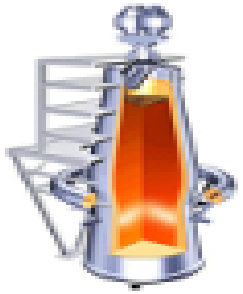


TRADITIONAL DRIVERS FOR DRI USE

DRI was initially **invented** and used **out of necessity in developing countries** that **didn't have access to local scrap** or because of an extremely high cost for scrap in the production of regular steel.

In **developed countries** DRI is used in conjunction with scrap or to replace more expensive metallics in the production of **high-grade steel**.

The more the steel production **shifts from BF to EAF** the more increase the consumption of Ore Based Metallics such as Pig Iron and DRI.



BF

EAF

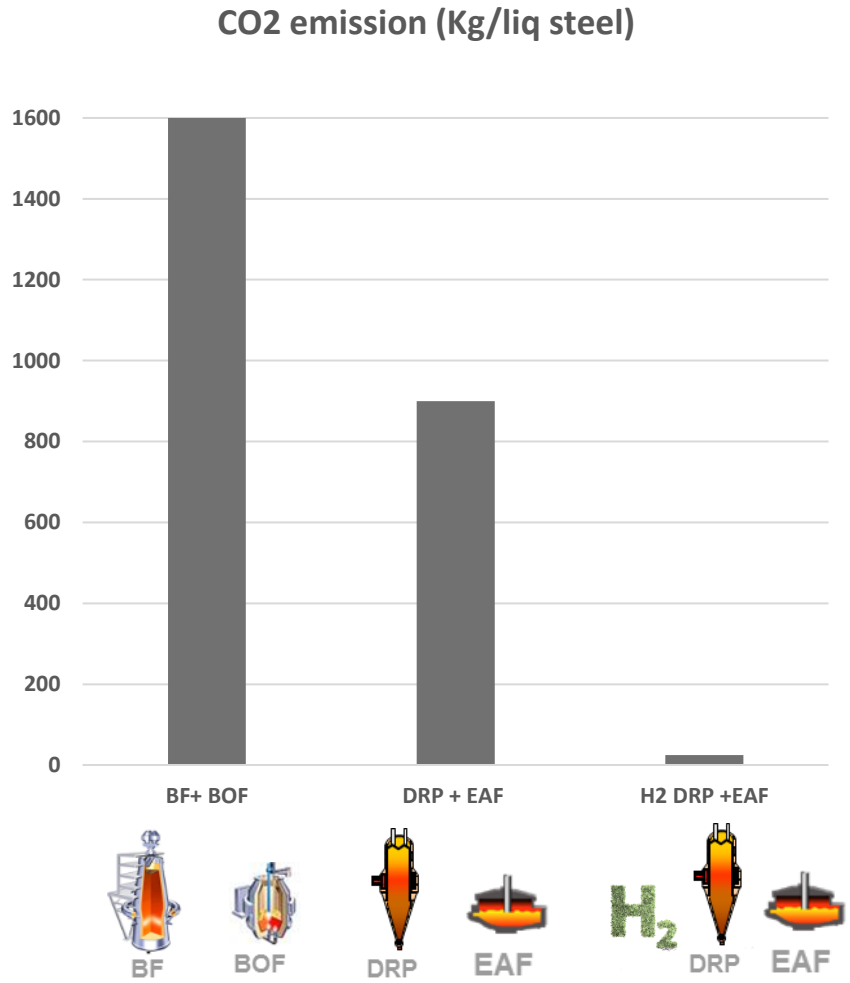
This is because, to replace BF steel that, is normally used to produce high grade steel, the EAF needs growing percentages of DRI to dilute scrap residuals.

NEW DRIVER FOR DRI USE: DECARBONIZATION

To the previous two main drivers it was added in the last few years a new one: Decarbonization of the steel production

Compared to an Integrated Steel mill based on a Blast Furnace and BOF an EAF Mill coupled with a gas based DRI plant emit about half of CO2. (from 1600 to about 900 kg/t liq. steel)

If the DRI Plant is fed with 100% green Hydrogen the CO2 emission goes to only 25kg/t (HYBRIT process)



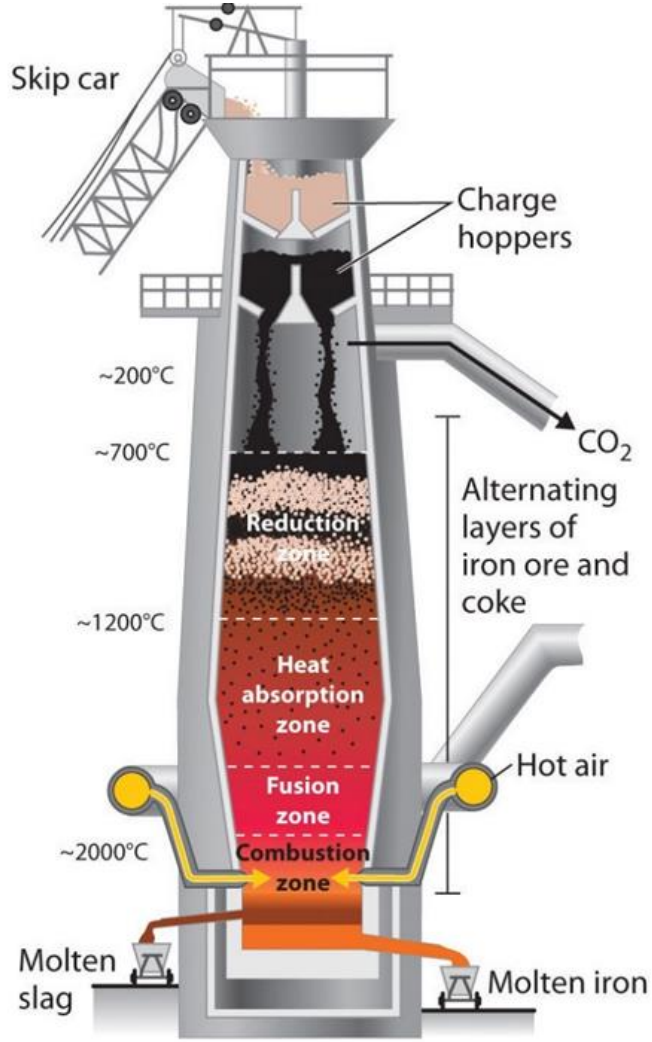
DRI USE IN THE INTEGRATED STEEL PRODUCTION

DRI/HBI is not used exclusively in EAF.

It can be used also directly in Blast Furnace (BF):

