“Hydrogen-Hype” in Refractories or just only an Old Hat for Refractory Engineering and Construction?

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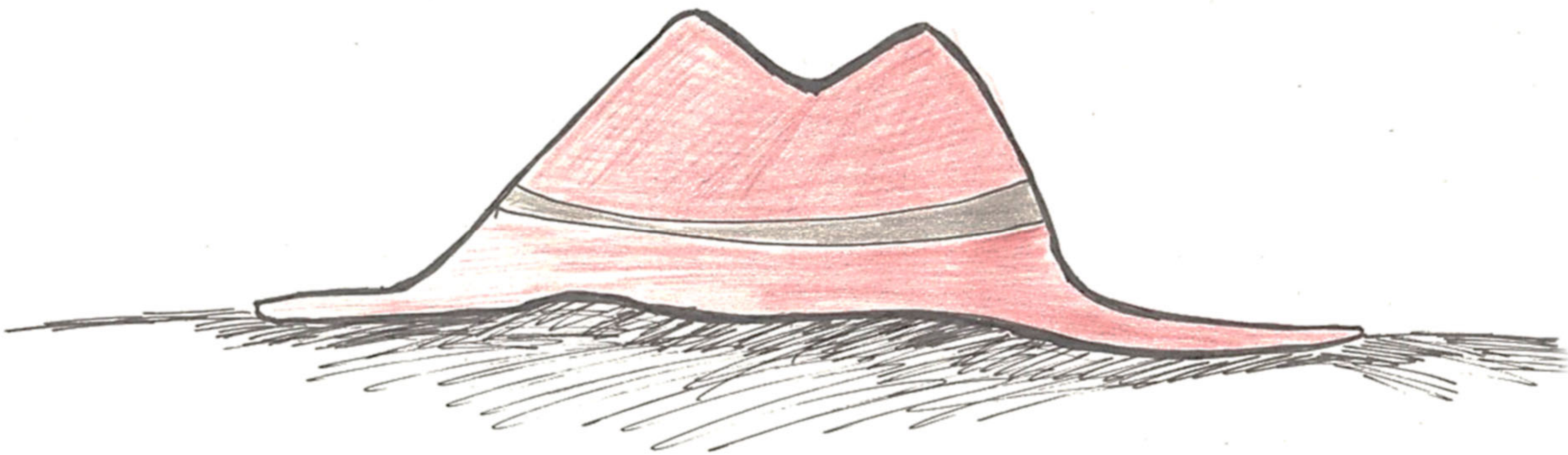

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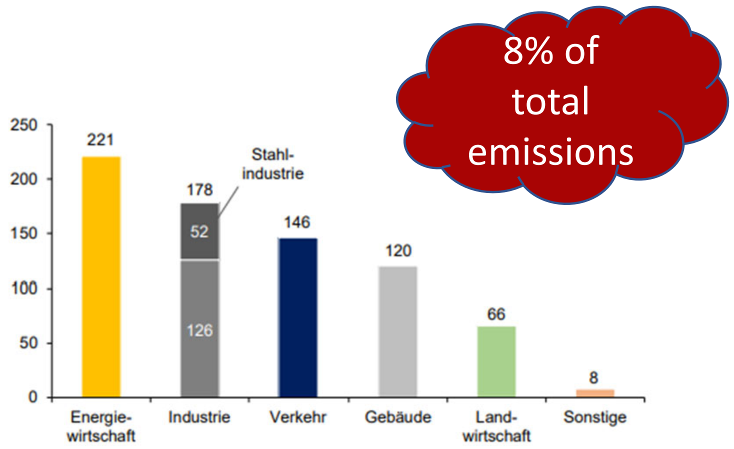
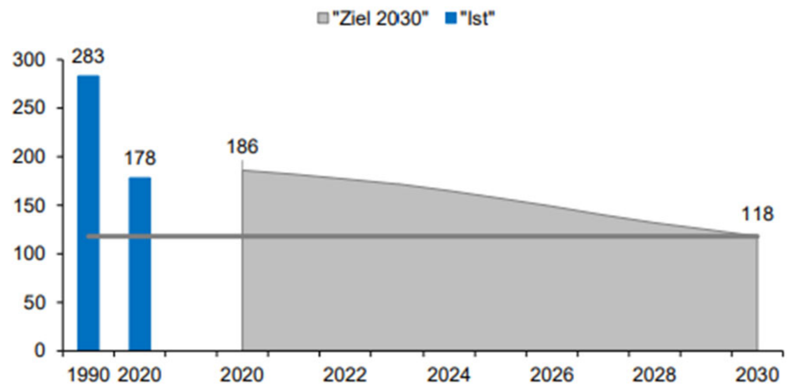
Some Figures

