ASHTON HERTRICH GIRALDO
Sales engineer,
Danieli Centro Metallics

GREEN STEEL PRODUCTION THROUGH HYDROGEN-BASED ENERGIRON DRI PROCESS

SEAISI 2021,
THE ASEAN IRON AND STEEL
SUSTAINABILITY FORUM,
NOVEMBER 17-18, 2021

DANIELI / SINCE 1914
PASSION TO INNOVATE
AND PERFORM
IN THE METALS INDUSTRY

DANIELI TEAM
A CENTURY
OF PARTNERSHIP
EXPERIENCE

INDEX

INTRODUCTION

ENERGIRON HYL

DRI TECHNOLOGY BY TENOVA AND DANIELI

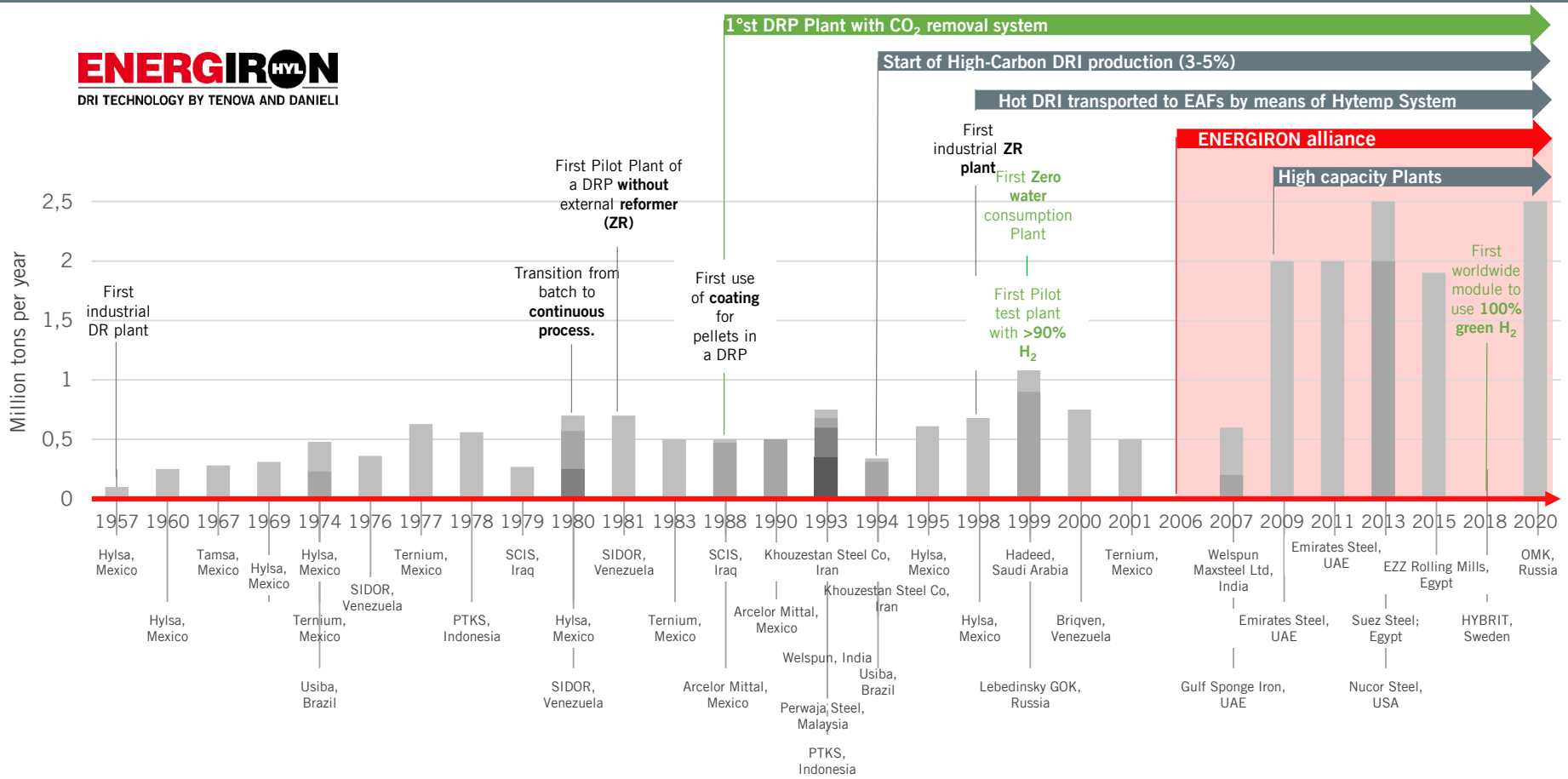
tenova DANIELI

> The innovative HYL Direct-reduction technology jointly developed by Tenova and Danieli