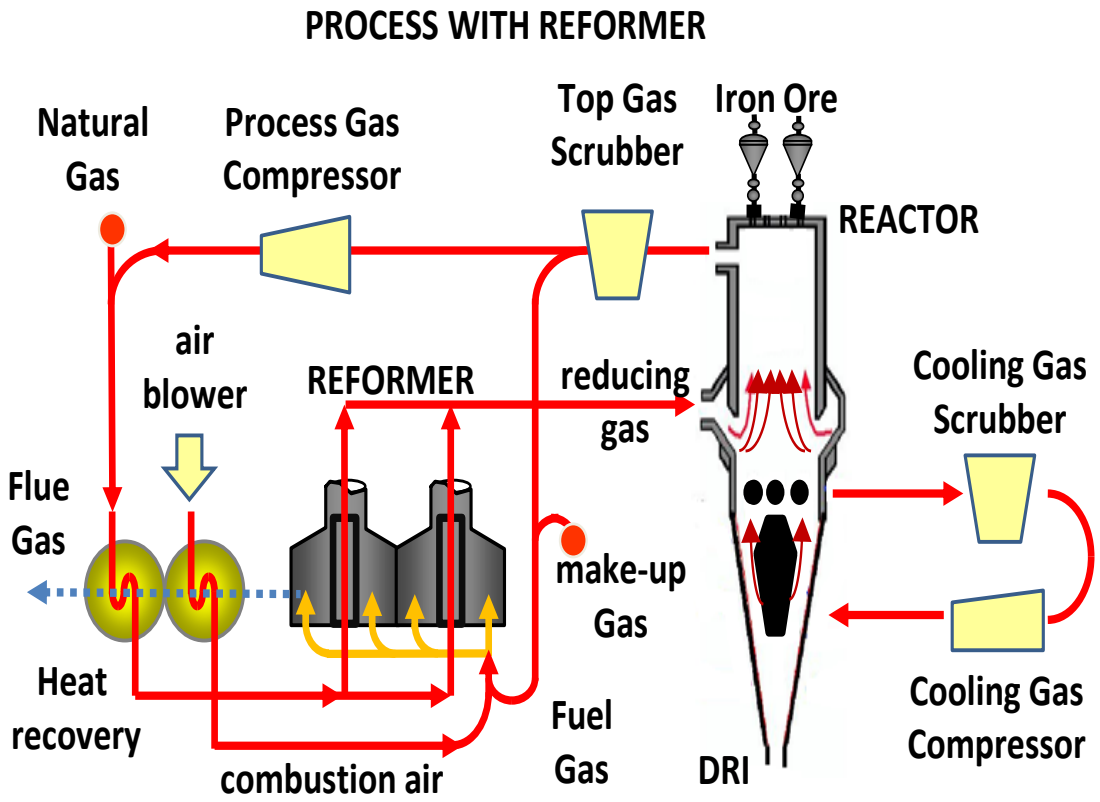
1. 1.To increase hot Metal productivity in the BF. Hot Metal production increase; about 7-8% per each 10% of burden metallization and coke rate decrease by about 7%.

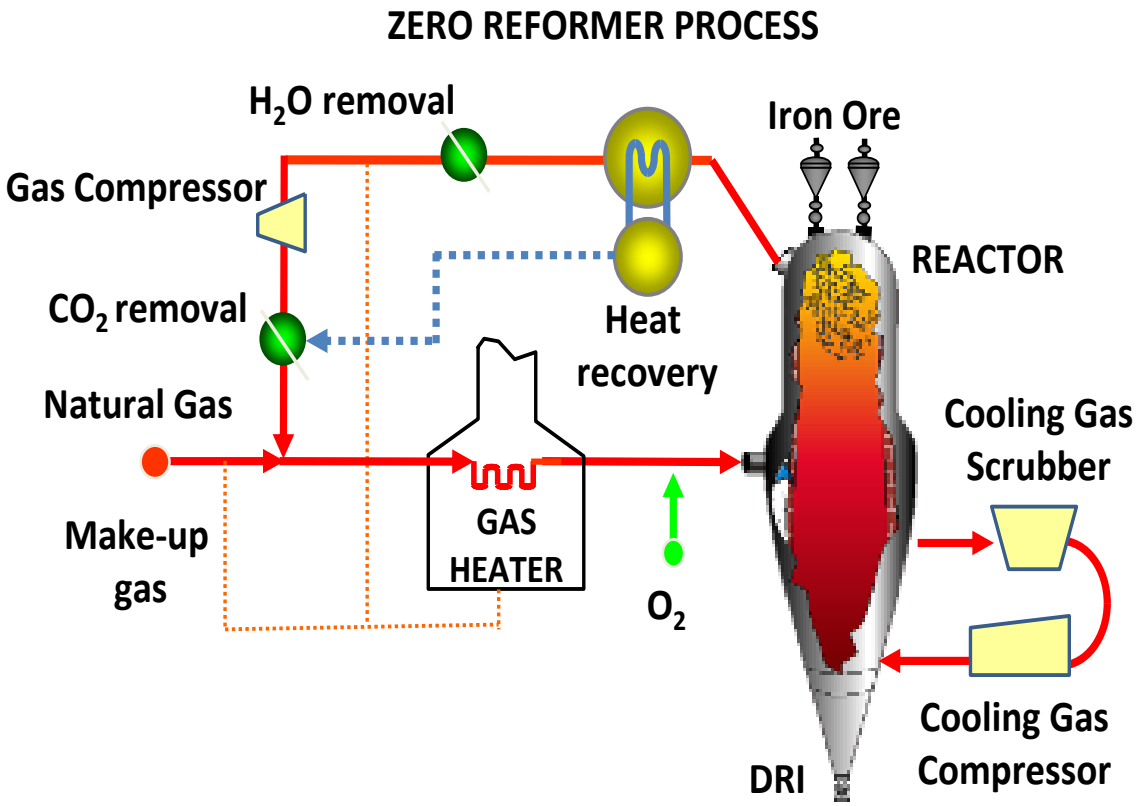
2. To keep the same liquid steel production rate but dramatically reducing the environmental impact. The reduction of coke rate results in significantly reduced CO2 emissions.



(a) Blast furnace

HOW DRI IS PRODUCED- GAS BASED PROCESSES





Source:

1) "Midrex® Process & HOTLINK® Process." Engineering || KOBE STEEL, LTD. Web. 18 Feb. 2015.
2) Duarte, Pablo E., Jorge Becerra, Carlos Lizcano, and A. Martinis. "ENERGIRON Direct Reduction Technology-Economical, Flexible, Environmentally Friendly." Acero LatinoAmericano 6 (2008): 52-58

CARBON CONTENT IN DRI AND ITS USE

DRI CARBON CONTENT	
> 4.0%	DRI used as P.I. Replacement
3.0 – 4.0 %	DRI used in combination with scrap
2.0 - 3.0 %	EAF fed by DRI only
< 2.0%	HBI/Special applications

Benefit of the Carbon in DRI for EAF

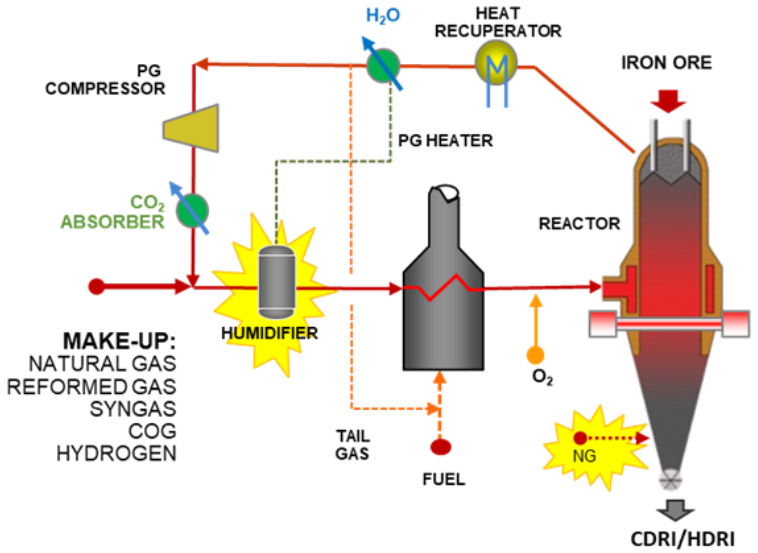
- ✓Carbon in DRI is a source of energy that lower electrical consumption and increase productivity
- ✓Foaming slag is essential for modern EAF operations and carbon in DRI helps the Foamy slag formation
- ✓Carbon in DRI is pure; no presence of ashes, sulfur, volatile matter, etc.
- ✓Carbon in DRI has a higher yield than injected carbon