Greenhouse gas-emissions in Germany 2020 by sectors (mio. tons CO2-equivalent)



Quellen: Umweltbundesamt (2022), Wirtschaftsvereinigung Stahl (2022)

Actual-emissions vs. admissible emissios in the industrial sector acc. the federal-climate protection law (in mio. tons CO2)



Quelle: Deutscher Bundestag (2021)

	Terminology	Technology	Feedstock/ Electricity source	GHG footprint*
PRODUCTION VIA ELECTRICITY	Green Hydrogen	Electrolysis	Wind | Solar | Hydro Geothermal | Tidal	Minimal
	Purple/Pink Hydrogen		Nuclear	
	Yellow Hydrogen		Mixed-origin grid energy	Medium
PRODUCTION VIA FOSSIL FUELS	Blue Hydrogen	Natural gas reforming + CCUS Gasification + CCUS	Natural gas | coal	Low
	Turquoise Hydrogen	Pyrolysis	Natural gas	Solid carbon (by-product)
	Grey Hydrogen	Natural gas reforming		Medium
	Brown Hydrogen	Gasification	Brown coal (lignite)	High
	Black Hydrogen		Black coal	

REFRACTORY PRODUCTS NEEDED

*GHG footprint given as a general guide but it is accepted that each category can be higher in some cases.

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H_2 Consumption, CO_2- Emission

	Unit	Value
H_2 amount:	Nm^3/t DRI kg/t DRI	650 58
H_2 purity:	vol%	99.8
H_2 pressure (at	bar_g	min. 4.5

Tk Steel needs 400t H_2/day

	CAS		2
H_2 used (Nm (kg			
Energy input:			
- Hydrogen (H_2) (mm			
- Natural gas (mm			
- Total (mm			
- H_2 energy/total energ			
Carbon content in DRI*)	2.5 wt%	~2 wt%	~0 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

Source: Midrex H2- the road to CO2 Direct reduction, Paper AISTech 2021

Shell produces „only“ 1300 t/Year

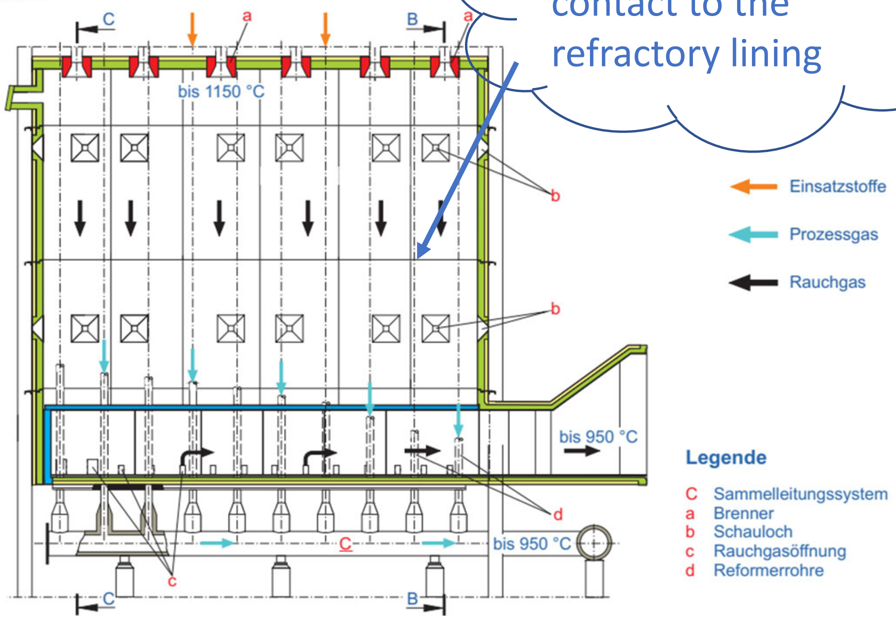
Main processes for hydrogen production:

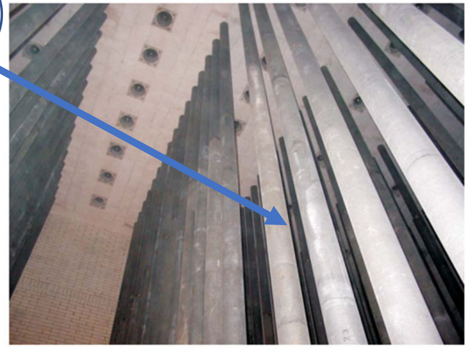
- Steam reforming of methane or other hydrocarbons
- Gasification of organic feedstock to syngas (H_2/CO)
- Recovery from gaseous waste streams
- Electrolysis of NaCl.

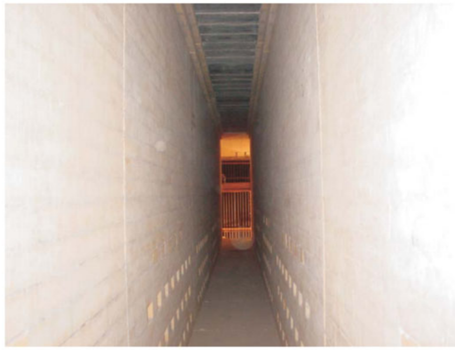
Steam Reforming

Syngas only in the steel tubes- no contact to the refractory lining

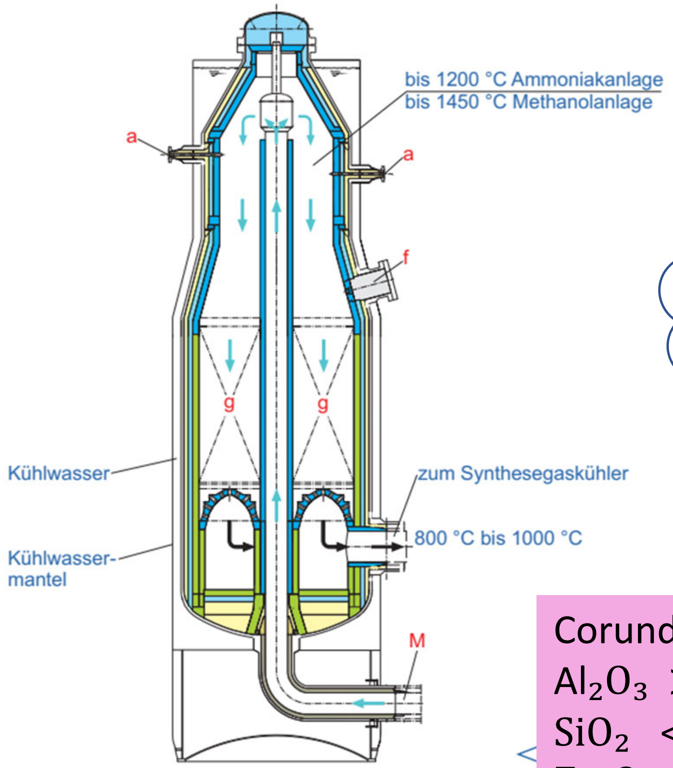
Primärreformer Schnitt A-A







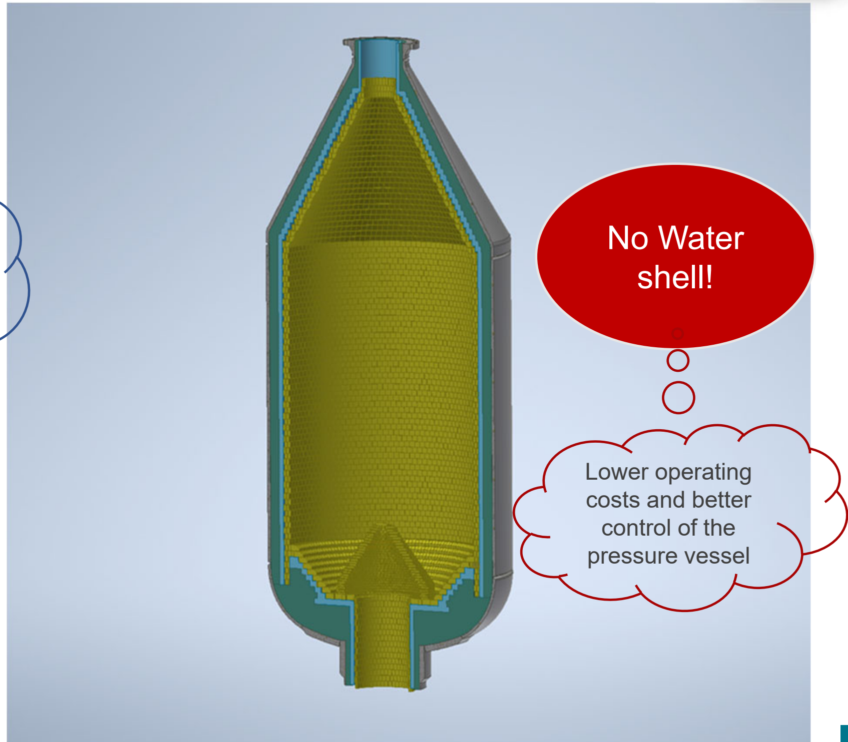
Autothermal Reforming



~40
bar

50-60% H2

Corundum Brick
Al_2O_3 > 99%
