GREEN STEEL TECHNOLOGIES AND COMPETITIVENESS

PATHS TO A SUSTAINABLE DECARBONIZATION OF STEELMAKING

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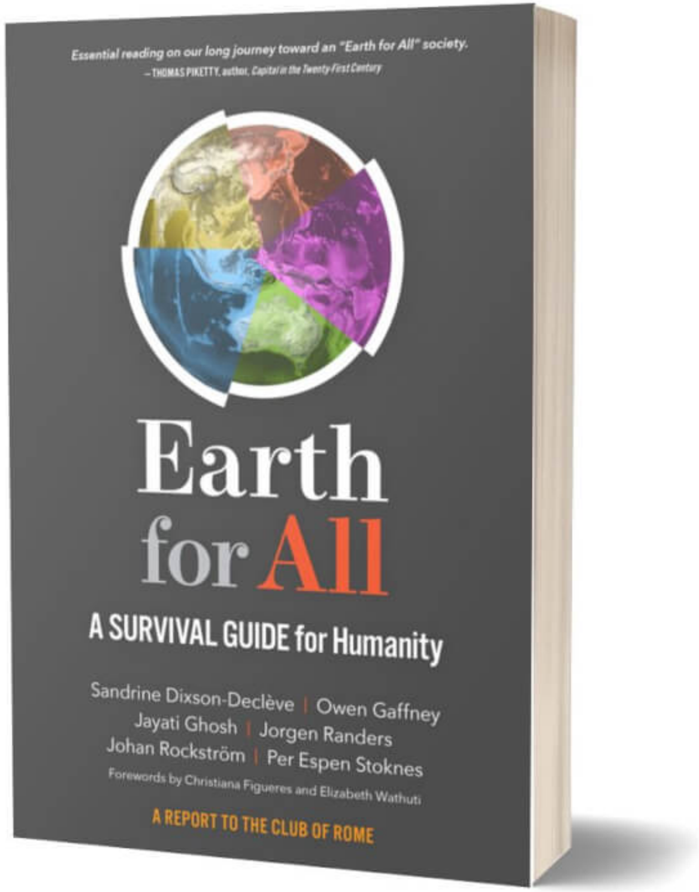
Düsseldorf, May 13, 2025

Time is now…

STEELMAKING ACCOUNTS FOR 31% OF TOTAL CO_2 INDUSTRIAL EMISSIONS



Final statement / sentence of the latest report from

“**Earth for All – A Survival Guide for Humanity**”
The Club of Rome

“… We know what you're going to say now, … The tasks are huge. The obstacles are huge. The dangers are enormous. The time we have left is short."

The hardest tasks of the fastest economic transformation in history must be tackled in the first decade…

Now. When you slam this book.