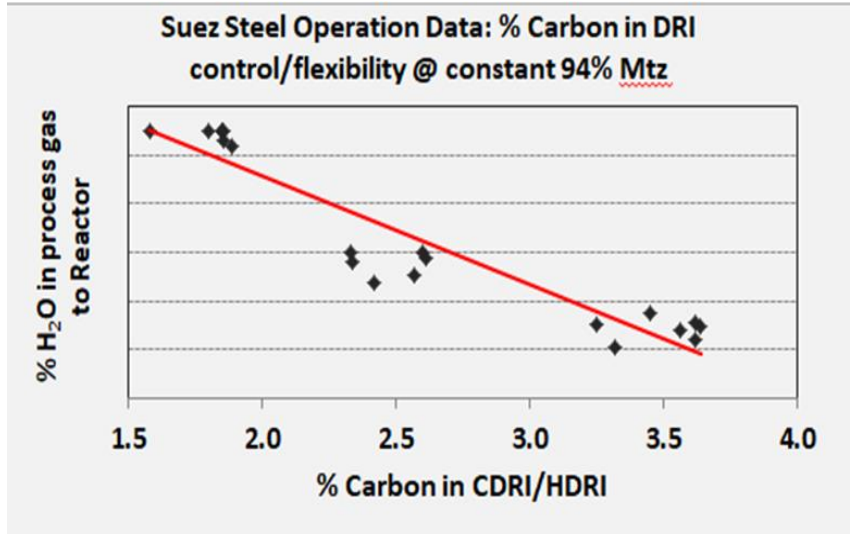
PRODUCTION METHODS FOR FLEX/HIGH CARBON DRI: HYL ZERO REFORMED

The **first plant** to produce high carbon was the HYL ZR (Zero Reformer) plant in HYLSA (now Ternium) **Monterrey Mexico in 1998**. Since then, more than 35 Million tons of high Carbon DRI has been produced with HYL ZR technology.

The Carbon deposition rate is controlled by changing the % of the humidity (through humidifier) in the reducing gas fed to the Reactor, promoting the re-gasification back to CO and H_2.

The Carbon in the DRI can range from 1.5% to more than 4%.





PRODUCTION METHODS FOR FLEX/HIGH CARBON DRI: MIDREX ACT

In this new technology, the CO- stream from the reformer is sent to the transition zone of the reduction furnace to produce heat and additional generation of carbon in the DRI.

The first implementation of MIDREX ACT™ is currently in the **HBI Cleveland-Cliffs, plant in Toledo, Ohio, started up in spring 2021**

The carbon in the HBI can range between 1.5 % to 3 % and currently is around 2.15 % with 96.2% metallization. (*)

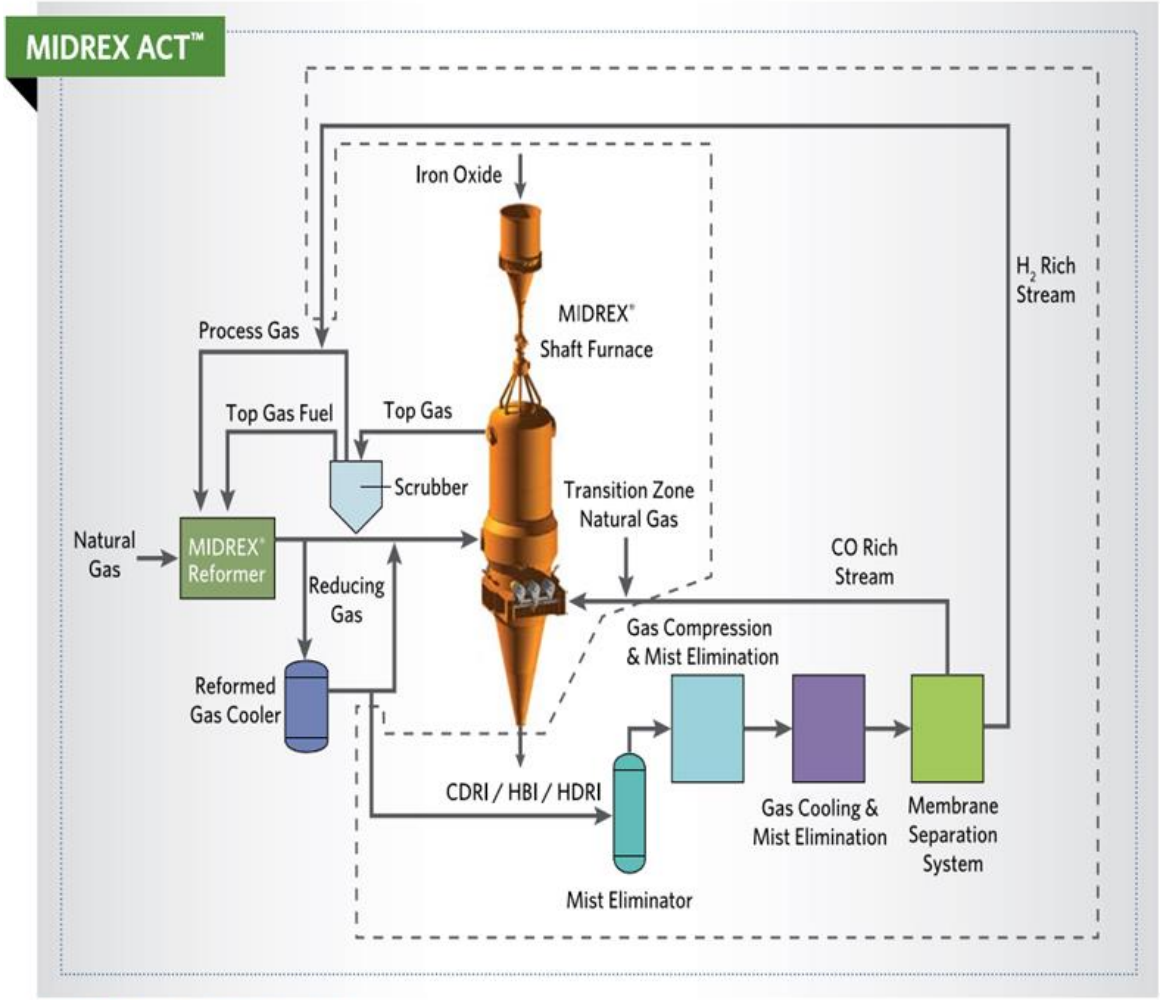


FIGURE 5. *Simplified ACT™ Flowsheet*

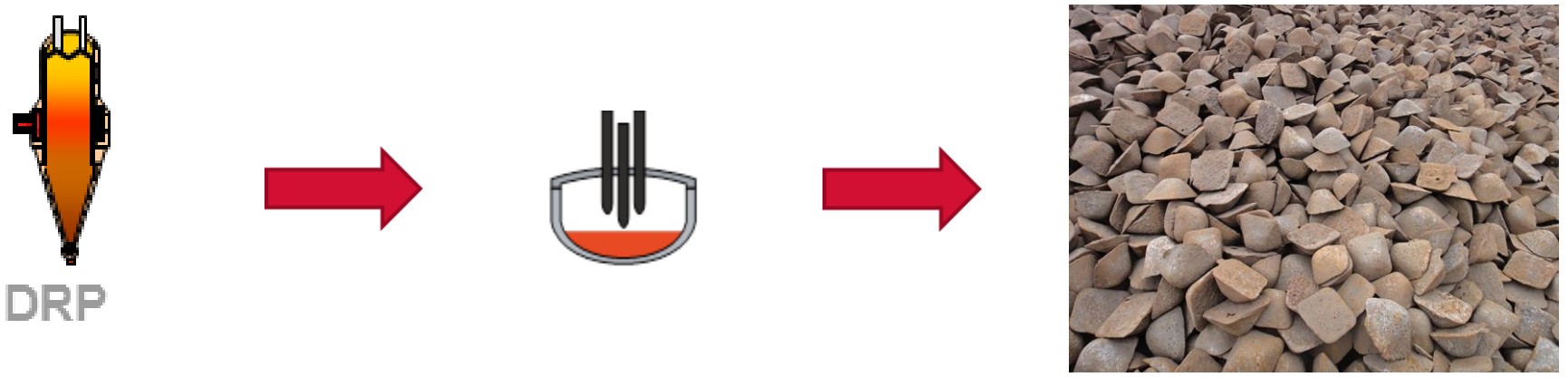
(*) Source: CLF website Product data sheet_072021

Source: Direct from Midrex 3rd and 4th Q 2018

PIG IRON PRODUCTION VIA DRI GAS BASED MODULE

Because we can produce High Carbon DRI with Carbon content > 4%, it is possible and feasible to produce High-quality Pig iron with a gas-based module coupled with a specially designed EAF or SAF Reducing Furnace.