> The most competitive and environmentally clean solution for EAF quality steelmaking

EVOLUTION OF ENERGIRON DIRECT REDUCTION PLANTS TECHNOLOGY FROM 1957 TO 2020

DANIELI

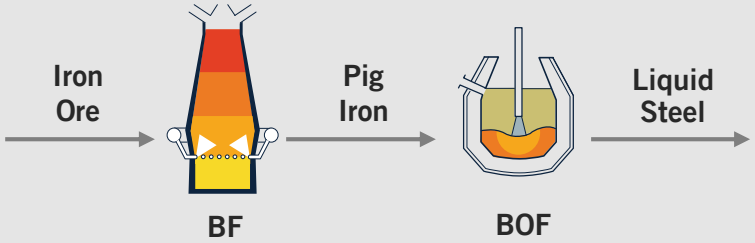


THE ENVIRONMENTAL CHALLENGE

STEELMAKING ROUTES

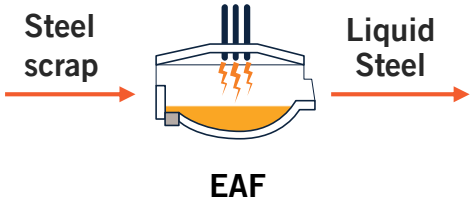
BF-BOF ROUTE

> High single module productivity 2.5 - 5 Mtpa
> High environmental impact



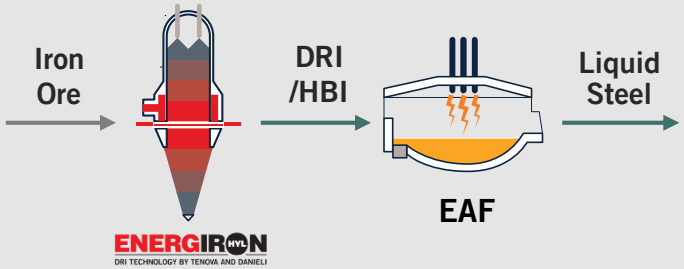
SCRAP-EAF ROUTE

> Steel quality depending on residuals in the scrap
> Low environmental impact



DRP-EAF ROUTE

> Single module capacity up to 2.5 Mtpa
> Any quality steel (also high)
> Reduced environmental impact
> High flexibility in productivity



REDUCTION OF OTHER POLLUTANTS

The **ENERGIRON + EAF** route allows to avoid, or drastically decrease, the emissions of other pollutants usually generated by coking plants and blast furnaces

POLLUTANT	EMISSION reduction
CO	-99%
NOx	-78%
VOC	-100%
BTX	~ -100%
PCDD/F	~ -100%
SOx	~ -91%
BAP	-100%
IPA	~ -100%

GREENSTEEL
ENERGIRON + DIGIMELTER Q-ONE

> BAT
> Up to -80% CO_2 emissions
> Up to -50% PM
> Drastic reduction of NO_X SO_X and other pollutants

LOW-CARBON EMISSION FOOTPRINT IS POSSIBLE

ENERGIRON DRP-EAF grants **-50%** CO_2 emissions with respect to BF+BOF.
Using H_2 ENERGIRON DRP allows to achieve **-86%** CO_2 emissions.