Techint Group

OUR FAMILY

USD **36.3** billion
Annual Revenues

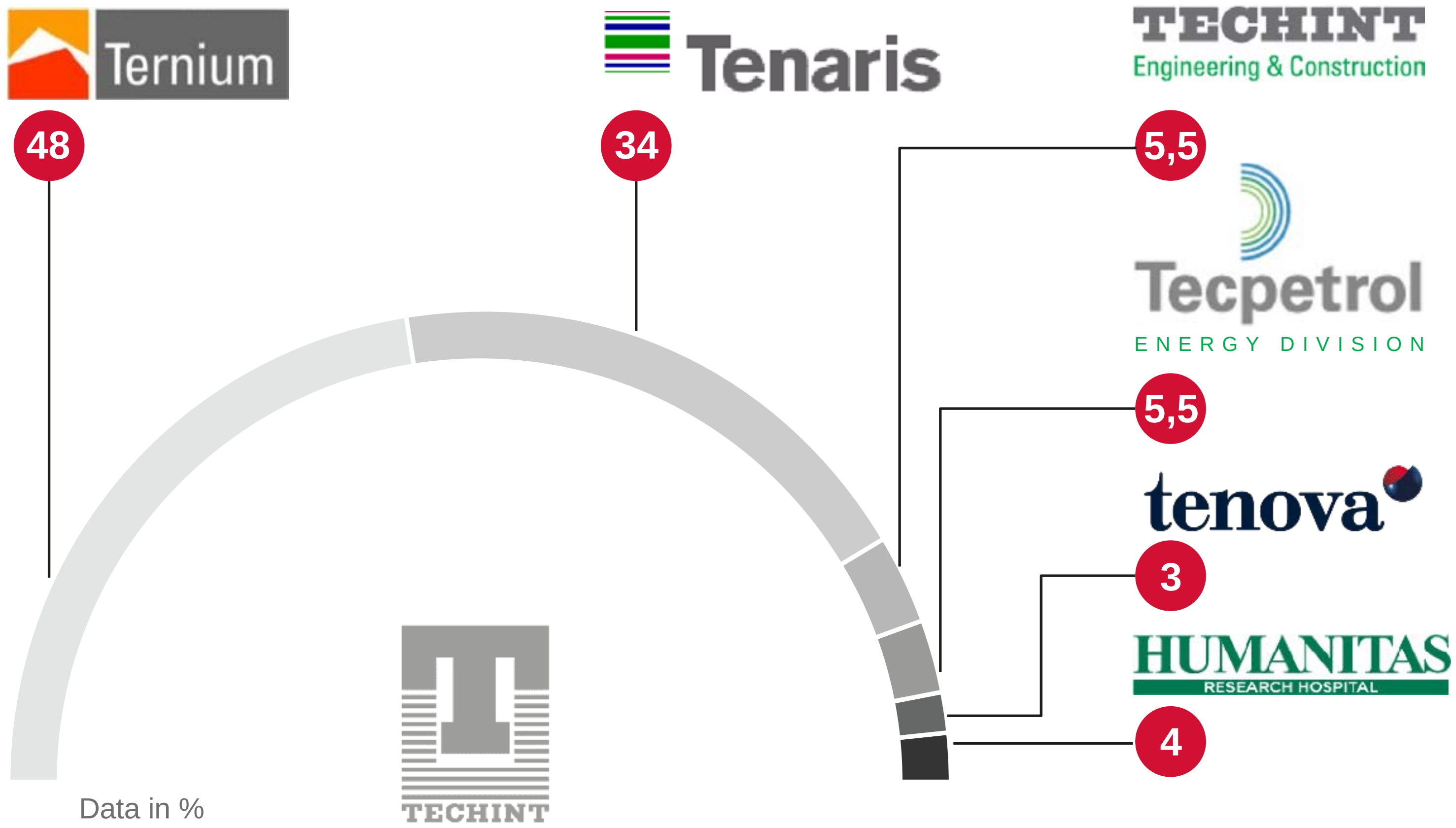
74,500
Permanent Employees

89,000
Total Employees

5
Continents

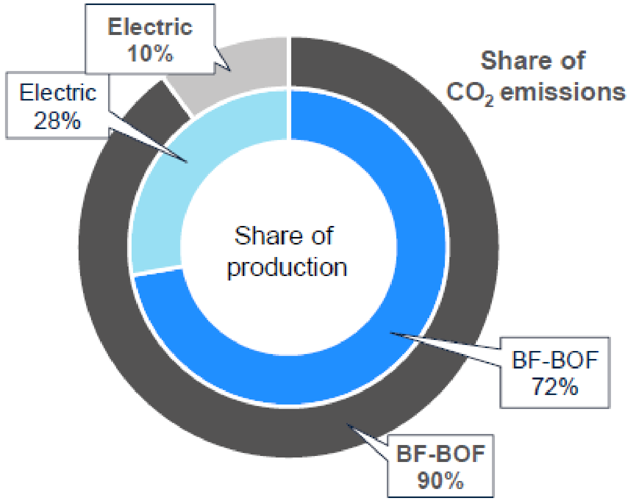
Revenues as of December 31, 2024

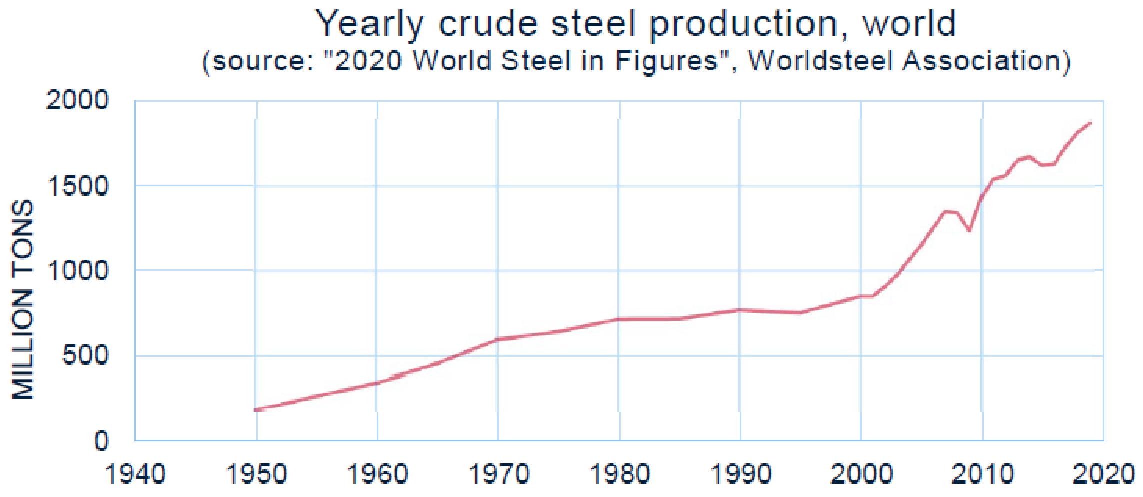
Six main Companies with operations worldwide



Different Routes - Different CO_2 Emissions

STEELMAKING ACCOUNTS FOR 31% OF TOTAL CO_2 INDUSTRIAL EMISSIONS





tCO_2/ton (tot. crude steel)	BF/BOF min	BF/BOF max	EAF min	EAF max	ng-DRI EAF min	ng-DRI EAF max	C/DRI EAF min	C/DRI EAF max
IEA 2003	1.62	2.2	0.56	0.91	1.38	-	1.96	-
Carbon Trust 2011	1.8	3	0.2	0.4	0.7	1.2	2	3
EUROFER 2015	1,876		0,410					
ETS benchmark			*0,352*					

Source: author's own elaboration of data from Carbon Trust. (May 2011). Steel. London, UK: International Carbon Flows and de Beer, J., Harnisch, J., & Kressemeeckers, M. (Oct 2003). Greenhouse Gas Emissions from Steel Production. Greenhouse Gas R&D Programme: International Energy Agency - Greenhouse Gas R&D Programme

Holistic Approach / Carbon Direct Avoidance

HYDROGEN AND ELECTRIFICATION ARE THE GAME CHANGERS

ENERGIRON

H_2

Hydrogen for Steel Making

HYDROGEN

Process Atmosphere

H_2

Annealing of Silicon Steel
Heat Treatment of High Grade Steel Tubes

High **EFFICIENCY**

Heat Treatment Solutions

HEATING Technologies

Electrical
Hybrid
Regenerative

BURNER Technologies

H_2 Burners
Regenerative
Flameless Burners

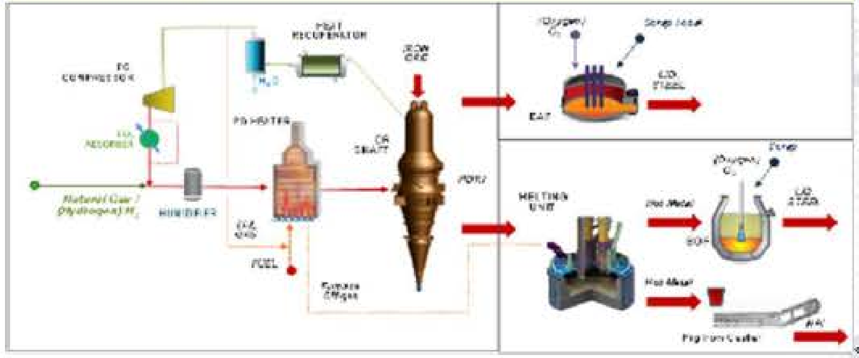
Aluminium **RECYCLING**

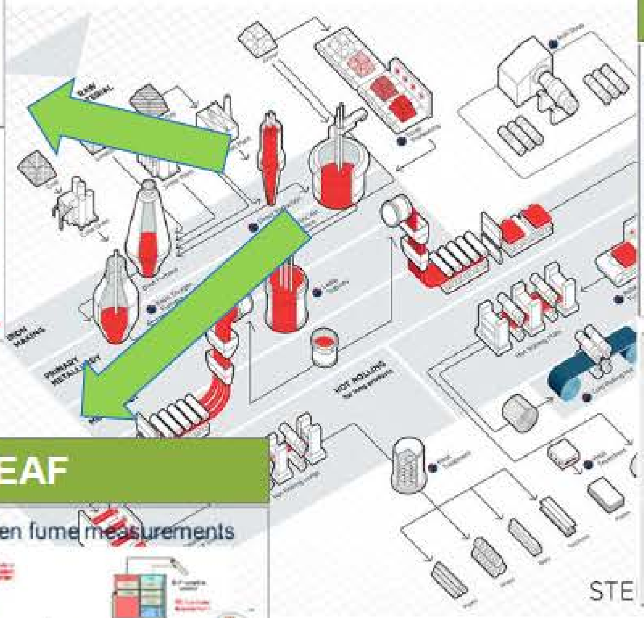
Twin-Chamber Melting Furnace

We ARE ready for hydrogen!

