



Webinar Hydrogen Steelmaking

**GrInHy2.0 - Another step
towards hydrogen based
steelmaking**

**TECHNOLOGIES FOR A
SUSTAINABLE STEEL INDUSTRY**

Dr.-Ing. Markus Dorndorf

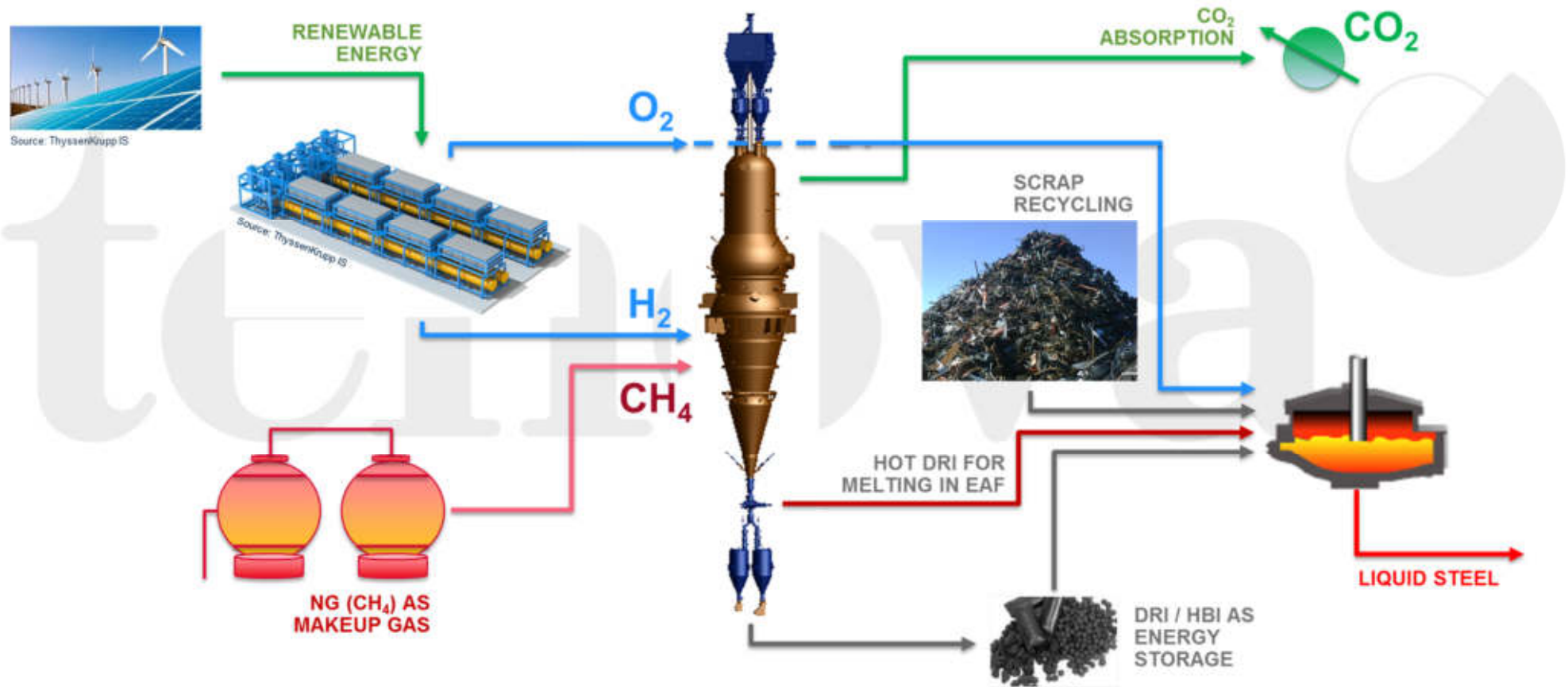
Director Vacuum Degassing Technologies
Business Development Iron & Steelmaking