ENERGIRON DRP	BF	EAF	BOF	
	●		●	BF + BOF 100%
	●		●	DRI in BF -15%
	●	●	●	BF + EAF + BOF -25%
	●	●	●	DRI in BF+EAF+BOF -40%
●		●		-53% Base Case, Natural Gas
●		●		-67% Natural gas with CCU/CCS
●		●		-86% 100% H_2 use

ENERGIRON + EAF

Assumed ~0,50 kg CO_2/kWh

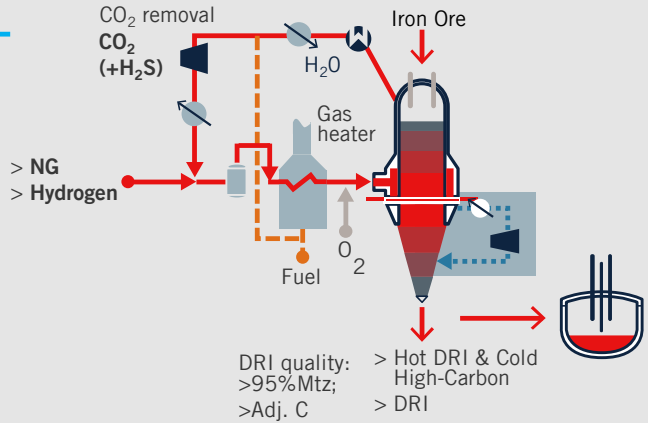
CO_2 emissions (Kg/t LS)

0 500 1000 1500 2000

ENERGIRON SELECTIVE CO_2 REMOVAL

CARBON IN DIRECT REDUCTION PLANTS

The **ENERGIRON** DR process intrinsically includes a CO_2 absorption system for selective elimination of CO_2



Example:

100%

Total carbon input

45% carbon selected removed

25% carbon in the DRI

30% carbon released into atmosphere

SUSTAINIBILITY: CARBON FOOTPRINT

CO_2 EMISSIONS FOR EACH TON OF DRI PRODUCED

	ENERGIRON ZR	ENERGIRON III	Any other plant without CO_2 removal system
SELECTIVE CO_2 EMISSIONS Captured and sold as by-product	256 [kg_{CO2} / t_{DRI}]	256 [kg_{CO2} / t_{DRI}]	0
NON-SELECTIVE CO_2 EMISSIONS Released to atmosphere	159 [kg_{CO2} / t_{DRI}]	256 [kg_{CO2} / t_{DRI}]	~ 500
	NON SELECTIVE 38%	NON SELECTIVE 50%	NON SELECTIVE 100%
			
	SELECTIVE 62%	SELECTIVE 50%	SELECTIVE 0%

COMMERCIALIZATION OF CO_2

CO_2 gases by **ENERGIRON** absorption system are used in different by-products:

HYL/ENERGIRON DR Plant	Off-taking company	Use
Ternium; Monterrey, Mexico	Praxair	Food and beverages industries
Ternium; Puebla, Mexico	Infra	Beverages industries
PTKS; Indonesia	Janator	Food industry
PSSB; Malaysia	Air Liquid/MOQ	Food industry
JSW Salav; India	Air Liquid	Dry Ice
Emirates Steel; UAE(1)	Masdar/ADNOC	Enhanced Oil Recovery (EOR)
Nucor; USA(2)	Denbury Resources Inc.	Nearby piping Network; EOR

Note (1): On going project
Note (2): to be executed. Additionally NUCOR has a SULFEROX system that remove Sulfur from CO_2 stream

HYDROGEN USE IN DIRECT REDUCTION

USE OF H_2 IN DIRECT REDUCTION PLANTS

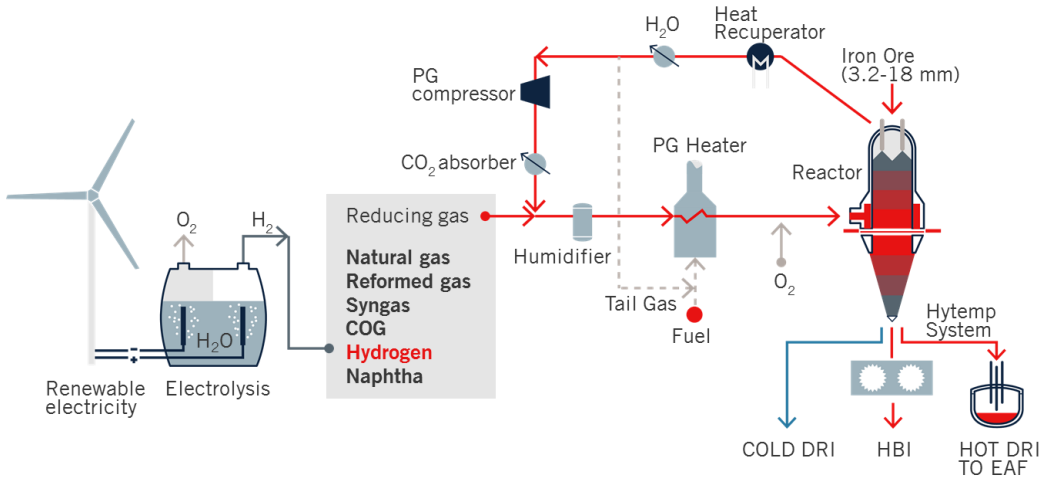
For any reformer, H_2 is produced in different concentration depending on the oxidants ratio:

$CH_4 + H_2O = 3H_2 + CO$ (3 vol. H_2 / 1 vol. CO)
$CH_4 + CO_2 = 2H_2 + 2CO$ (2 vol. H_2 / 2 vol. CO)

The Energiron technology includes a conventional steam/NG reformer with reformed gas used as reducing agent.

Typical operational characteristics

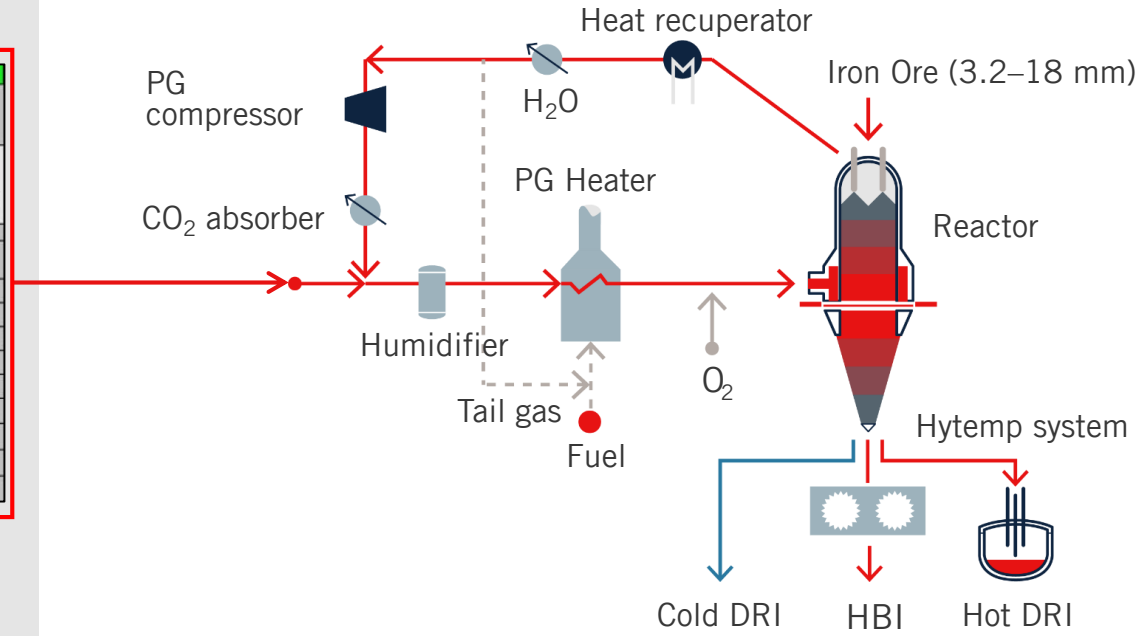
Parameter related to H_2	ENERGIRON
H_2/CO ratio in reducing gas	4 - 5
H_2 to reactor (% vol.)	~70%



> Scheme "natively" suitable for **ANY** reducing gas make-up
> H_2 make-up **directly** replaces NG to the process
> **High operating pressure** to better handle the lightest and more diffusible compound in nature

Energiron plants already uses Hydrogen as input material:
indeed, **reformed gas contains >70% H_2**