THE HOLISTIC APPROACH

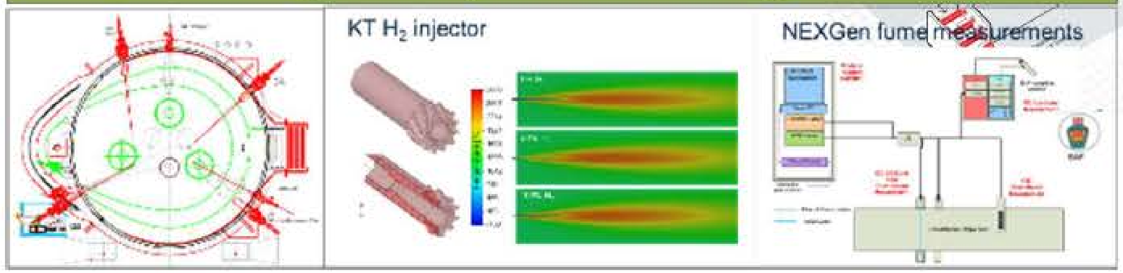
ENERGIRON Direct Reduction Process +
EAF for Liquid Steel / OSBF for Hot Metal Production





Smart Burner: working with any mixtures of NG/H_2 up to 100% H_2 **for re-heating and treatment furnaces**

KT injection system for **melting in EAF**



ENERGIRON - The Process as Basis

THE DIRECT-REDUCTION TECHNOLOGY

ENERGIRON HYL
DRI TECHNOLOGY BY TENOVA AND DANIELI

Highest DRI Quality / Flexibility

- High-C CDRI, High-C HDRI, High-C Briquettes
- > 94-96% Mtz; 1,5%- 5,7% Carbon (as Fe_3C)

Hydrogen Ready!

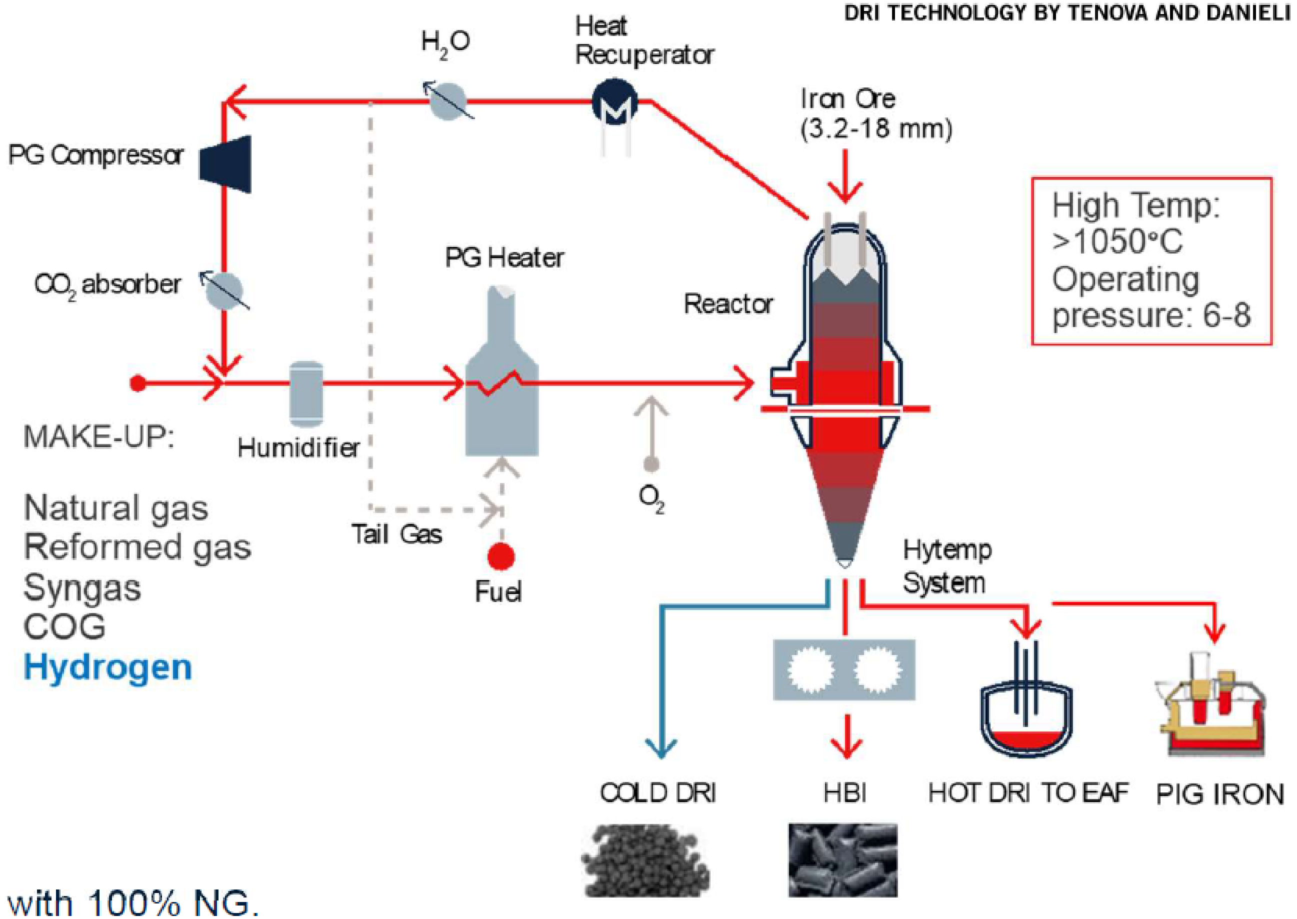
- Same process scheme / plant configuration for any combination of NG/H_2
- Inherently suitable for any reducing gas
  ➔ Hydrogen ready!

Removal of CO_2

- Selective removal of iron ore reductions by-products: H_2O & CO_2
- Inherent capability for CCU and CCS

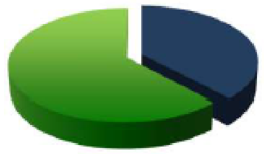
High C DRI for HM production

- Only proven technology to produce > 4% C DRI with 100% NG. Even with 30% H2 (energy), C > 3.3% can be achieved

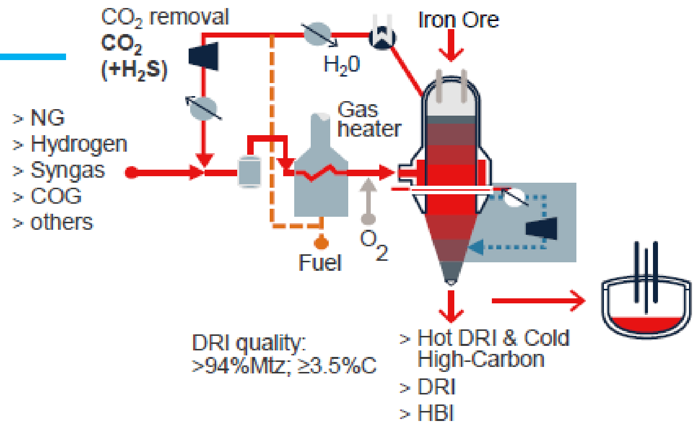


ENERGIRON - Carbon Capture and Use (CCU)

From Total Carbon input:



62% as **SELECTIVE** CO_2
Approx. **256 kgCO_2 / t$_{DRI}$ a**



For **Mass Conservation Principle**, total Carbon feeding the **ENERGIRON** DRP is ultimately found as CO_2 as:

- **Sequestrated Emissions**
- **Free Emission to Atmosphere (mainly from PG Heater)**
- **Carbon in Product (DRI/HBI)**