The production of hot metal using DRI instead of the traditional blast furnace route has a **significantly lower environmental impact with half of the CO2 emission**.



This production scheme would allow for mining companies an **outlet for low-grade ores**, that eventually could not be utilized in BF for environmental constraints, to be used to produce a merchantable product.

HYDROGEN USE AS A REDUCTANCT: WHY?

What is the major advantage to use H2 Instead CH4 in the reduction process?

WE WILL PRODUCE ONLY WATER AND NOT CO_2 AS BY PRODUCT

CH4

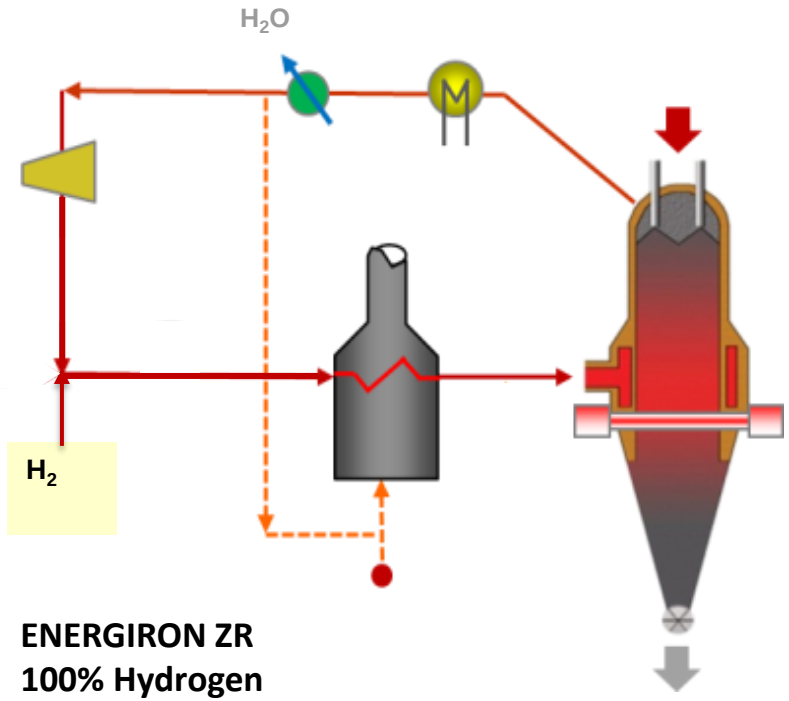
$$Fe_2O_3 + 3CO \Rightarrow 2Fe^\circ + 3CO_2$$
$$Fe_2O_3 + 3H_2 \Rightarrow 2Fe^\circ + 3H_2O$$

H2

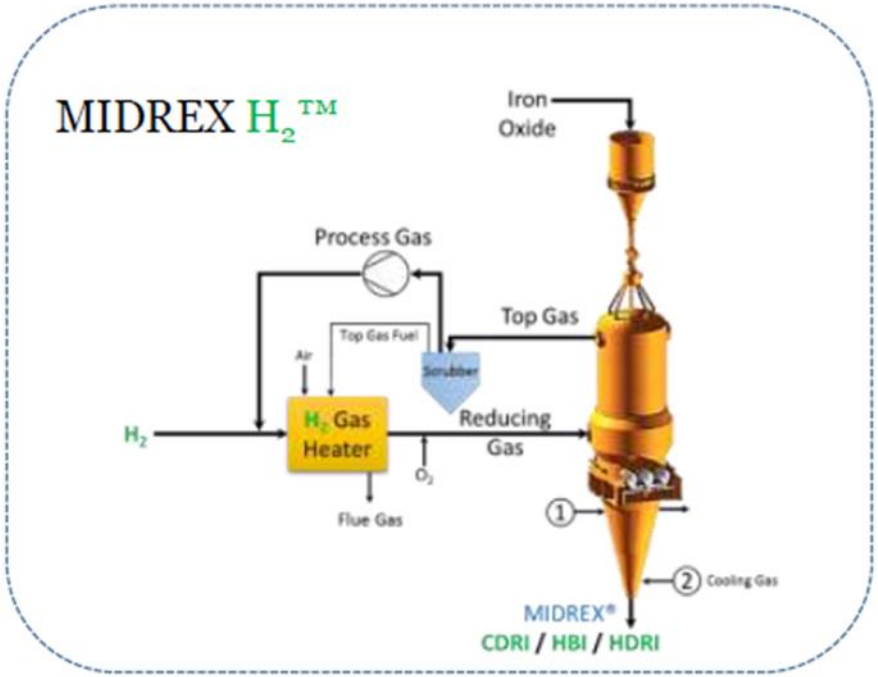
$$Fe_2O_3 + 3H_2 \Rightarrow 2Fe^\circ + 3H_2O$$

DRI TECHNOLOGIES AND HYDROGEN

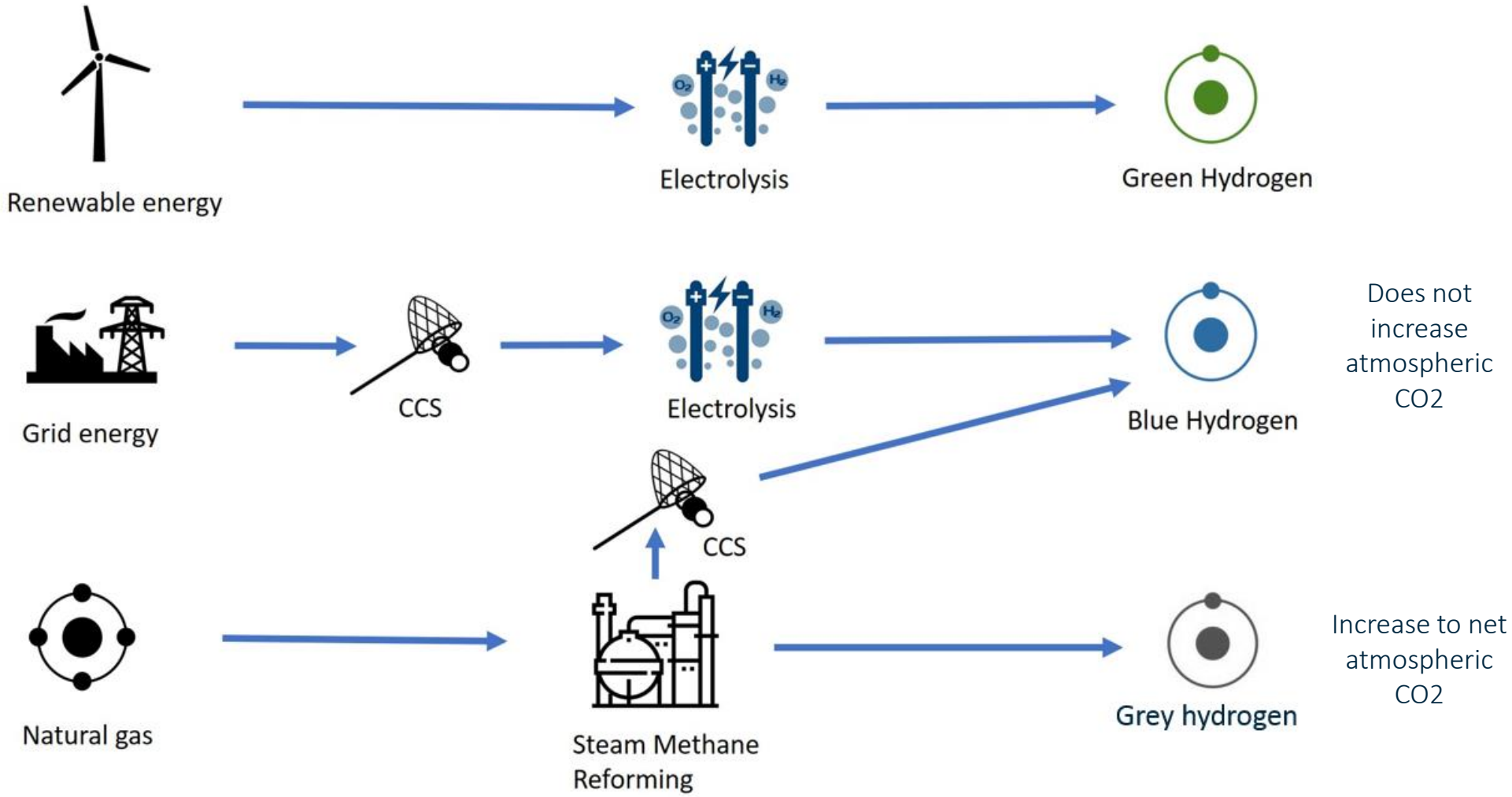
Both mayor Gas Based DRI technology suppliers, Midrex and ENERGIRON/HYL, are capable to produce DRI using Hydrogen.