Stream	1	2	3	4
Description	Natural Gas	Tail Gas at RGC Suction	PT Gas	Reformed Gas
Results	Total 100.	Total 100.	Total 100.	Total 100.
	LHV 8722.44	LHV 2641.063	LHV 3061.215	LHV 2632.925
	MW 17.3761	MW 14.5076	MW 22.4563	MW 9.966
	GY 0.5999	GY 0.5009	GY 0.7753	GY 0.3441
	C 1.0312	C 0.1613	C 0.3399	C 0.109
Component				
H2	0.4012	57.48	7.06	73.19
CO	0.	17.38	0.29	14.67
CO2	2.0961	14.39	0.01	8.66
CH4	92.4481	7.29	31.49	3.44
N2	0.0602	3.41	60.06	0.
C2H6	4.3125	0.	0.92	0.
C3H8	0.682	0.05	0.17	0.04
C4H10	0.29			
H2S	5.5			
H:M	13 : 34	13 : 34	13 : 35	13 : 36



ENERGIRON UNMATCHED EXPERIENCE WITH HIGH % OF H_2

Energiron can make use of the continuous advancements of research and development activities:

- **Extensive tests carried at Proprietary Pilot Plant, since 1990's, with ≥ 90% H_2**
- Testing activities provided capability results for all type of reducing gases
- Low and high carbon condition (depending with downstream requirements) have been explored
- CO_2 emissions with different % of H_2 have been defined
- **New pilot plants and testing campaigns are under development**, jointly with partners and customers

** Pilot plant in Monterrey*

DRI ENERGY CONSUMPTION IN ENERGIRON PROCESS

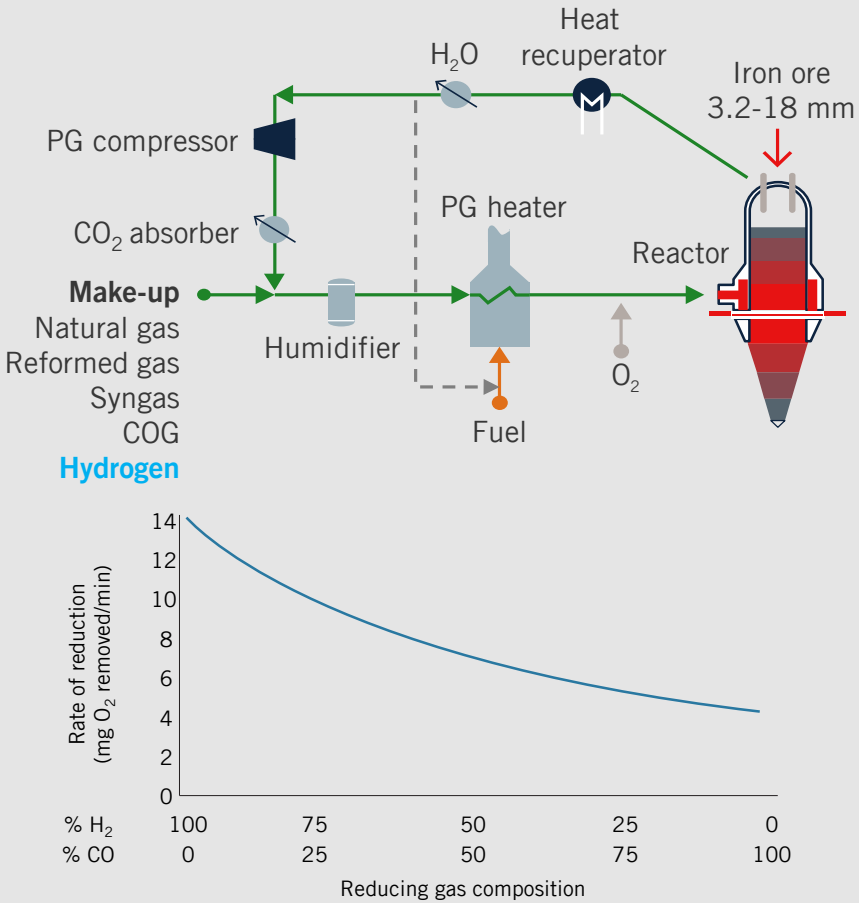
Results of testing activities confirmed that Energiron:

> **Is ready for H_2 use** if needed

> Can switch from any reducing gas to H_2 **without changing basic scheme configuration** (vs. integrated reformer technologies)

> **Is designed to run with several gases** or a mixture of them (e.g. natural gas and H_2)

> Testing results are applicable to **any new or existing** DR plant installation.