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

ENERGIRON - Experience in the Use of H_2

Derivation of the Design Principles

- In the 1990's, Tenova HYL carried out extensive tests at pilot plant with up to 90% H_2, to define:
  - Process parameters
  - DRI quality
- Optimization of operating pressure, reactor L/D ratio, etc. for gas distribution and design of the scheme for H_2 utilization.
  ➔Scheme natively fitted for direct use of H_2
- Extensive experience and operation with Process Gas Heaters and Gas Sealing Valves design, specifically with high percentages of H_2

ENERGIRON
DRI TECHNOLOGY BY TENOVA AND DANIELI

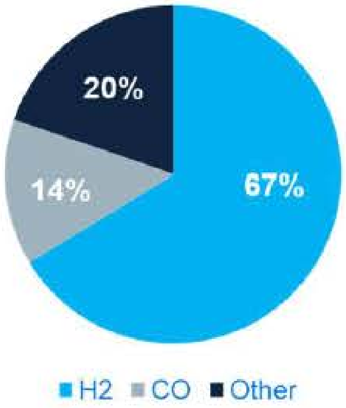
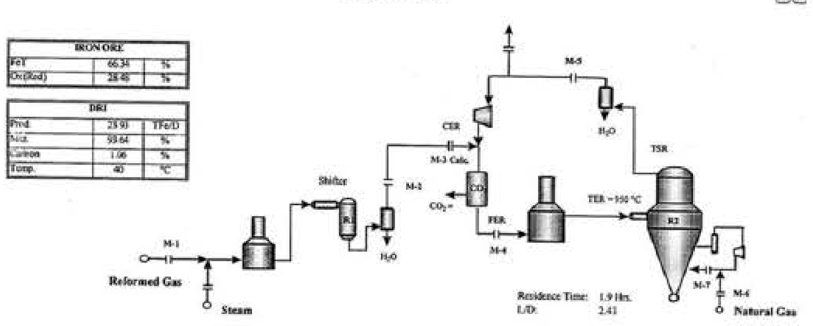
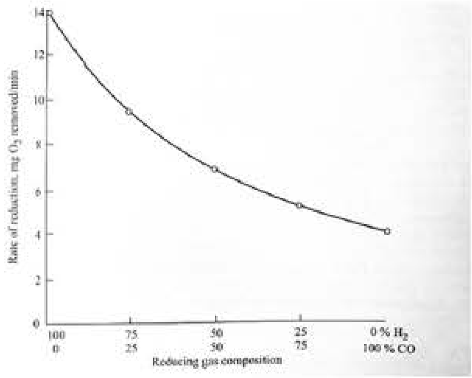


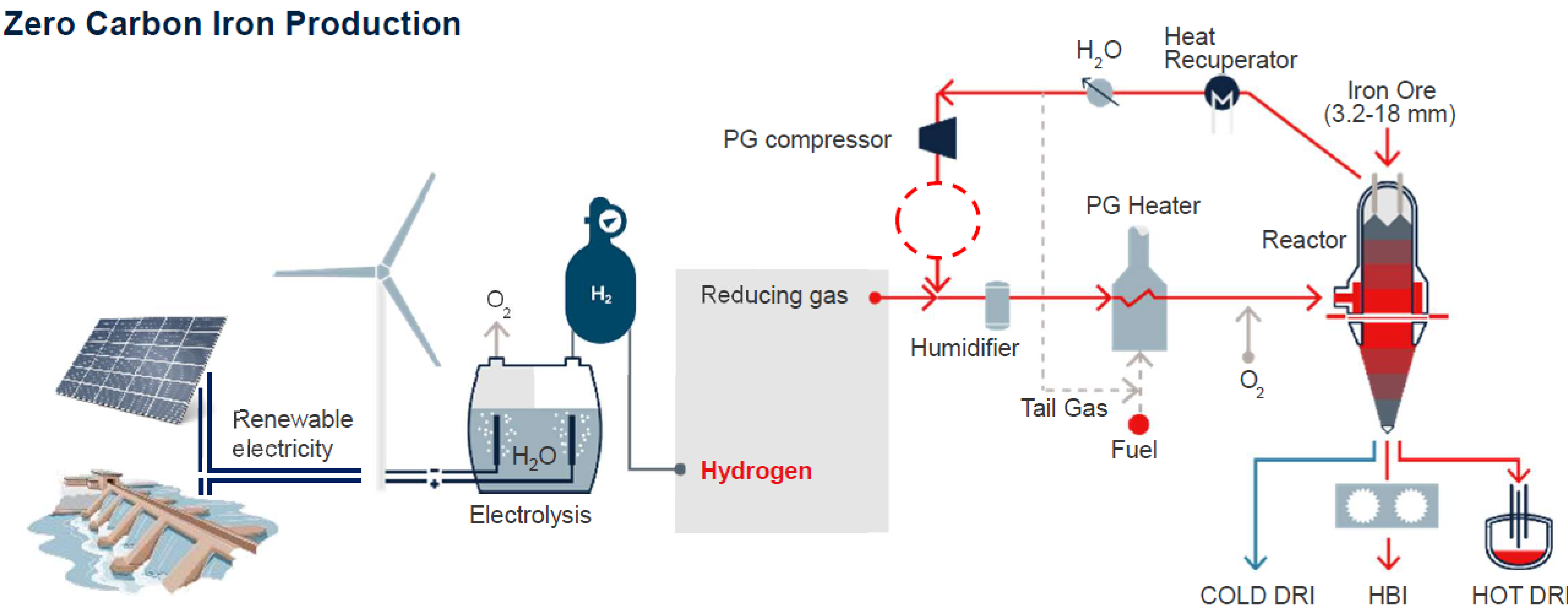
Figure VI.2.1 Material Balance for Condition 10
High Hydrogen





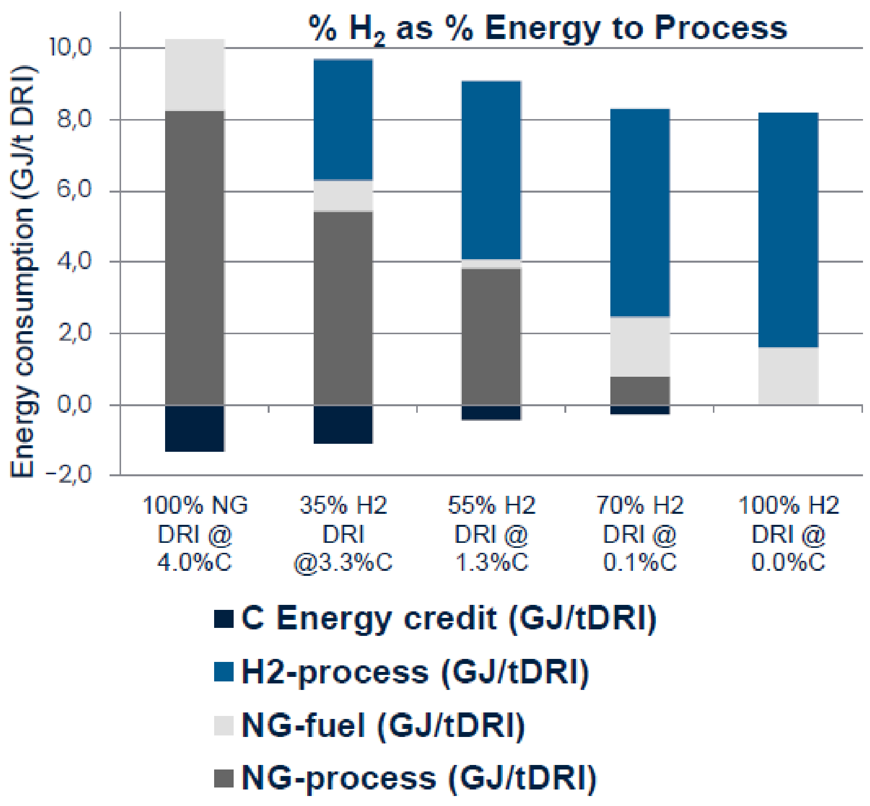
ENERGIRON - Experience in the Use of H_2