ENERGIRON ZR
100% Hydrogen

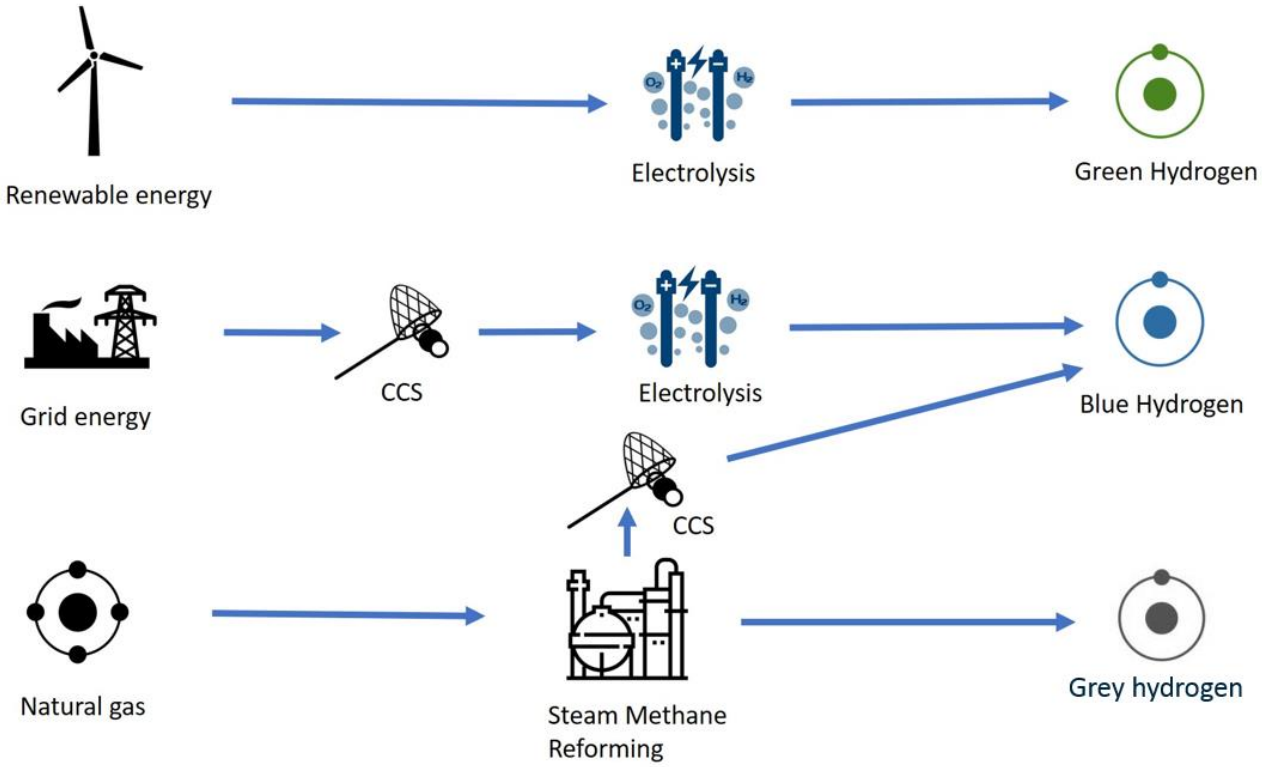


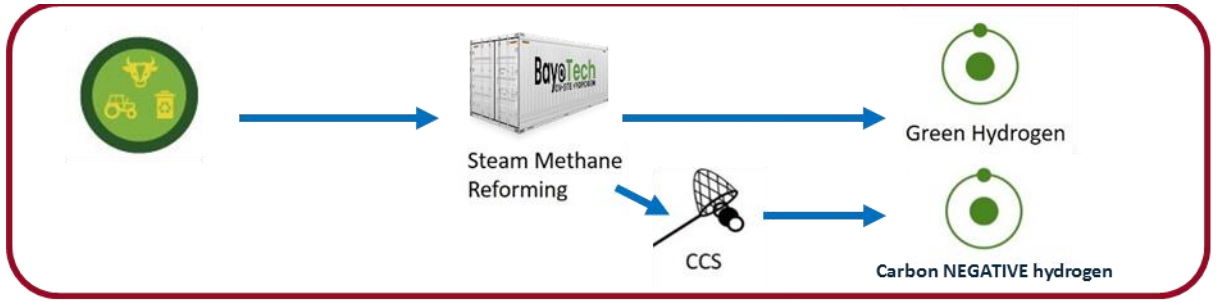
HYDROGEN COLORS



Picture credit – MIDC

HYDROGEN COLORS



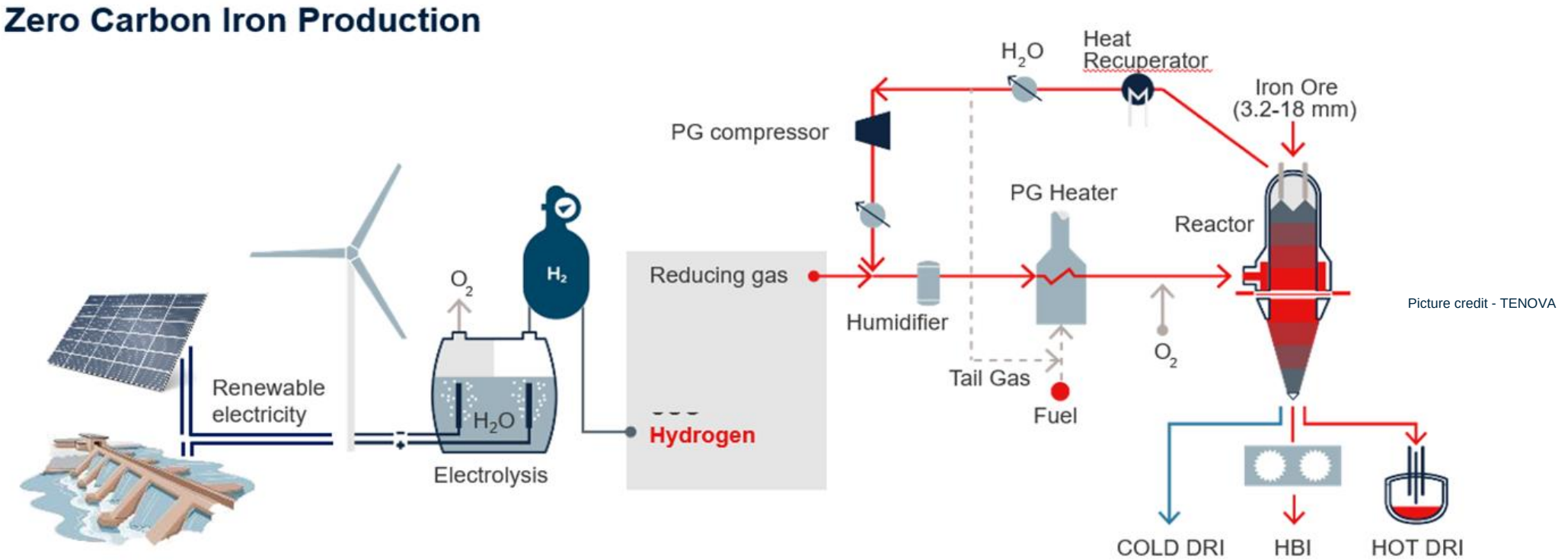


Biomethane to hydrogen with CCS is the ONLY way to generate carbon negative CO_2

Picture credit – MIDC

PRODUCTION OF “GREEN” H2 - ELECTROLYSIS

The most popular way to produce carbon-free or **“green” H2 is made from water electrolysis** and using renewable energy. For carbon-free H2 generation, there are different available electrolyzer technologies, such as **Proton Exchange Membranes (PEM)**, **Atmospheric Alkaline Electrolyser (AAE)** with units already in operation for high purity H2