SiO_2 < 0,15%
Fe_2O_3 <0,15%



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Mr. CO & Mrs. Hydrogen

the unsaint couple for refractory

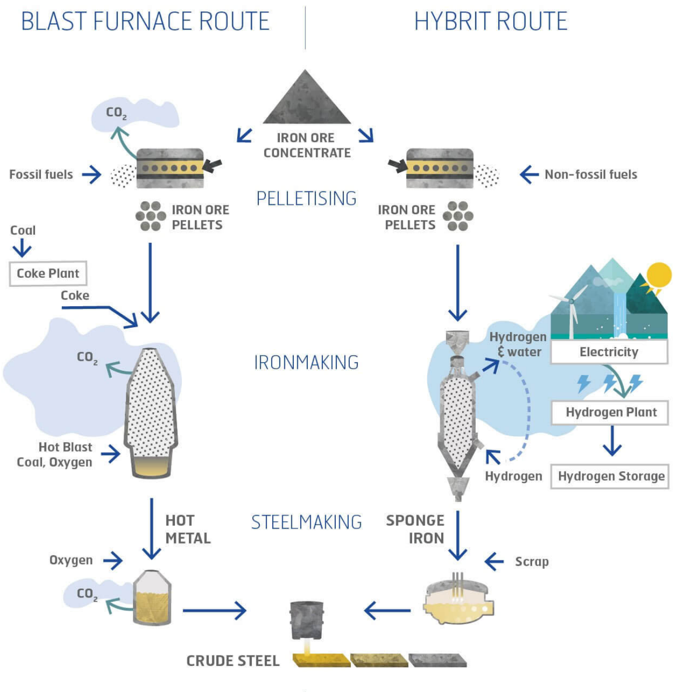
- Temperature and good thermal shock behaviour (inlet area)
- Abrasion Resistance
- Resistance to **CO attack**
- $CO_2 + C \rightleftarrows 2\,CO$ **Boudouard Reaction**

Steam enhance

- Resistance to **H2 attack**
- $2\,H_2 + SiO_2 \rightleftarrows 2\,H_2O + SiO$ **Reduction of Silica**
- Resistance to steam no basic material