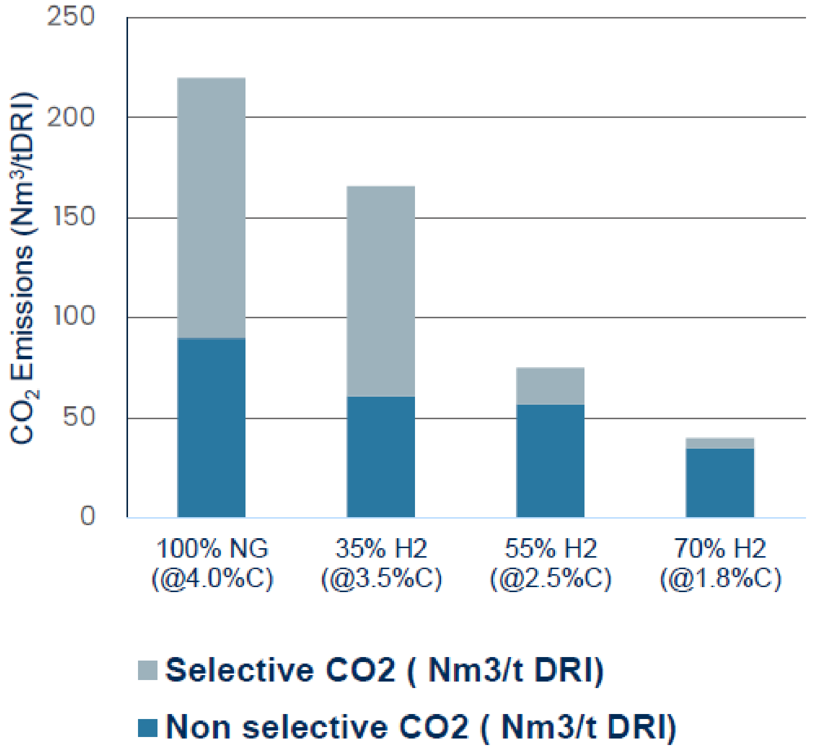
THE DIRECT-REDUCTION TECHNOLOGY



ENERGIRON - 100% Hydrogen

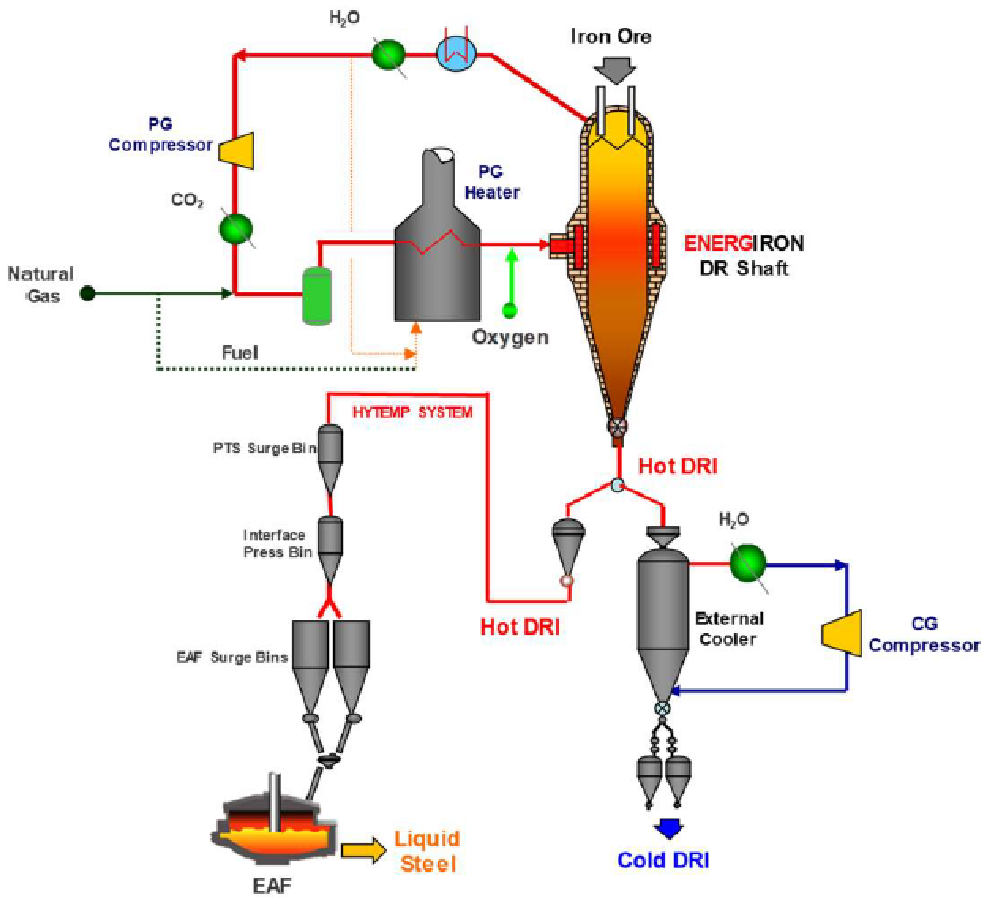
THE DIRECT-REDUCTION TECHNOLOGY



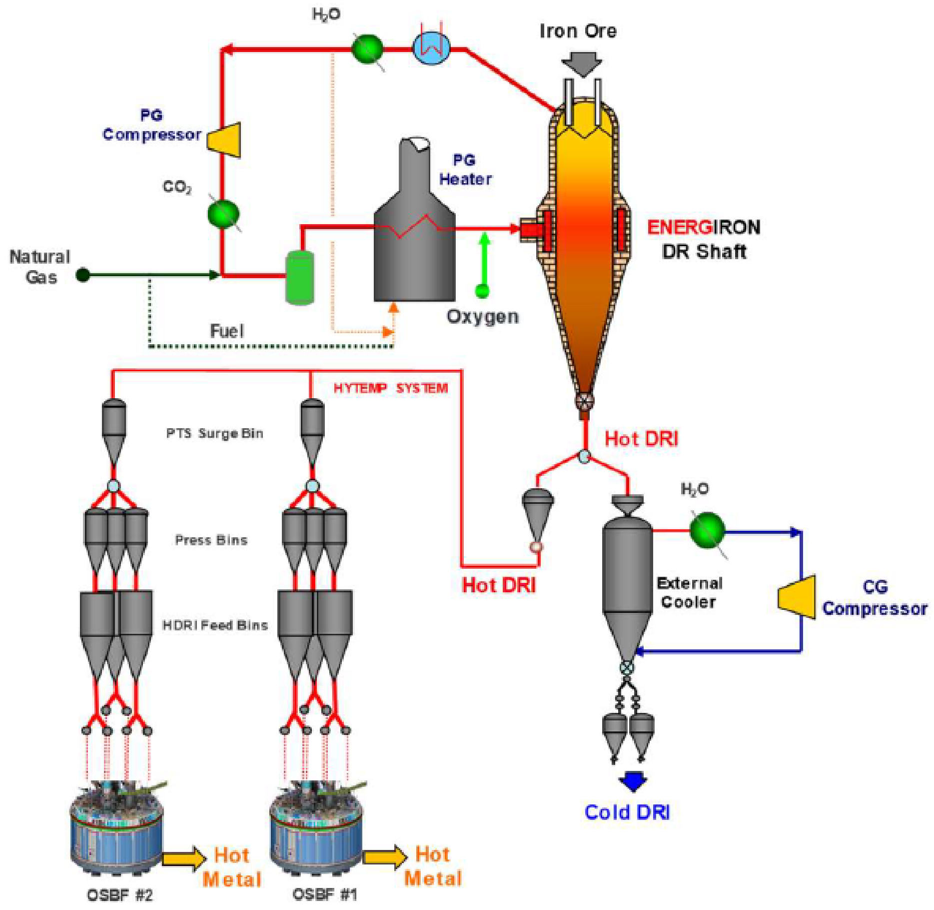


Routes for Low-C Footprint Steelmaking

THE TWO NEW WAYS TO PRODUCE STEEL



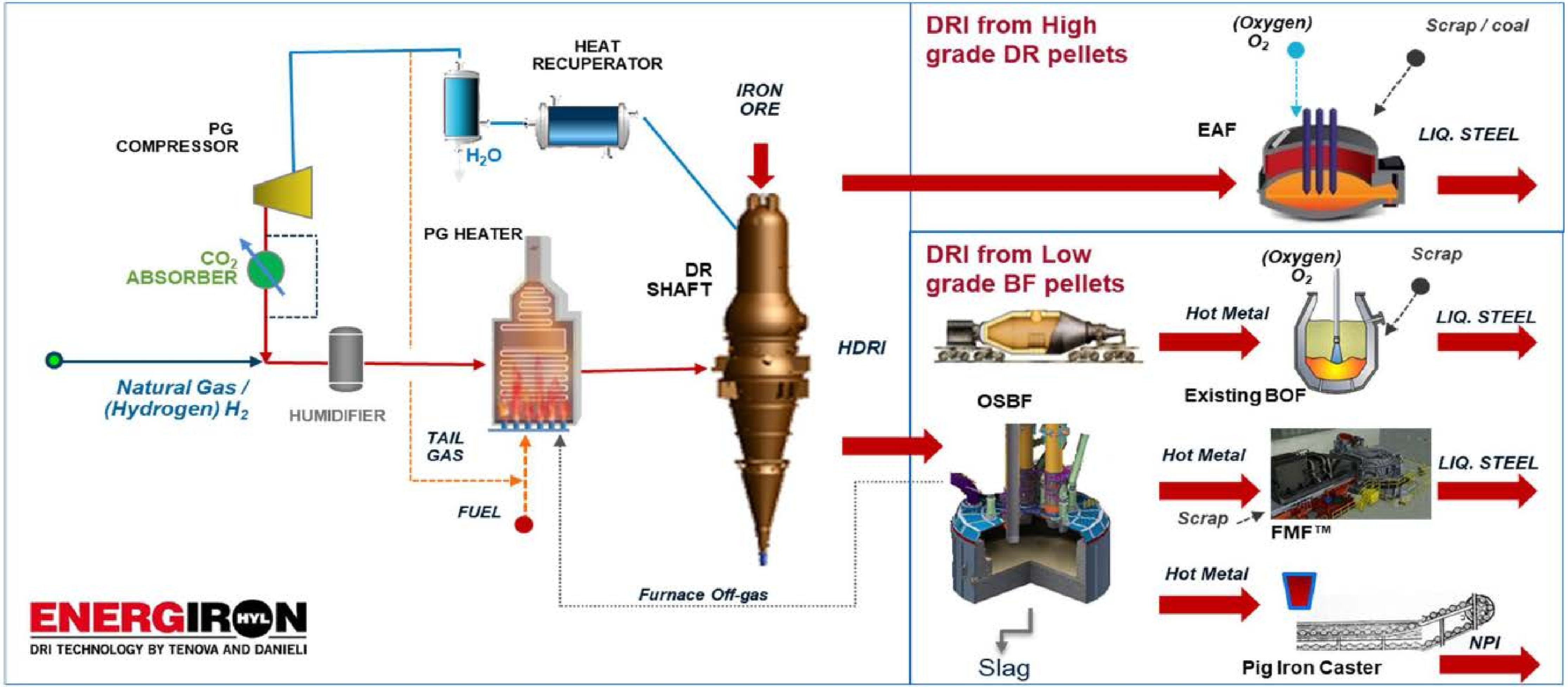
DRI Plant + EAF



DRI Plant + 2xOSBF

Routes for Low-C Footprint Steelmaking

THE TWO NEW WAYS TO PRODUCE STEEL



Tenova iBLUE® - The DRP/OSBF Concept

THE TWO NEW WAYS TO PRODUCE STEEL

Inputs

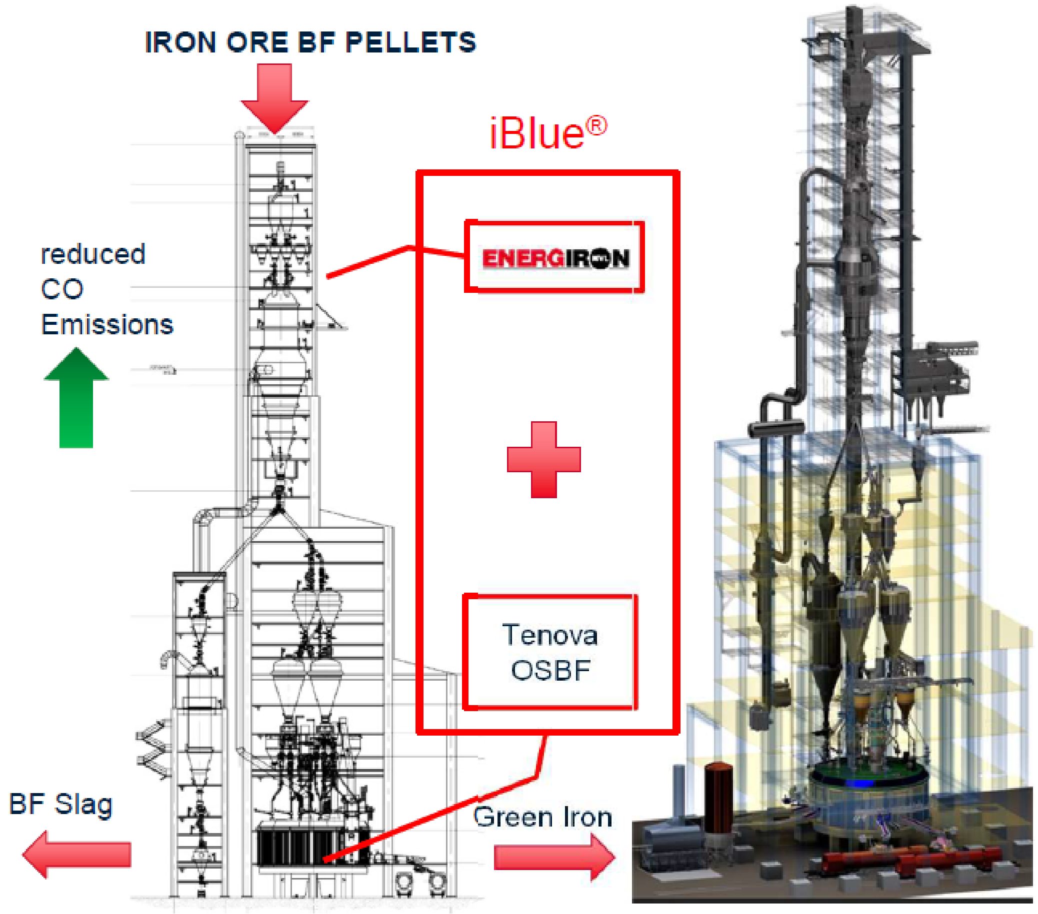