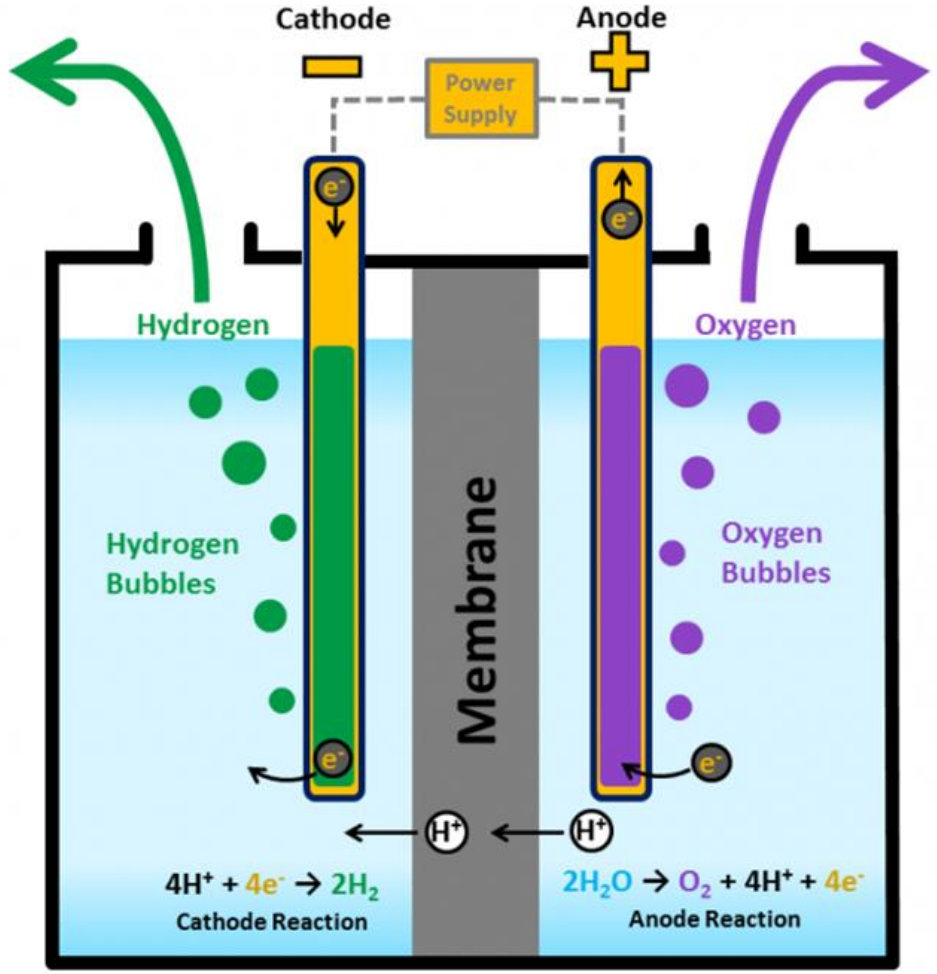


Picture credit - TENOVA

Currently, the largest Electrolyzer module is sufficient only for the operation of a DR module of about 50,000 t/y DRI.

DISADVANGES OF H2 ELECTROLYZERS PRODUCTION

- ✓ Electrolysis systems are driven by the price of electricity and for each kg of hydrogen you need about 55kWh of electricity to produce.
- ✓ Metal processing requires A LOT of hydrogen therefore the electrolyser size is large and expensive.
- ✓ Metal processing needs a consistent supply of hydrogen – electrolysis powered by wind/solar is not 24/7 available. Consequently, a storage may be required which adds to the cost.



