

Hydrogen uses in ironmaking

AUGUST 1ST, 2018

VINCENT CHEVRIER, PHD.

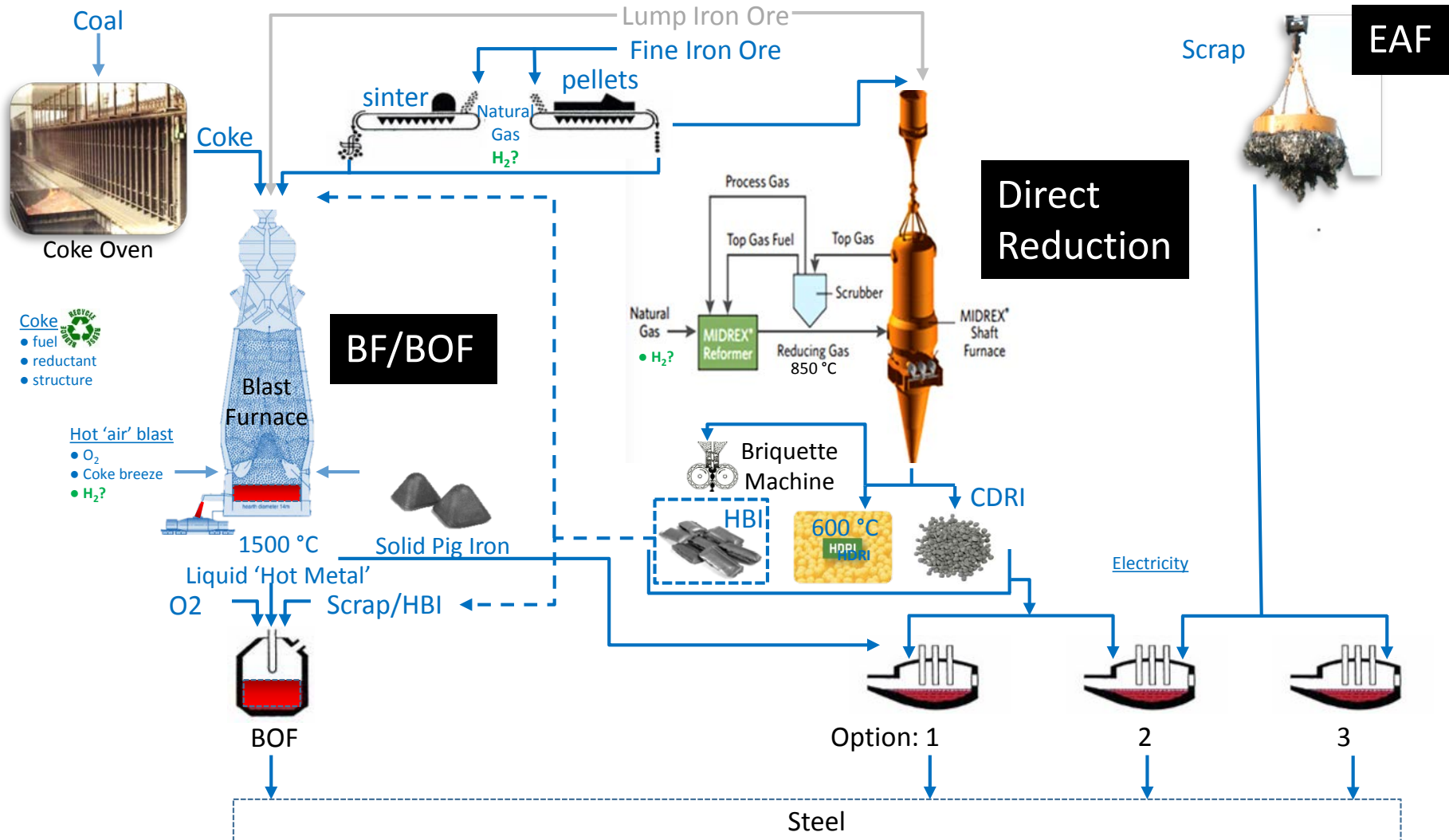
**DIRECTOR – RESEARCH AND
TECHNOLOGIES DEVELOPMENT**

MIDREX TECHNOLOGIES, INC.