Steam inhibit

The future use of hydrogen in the steel industry



Quelle: rwe_enformer_stahl_aus_wasserstoff_grafik-hybrit.jpg

TODAY

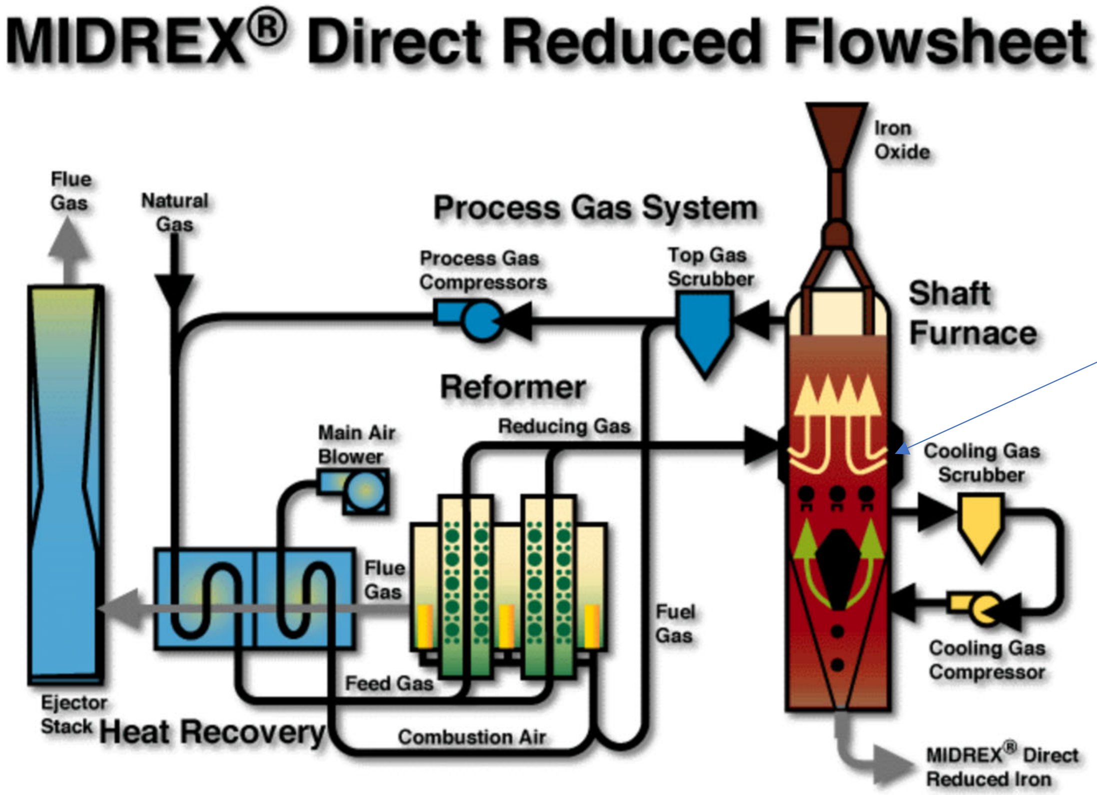
$Fe_2O_3 + 3CO \Rightarrow 2Fe + 3CO_2$

THE FUTURE:

½ Fe2O3 + ½ H2 FeO + ½ H2O

$Fe_2O_3 + 3H2 \Rightarrow 2Fe + 3H_2O$

Midrex now



Gas Plenum Inlet Area:
Corundum Brick & Castable
Al_2O_3: 79%
SiO_2: 20%
CCS: 70 N/mm²
Rev. Linear change (20-1200°C):
6,67 $10^{-6}K^{-1}$

Temperature: 850 – 1200 °C

Conclusion

- It is obvious that for the transition time until sufficient renewable energy is available and hydrogen production plants are in place to cover the requirements, the hybrid form of processes working with natural gas and later with H2 is the realistic scenario.
- The refractory engineering with syngas concerning Carbon oxides **and** hydrogen is by far more challenging and experienced
- Moreover, a DR plant using only hydrogen would be much simpler than MIDREX and HYL-ERNERGIRON, because the gas loop is shorter and methane reforming is not required.
- It could be expected that due to the fast reduction kinetics with H2, the reactor geometry could change but this would have no big influence on the refractory lining

Thank you for listening!