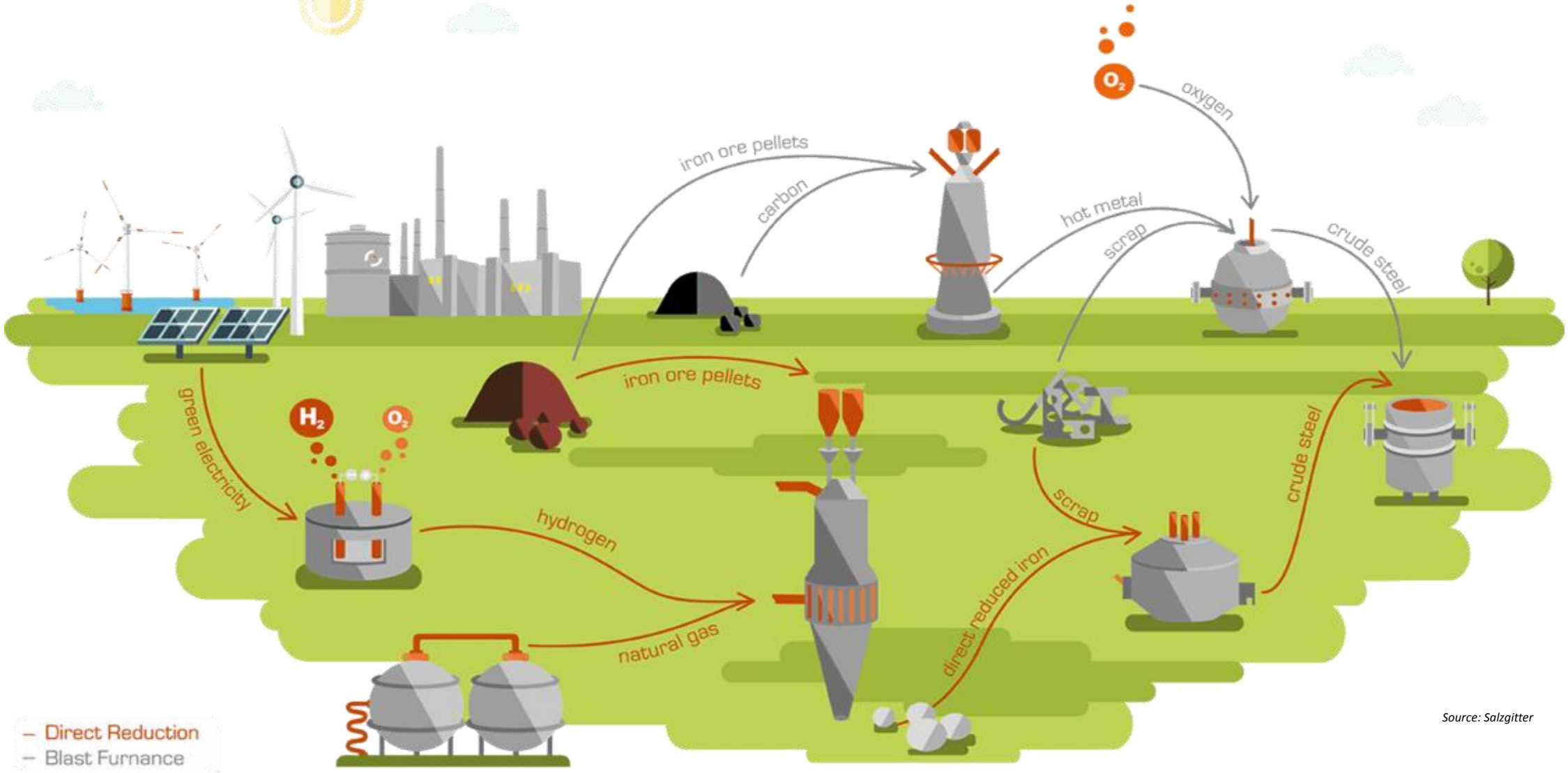
HURDLES FOR HYDROGEN BASED ROUTE

- ✓ Hydrogen cost produced via electrolyzers (Green Hydrogen) is sensibly more expensive than the one produced via natural gas (grey Hydrogen)
- ✓ Cost of producing steel with and Hydrogen route cost 20-30% higher than with BF
- ✓ A large amount of H2 is required by DRI plants (not achievable with today's Electrolyzers)
- ✓ Low or 0%C DRI, will require specific EAF melting practices and a minimum carbon injection, together with particular slag practices

MAIN EUROPEAN HYDROGEN GAS BASED DRI PROJECTS

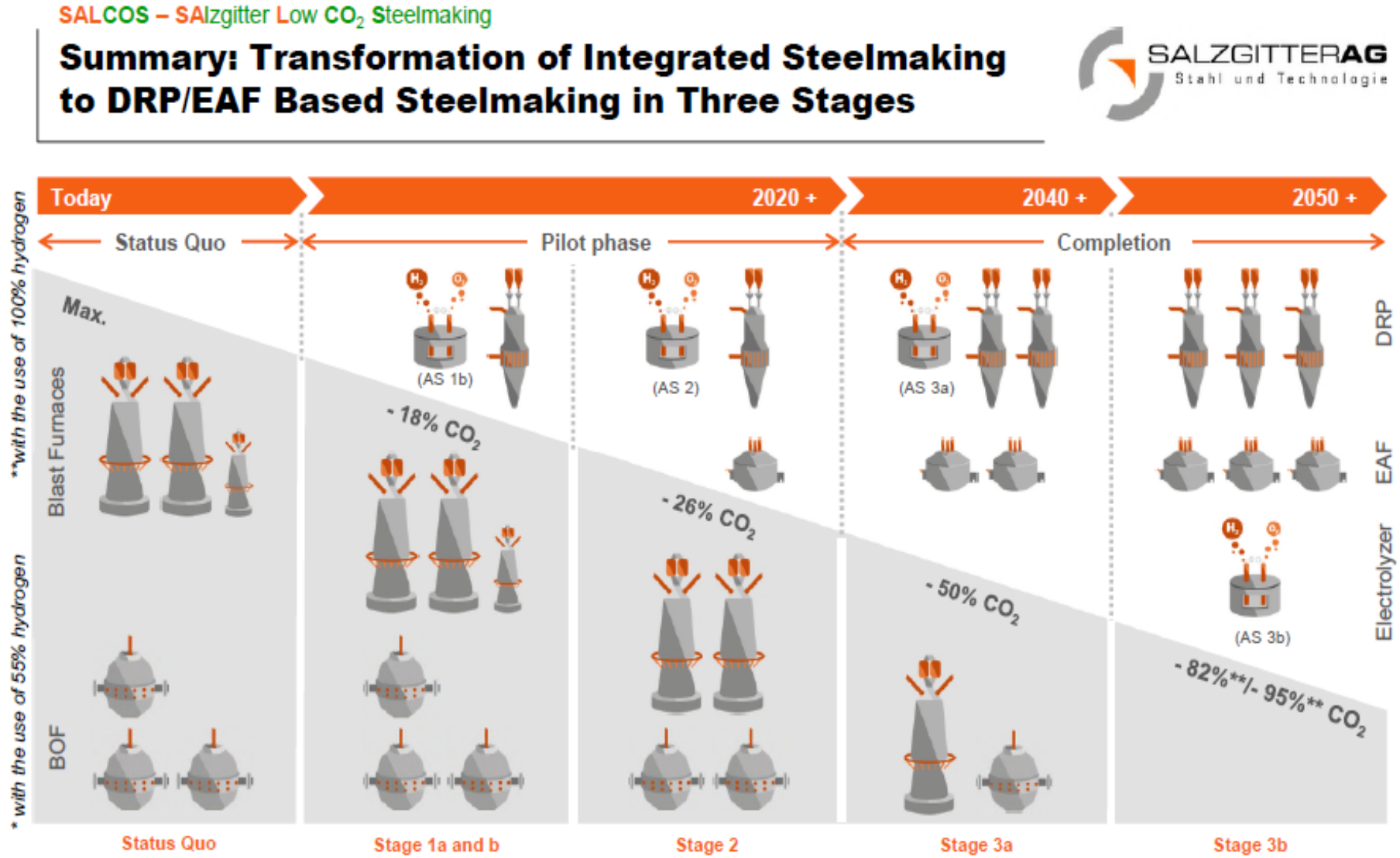
PROJECT	COMPANY	DRI Hydrogen Technology	Potential CO2 Reduction	NOTES
HYBRIT	SSAB,LKAB, Vattenfal	HYL	Fossil Free	Pilot Plant –H2 based reduction and melting trials 2020-24
SALCOS	Salzgitter AG	HYL	Up to 85%	Progressive substitution of BFs with H2 DRI reactors
AM HAMBURGH	Arcelor Mittal	Midrex	Data not available	100,000 t/y - initially with hydrogen sourced from natural gas