- Low grade Iron Ore pellets (BF quality), lime, steel returns, scrap (DR grade pellets also possible, with associated lower kWh/t)
- Electricity, CH_4 (with possibility to use partially H_2).

Outputs

- Hot Metal compatible with BF product (e.g. C 4%, Si 0.2 - 0.4%)
- Slag with BF slag composition, fully compatible with Cement industry requirements
- CO rich cleaned furnace gas – used as an energy source within the Direct Reduction Plant
- High reduction of CO2 emissions (-54% - -85%)

Key technological advantages

- Same possibility as BF to run long continuous campaigns (OSBF refractory: 7 to 10 years).
- Higher flexibility (vs. BF): possibility to switch on and off.
- Lowest impact on power grid, Small foot print as BF



Tenova iBLUE® - The DRP/OSBF Concept

THE TWO NEW WAYS TO PRODUCE STEEL

Process

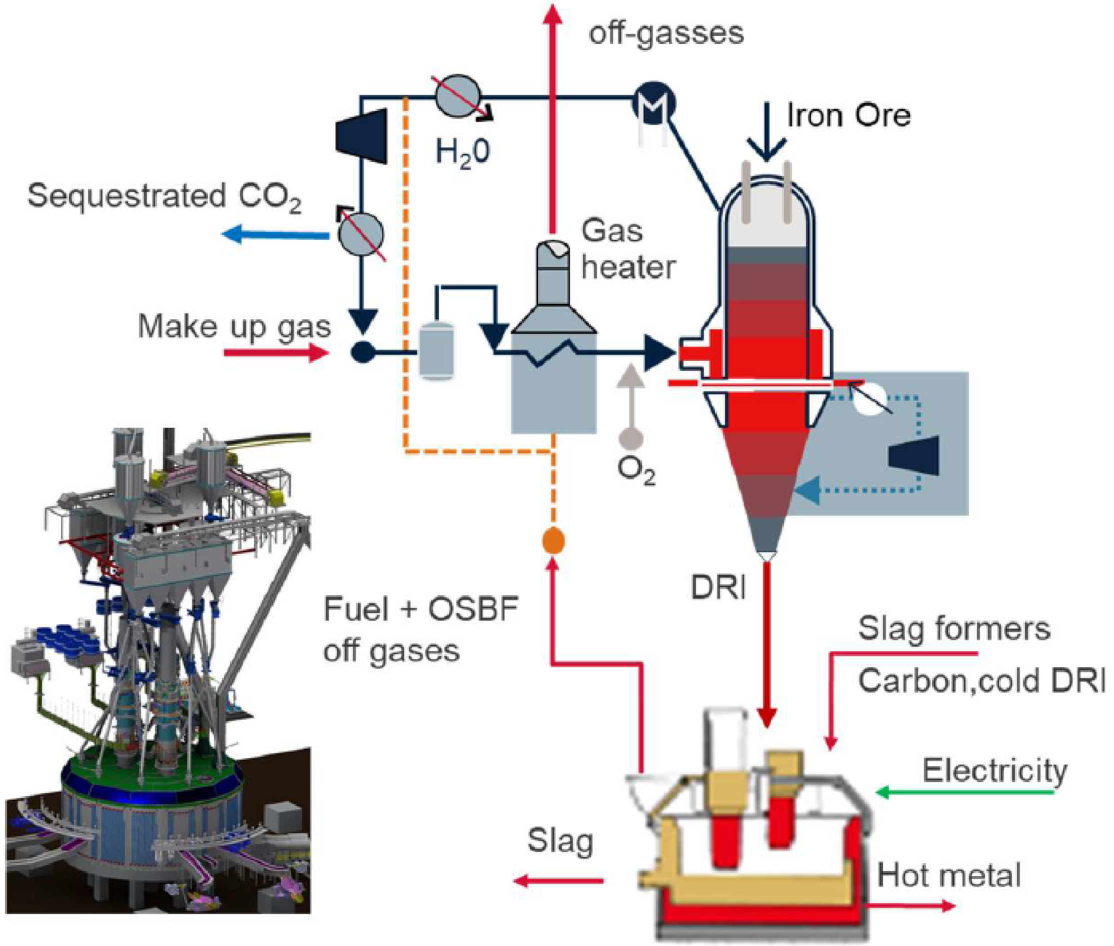
The task of the OSBF is to separate the gangue from the metal and to increase the temperature to create hot metal

Additional important points are:

- Sellable Blast Furnace quality slag
- Hot metal (typically with 3,5% - 4% C content)
- The fumes are rich in CO and they are utilized to pre-heat the process gas in the DRI plant.
- Electrical consumptions depend on the type charge (typically 500 – 700 kWh/t). The higher the total metal charge quality, the lower the electrical consumption.