MIDREX

Overview of the steel production process



CO₂ Emissions from steelmaking

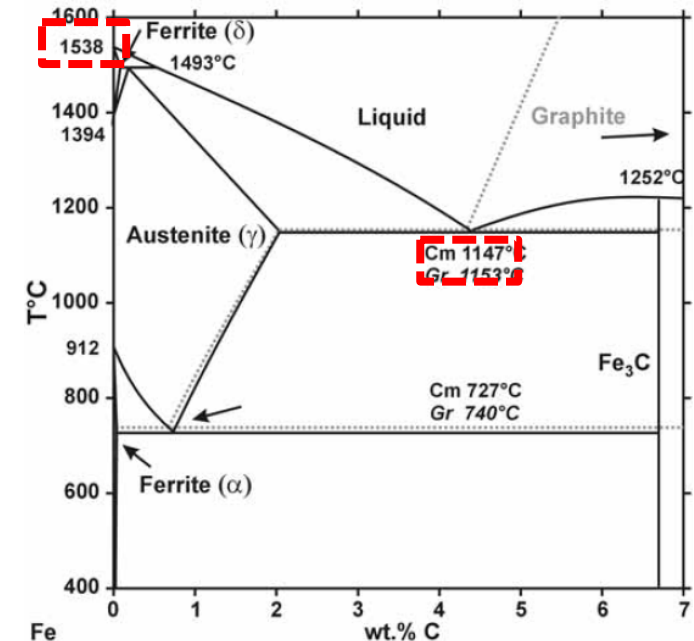
- Steel accounts for 4-5% of the total CO₂ emitted
- Emissions strongly depend on boundary
 - Majority of CO₂ emissions come from power generation, **conversion of iron ore to iron** and re-heating
 - Emissions varies based on how electricity is generated (e.g. coal or nuclear)
- BF-BOF route:
 - 1,600 – 2,000 kg CO₂/ton HRC
 - Limited potential to reduce further (mature technology)
 - Capture / re-use if possible
- EAF (scrap) route :
 - 500-600 kg CO₂ / ton HRC
 - EAF can be misleading: scrap / OBM were previously converted from iron ore
- EAF+DR route:
 - 1,100 – 1,200 kg CO₂ / ton HRC for 100% HDRI charge
 - Lowest commercially proven CO₂ emissions from ore

Carbon in Iron & Steelmaking

Role of carbon in steelmaking:

- Reduces melting point
- Provides energy (with oxygen)
- Steel products contain carbon as alloying element

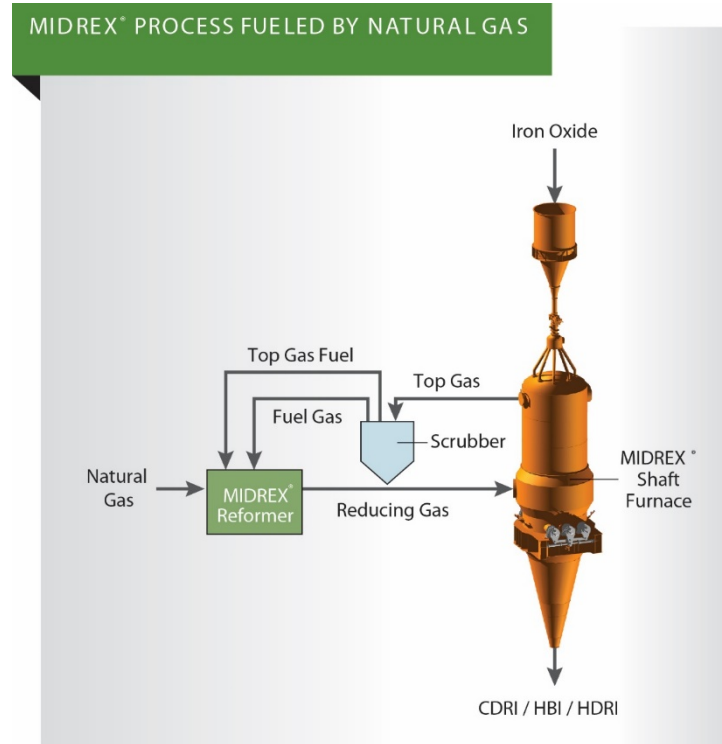
→ Carbon-free steelmaking is very unlikely but significant reductions in CO₂ emissions can be achieved with H₂



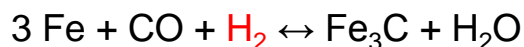
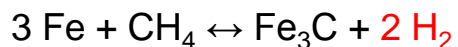
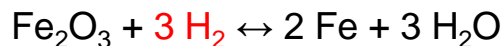
Source: Durand-Charre M. The Microstructure of Superalloys. 1999

Midrex® NG process

- First plant built in 1969
- Over 70 units constructed worldwide
- Over a **billion tons of iron** produced by the MIDREX® process
- Iron ore is reduced to metallic iron in the MIDREX® Shaft Furnace by **Hydrogen** and CO
- MIDREX Reformer reducing gas composition is typically 55% H₂ and 36%CO (ratio ~1.5)
- Midrex plant with SMR has operated since 1989 ~75% hydrogen



Reactions (w/ Hydrogen only)