THE SALCOS (SALZGITTER LOW CO2 STEELMAKING) PROCESS



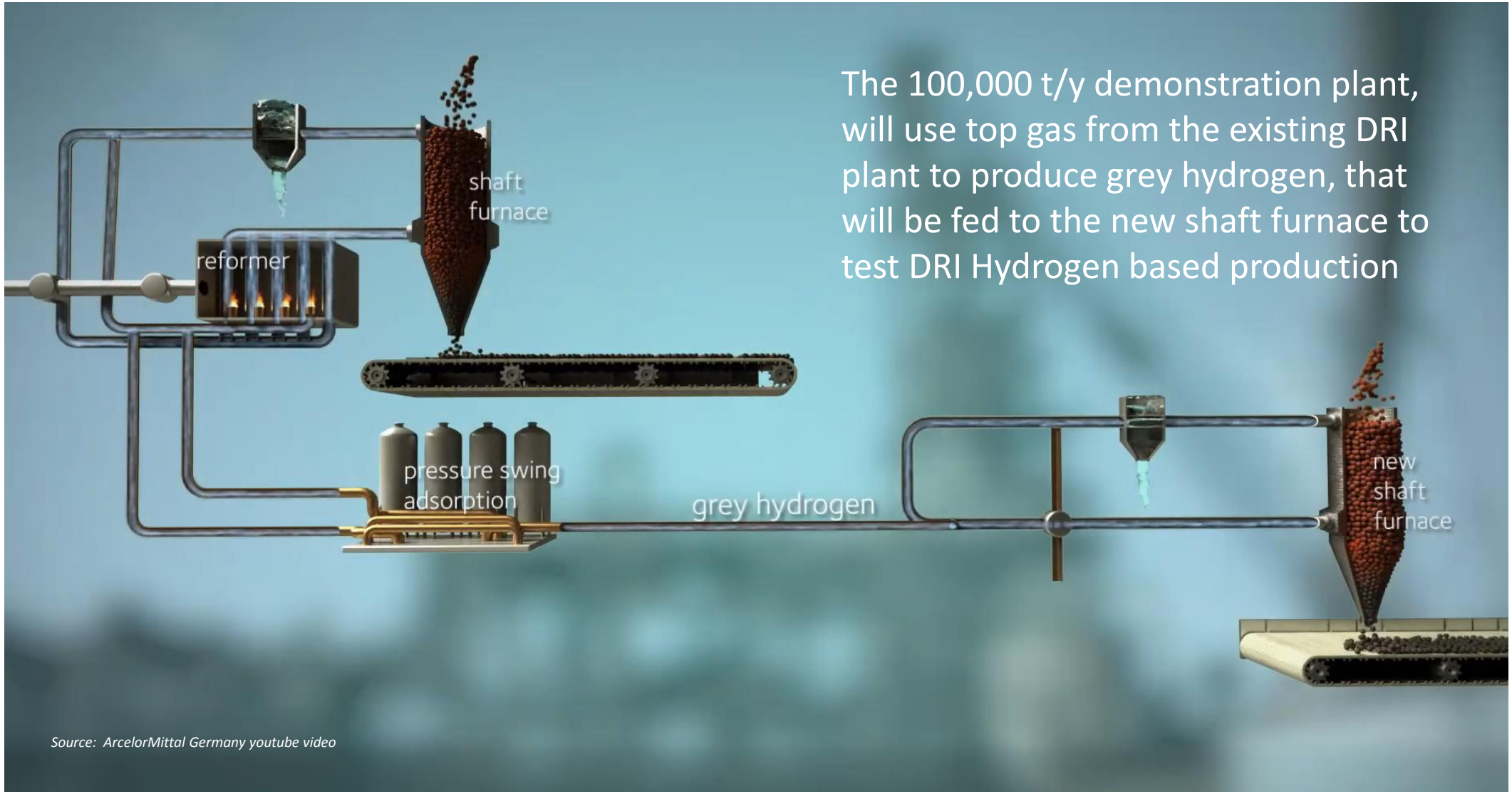
Source: Salzgitter

THE SALCOS (SALZGITTER LOW CO2 STEELMAKING) PROCESS



Source: Salzgitter

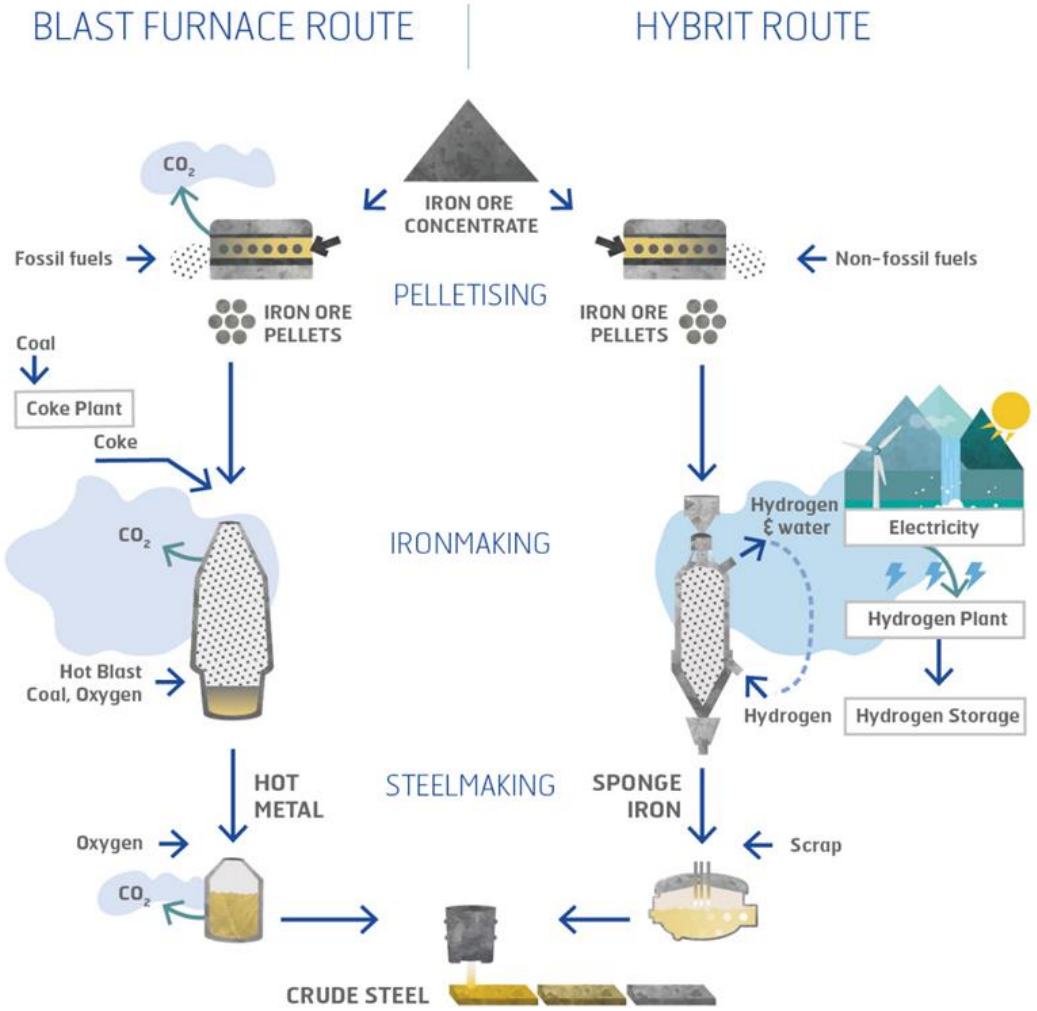
ARCELOR MITTAL HAMBURG



THE HYBRIT PROCESS

HYBRIT (Hydrogen Breakthrough Ironmaking Technology) is a joint venture between **SSAB, LKAB and Vattenfall**, aiming to replace coal with hydrogen in the steelmaking process significantly reducing CO2 emissions.

The idea is to remove fossil fuel from the ironmaking process and substitute them with electrical energy generated by renewable energy.



Source: Hybrit

THE HYBRIT LOCATION

The HYBRIT plant is in Luleå a coastal city in Swedish Lapland.
In June of 2021, the plant produced the first 100 t of 100% green hydrogen based (and zero carbon) HBI

Source: Hybrit

FIRST COMMERCIAL SCALE H2 PLANT

The first Commercial-scale H2 based plant will be build **in China** for HBIS group by TENOVA HYL.

The plant will produce **550,000 t/y of DRI using 70 % H2** in the reactor. The rest will be fossil gas.

This compromise stems from the need to have some sort of Carbon content in the produced DRI to be able to be melted with regular EAF.

The plant startup is scheduled for 2022.

Metal Consulting

Thank you

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