ACCURATE DESIGN

ASSURING PROPER SAFETY

> Reactor top and bottom mechanical lockhoppers

> Solids cutoff and gas sealing valves with double protection for reactor charging and discharging

> Zero leakage of process gas

> Dynamic gas seals or bubblers are avoided

PERFECT INERT GAS

High purity nitrogen is used instead of compressed flue gases for sealing reactor valves, equipment purging and blanketing

ADVANTAGES OF NITROGEN

> Uninterrupted supply independently of DRP operation

> Fixed purity and no moisture

> No additional equipment in DRP

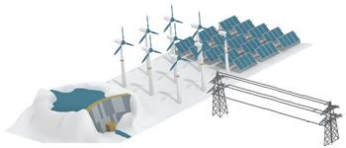
> Low maintanence costs

Iron ore charging system

DRI discharging system

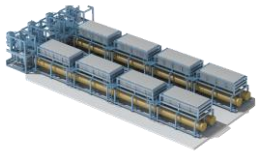
CARBON DIRECT AVOIDANCE (CDA)

Renewable energy sources



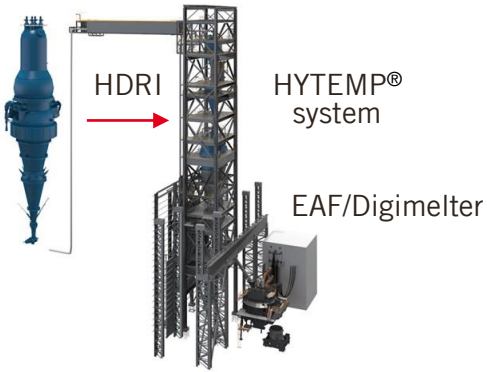
Carbon-free energy

Hydrogen + Oxygen



High-efficiency electrolyzer

ENERGIRON
DR plant



Liquid steel

H_2 AND ELECTRICITY REQUIREMENT

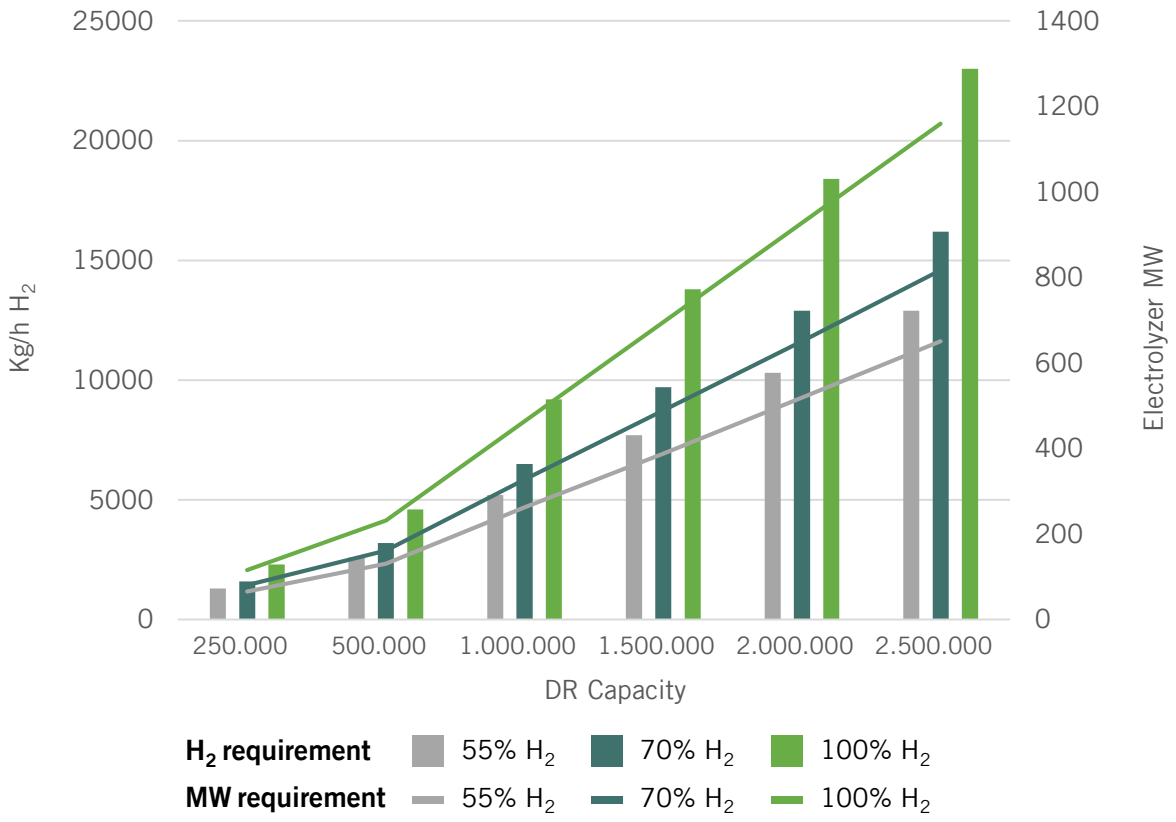
ENERGIRON can use different blends of hydrogen from 0 up to 100% undependably from its capacity.