Heat

Endothermic

Endothermic

Exothermic

Description

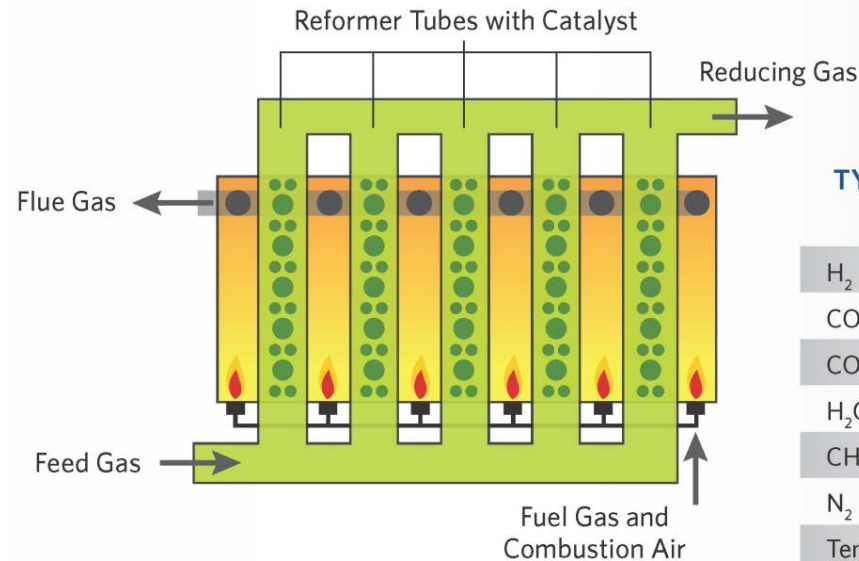
Reduction by H₂

Carburization

Carburization

Midrex® NG process

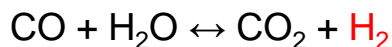
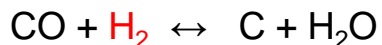
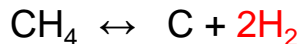
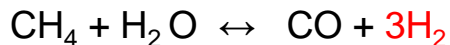
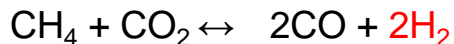
- Reducing gases are generated in MIDREX® Reformer.
- Process can use any Natural Gas source regardless of sulfur or heavy hydrocarbon content
- NG consumption ~2.35 Net Gcal / ton DRI



TYPICAL COMPOSITION

	INLET	OUTLET
H ₂	35	55
CO	19	35
CO ₂	15	2
H ₂ O	13	6
CH ₄	17	1
N ₂	1	1
Temp. (°C)	580	980

Reactions (w/ Hydrogen only)



Heat

Endothermic

Endothermic

Endothermic

Exothermic

Exothermic

Description

CO₂ reforming

H₂O reforming

Methane cracking

Beggs or Water/carbon shift

Water/gas shift

Newest MIDREX® Plants in North America

Voestalpine (Corpus Christi, Texas USA)

- 2.0 MTPA HBI
- Performance test passed February 19, 2017



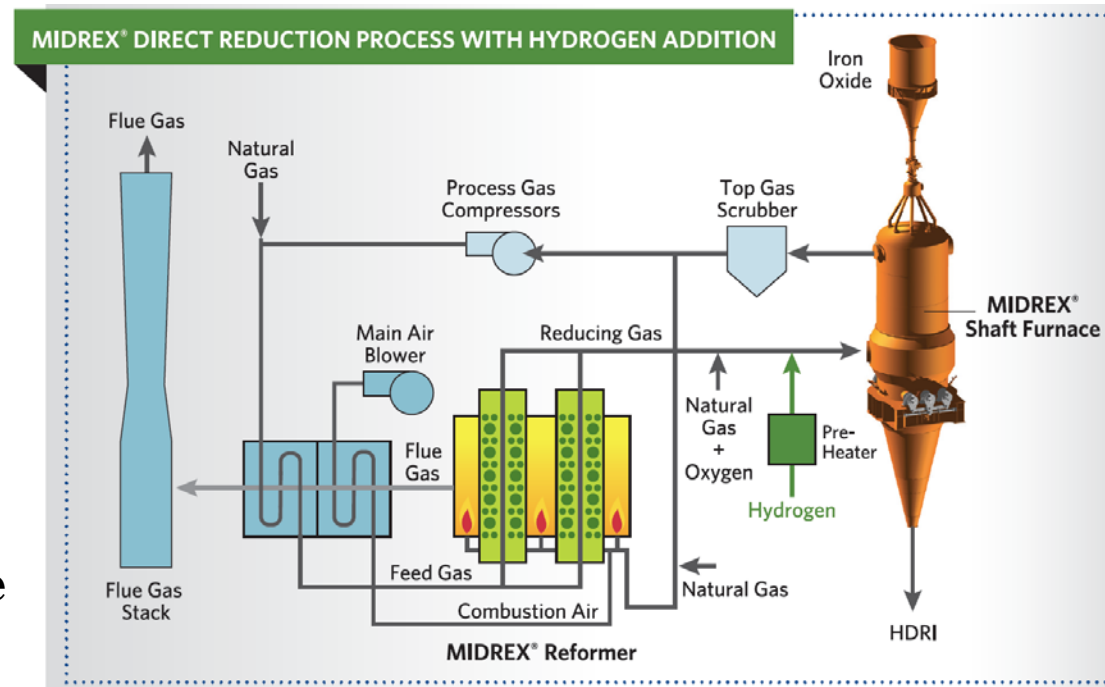
Cleveland-Cliffs (Toledo, OH USA)