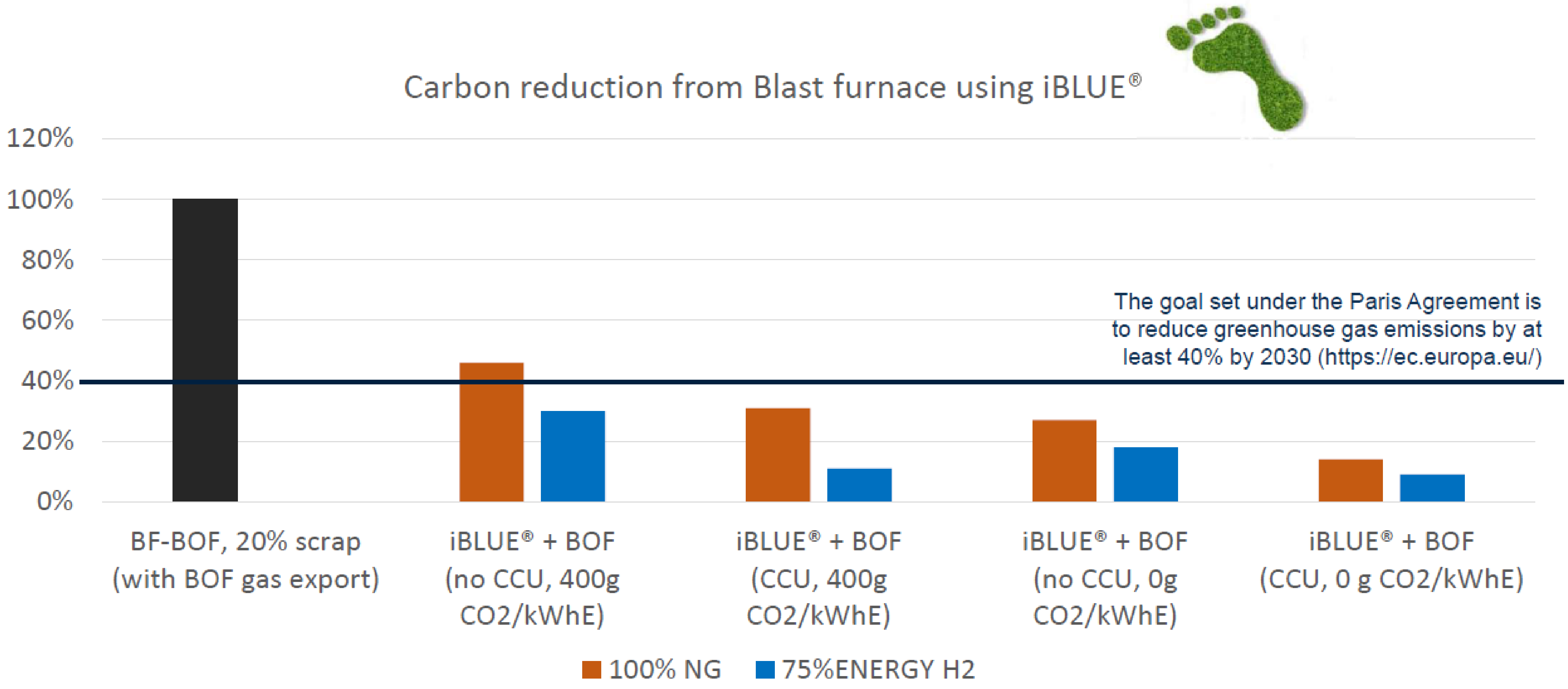
Typical plant configurations are:

- One DRI Module of 2 – 2,5 Mt/y feeding 2 OSBF furnaces
- One DRI Module of 1 – 1,5 Mt/y feeding 1 OSBF furnace
- Primary and secondary feed system



CO_2 Emissions Reduction with iBLUE®

THE TWO NEW WAYS TO PRODUCE STEEL



What's about Energy / Gas Demand!? 1/4

SOME BASIC CONSIDERATIONS

Natural Gas and Hydrogen demand for DRP-EAF route after full transition

Case 1 with 100 % Natural gas for Germany

- **99 TWh** / 10 bn Nm^3 / 7.3 Mio. tons

Case 1 with 100 % Natural gas for Europe

- **630 TWh** / 62 bn Nm^3 / 45 Mio. tons

Case 2 with 100 % Hydrogen for Germany

- **94 TWh** / 26 bn Nm^3 / 2.4 Mio. tons

Case 2 with 100 % Hydrogen for Europe

- **589 TWh** / 160 bn Nm^3 / 14.5 Mio. tons

Germany 2021:

Natural Gas consumption: 1.000 TWh_{NG}

Hydrogen consumption: 55 TWh_{H2} (mainly from steam reforming)

What's about Energy / Gas Demand!? 2/4

SOME BASIC CONSIDERATIONS

Windmill: 4.5 MW
Full load hours: 4.500 hours
Annual output: 20.000 MWh

Green steel: 5 million tons / year
Hydrogen demand: 65.7 kg / t steel
328.500 t / year
900 t / day
~ 38 t / hour

Energy for Electrolysers: **13 TWh***

Windmills (minimum): 650
Electrolyser capacity: 1.5 GW

Necessary electrolyser capacity after full transition to DRP-EAF route with 100 % Hydrogen steel (Electrolyser efficiency 84 %)

Electrolyser capacity (minimum)**

Germany: 12 GW (36m tons Steel/Year)

Europe: 65 GW (220m tons Steel/Year)

** Expected capacity in Germany:
- 30 - 40 GW until 2030
- Up to 80 GW until 2050

Source: German Hydrogen and Fuel Cell Association

* Wind energy production On- and offshore Germany 2021: **122.4 TWh**

What's about Energy / Gas Demand!? 3/4

SOME BASIC CONSIDERATIONS

Electrical Energy (EE.) requirements as a result of electrification (DRP, EAF, HTE) to produce 1 ton of Liquid Steel

- Electrical energy without electrolysis: **1.1** MWh_{el} / t_{LS}
- Electrical energy with electrolysis*: **3.7** MWh_{el} / t_{LS}

Case 1: EE. without electrolysis

- Germany: 40 TWh_{el}
- Europe: 245 TWh_{el}

Germany 2021:

Gross electricity generation: 570 TWh_{el} of which 40 % comes from renewables

Case 2: EE. with 100 % Hydrogen

- Germany: 135 TWh_{el}
- Europe: 815 Twh_{el}

Europe 2021:

Electricity consumption: 3.200 TWh_{el} of which 21 % (670 TWh_{el}) was attributable to renewables

* 70 % of the total energy is required for electrolysis

What's about Energy / Gas Demand!? 4/4

SOME BASIC CONSIDERATIONS

- The way to decarbonization goes through Direct Reduction
- While DRP + EAF is a very well proven technology, this works only with high grades pellets
- The ENERGIRON process scheme is HYDROGEN READY!
- The increase of DRI production will most likely lead to a shortage of DR grade pellets and it is a question if the supply will be able to match the demand
- Tenova iBLUE® offers a proven way to produce steel from low grade Blast Furnace pellets
- Tenova iBLUE® can count on high Carbon DRI produced via the ENERGIRON™ process and can supply green hot metal to the traditional steelmaking route (i.e. BOF) or to other advanced technologies (i.e. Tenova FMF™) able to take advantage of an increased scrap addition to the metal.
- Currently ongoing projects outside Europe and basic engineering studies with European steelmakers under work.

Some of our Key Projects

WE ARE ON THE WAY…

tenova

sustenovability.

THANK YOU

Dr. - Ing. Markus Dorndorf

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