For a **2M ton per year** DR plant the H_2 needed for a full H_2 DR plant its nearly:

18.400 kg/h H_2

To produce 18400 kg/h of Hydrogen with an alkaline electrolyzers we need an installed capacity of nearly:

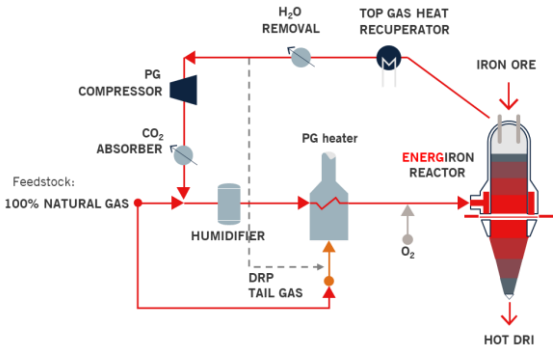
928 MW



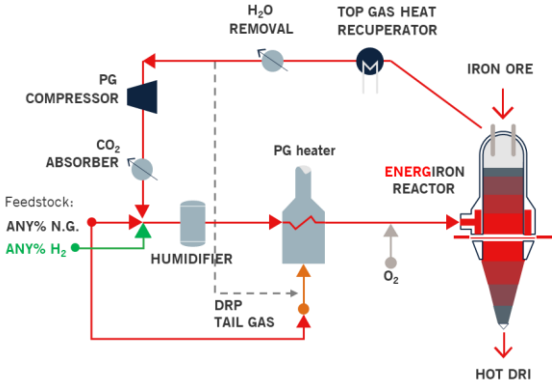
NG TRANSITION UP TO 100% H_2

SAME SCHEME FOR PRESENT, NEAR AND FAR FUTURE

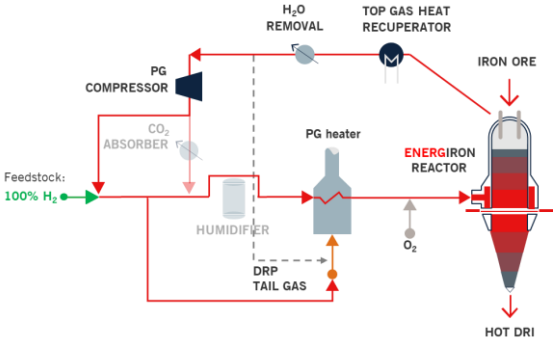
TODAY → **TOMORROW (BY 2030)** → **FUTURE (BY 2050)**