- 1.6 MTPA HBI
- Completion: 2020



MIDREX[®] NG with H₂

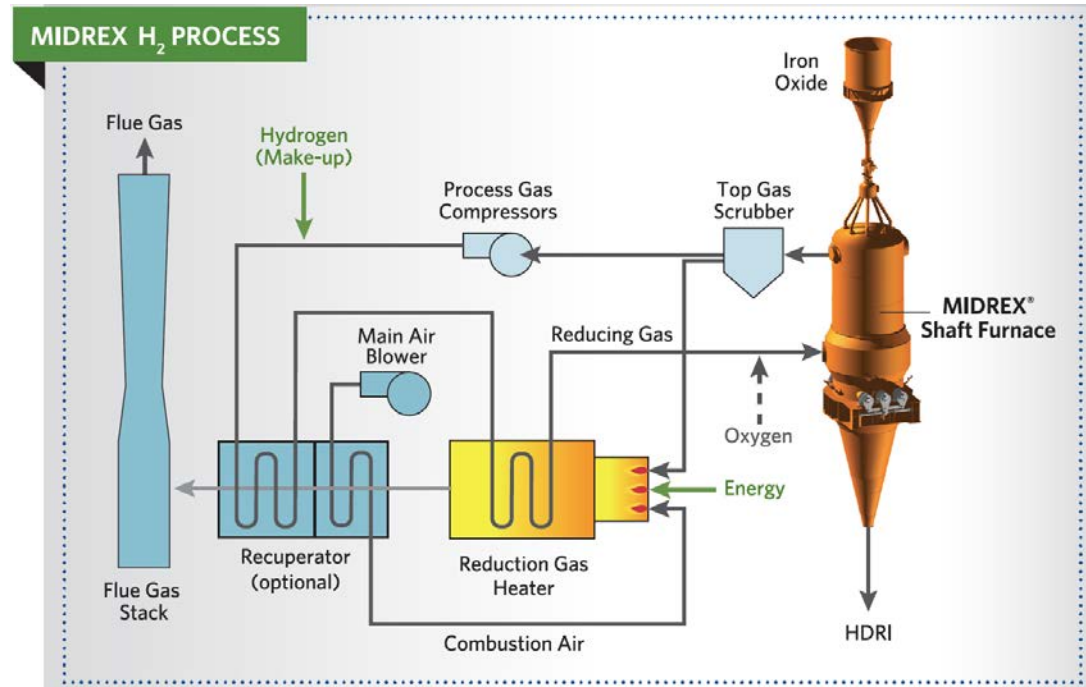
- Up to 30% of NG can be substituted by Hydrogen without changing the process
- Hydrogen may need to be pre-heated depending on quantities added
- Rough calculations for Cleveland- Cliffs:
1.6 MTPA (200 ton/h), up to 16,000Nm³/h of NG* can be replaced by 48,000Nm³/h of H₂
- Hydrogen can be increased in the process as it becomes available



* Assumes net heating value 8800 kcal/Nm³

MIDREX[®] H₂[™]

- Bustle gas composition is ~90% hydrogen, balance CO, CO₂, H₂O and CH₄ (for 1.4% carbon in DRI)
- Hydrogen consumption is approx. 650 Nm³/t DRI (54kg/t)
- For a Midrex plant the size of Cleveland-Cliffs, that's approx. **130,000Nm³/h of H₂**
- ~650MW per Midrex plant (at 200Nm³/h of H₂ per 1MW)



Conclusions

- MIDREX-NG[®] is a proven technology for industrial production of iron, using “fossil” hydrogen at scale. The process can reduce CO₂ emissions by 50%-80% over traditional BF-BOF.
- Direct reduction can be a bridge technology for ironmaking as Hydrogen becomes available at scale
 - New plants can be built or existing plants can be converted to 100% H₂ as the Hydrogen economy evolves
- Green hydrogen production volumes need to increase by 50x – 125x to supply one MIDREX[®] plant
 - Scale up to Demonstration plant will be needed
- Hydrogen production costs must be competitive: steelmaking is a very competitive business with small margins
- European steelmakers are very active