100% Natural Gas



any % Natural Gas
any % Hydrogen

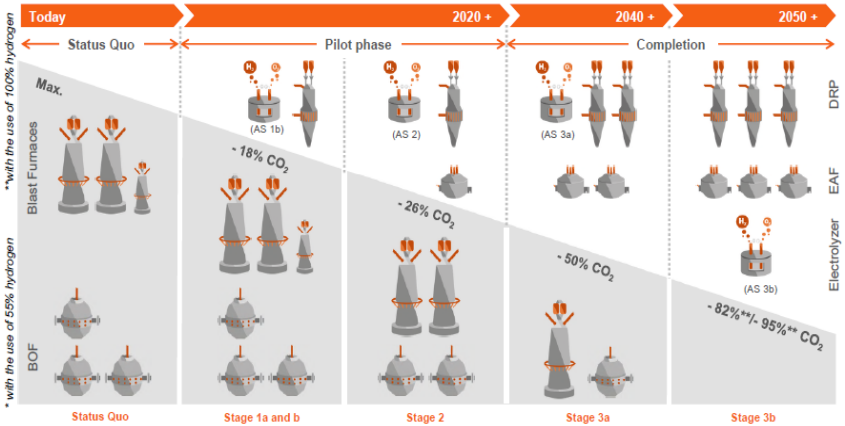


100% Hydrogen

HYDROGEN-BASED INITIATIVES FOR STEELMAKING

SALCOS
Steelmaking. Reinvented.
SALZGITTER AG
Stahl und Technologie

Summary: Transformation of Integrated Steelmaking to DRP/EAF Based Steelmaking in Three Stages



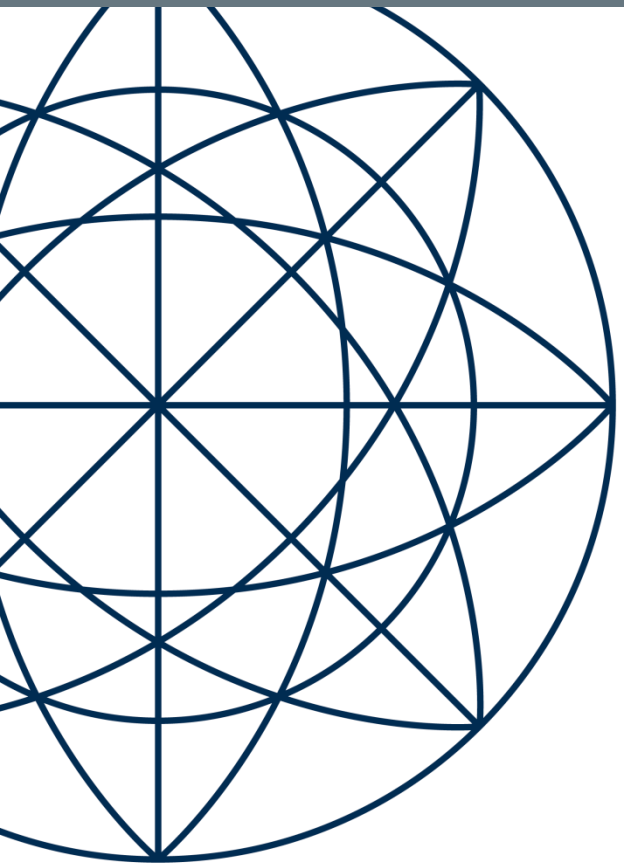
*Source: Salzgitter AG

HYBRIT
FOSSIL-FREE STEEL
SSAB LKAB VATTENFALL

*Source: SAAB

CONCLUSIONS

PILLARS



INNOVATIVE TECHNOLOGY LEADING FOR EFFICIENCY

Less iron ore and energy consumption

TOP QUALITY PRODUCTS

Adjustable metallization and carbon content

FLEXIBLE AND FRIENDLY

Wide variety of raw materials inputs

Smart automated control system

ENVIRONMENTAL SUSTAINABILITY

CCU/CCS-ready technology: -60% CO_2 emissions

Hydrogen-ready technology: -100% CO_2 emissions

ASHTON HERTRICH GIRALDO
Sales engineer,
Danieli Centro Metallics

GREEN STEEL PRODUCTION THROUGH HYDROGEN-BASED ENERGIRON DRI PROCESS

SEAISI 2021,
THE ASEAN IRON AND STEEL SUSTAINABILITY FORUM,
NOVEMBER 17-18, 2021

a.hertrichgiraldo@danieli.com

DANIELI / SINCE 1914
PASSION TO INNOVATE
AND PERFORM
IN THE METALS INDUSTRY

DANIELI TEAM
A CENTURY
OF PARTNERSHIP
EXPERIENCE