Steelmaking process of the future



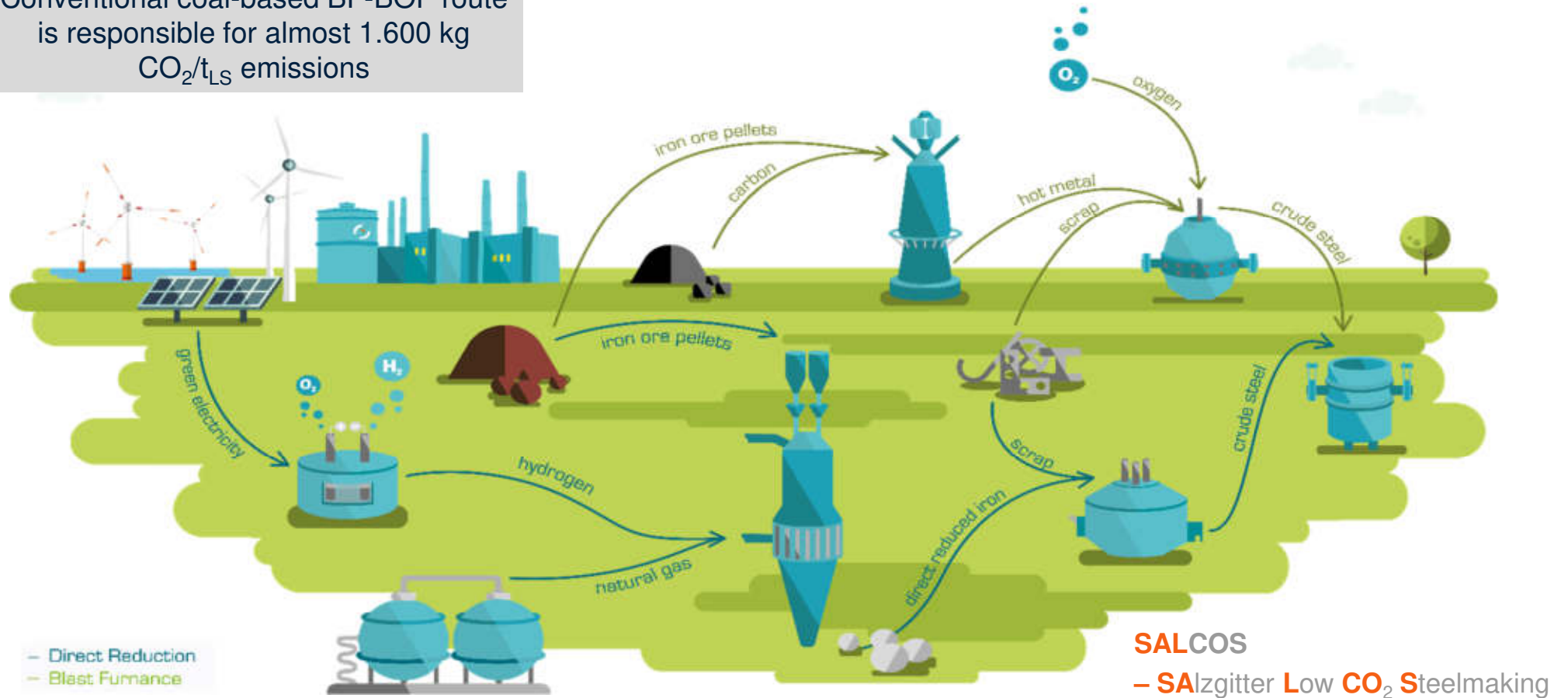
THE TRANSFORMATION PROCESS OF AN INTEGRATED PLANT



The SALCOS approach

THE TRANSFORMATION PROCESS OF AN INTEGRATED PLANT

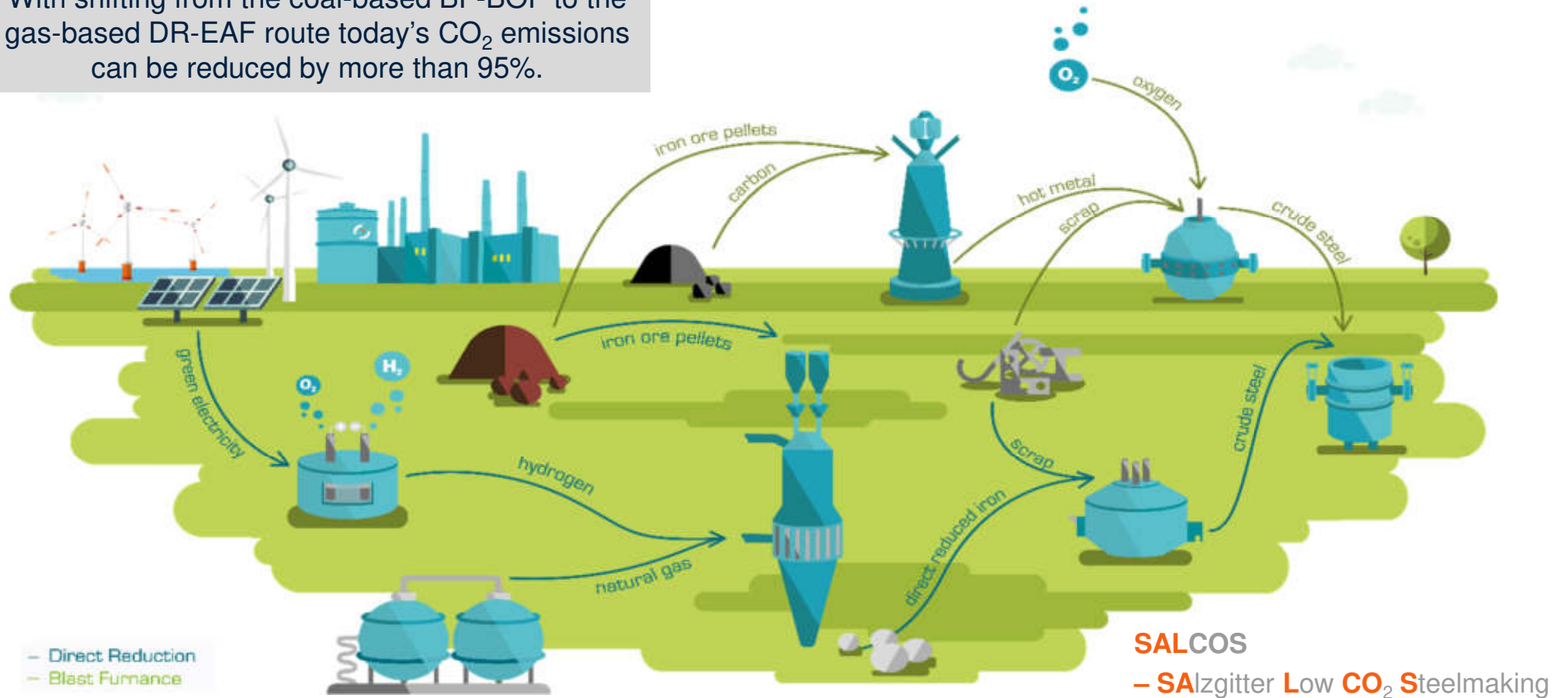
Conventional coal-based BF-BOF route is responsible for almost 1.600 kg CO₂/t_{LS} emissions



The SALCOS approach

THE TRANSFORMATION PROCESS OF AN INTEGRATED PLANT

With shifting from the coal-based BF-BOF to the gas-based DR-EAF route today's CO₂ emissions can be reduced by more than 95%.



Incremental steps of the transformation process



THE TRANSFORMATION PROCESS OF AN INTEGRATED PLANT



First steam electrolysis in megawatt scale at Salzgitter Flachstahl beginning in 2020



Wind-H2 – Sector coupling



Production of electric energy by means of windpower and electrolytic hydrogen on the premises

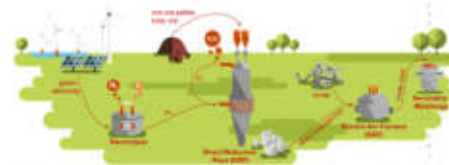


MACOR – SALCOS-Feasibility Study

BMBF-funded, May 2020 finalized

BeWiSe – SALCOS-Supporting Research

BMBF-funded, July 2020 - June 2023



The GrInHy2.0 project - consortium



THE TRANSFORMATION PROCESS OF AN INTEGRATED PLANT



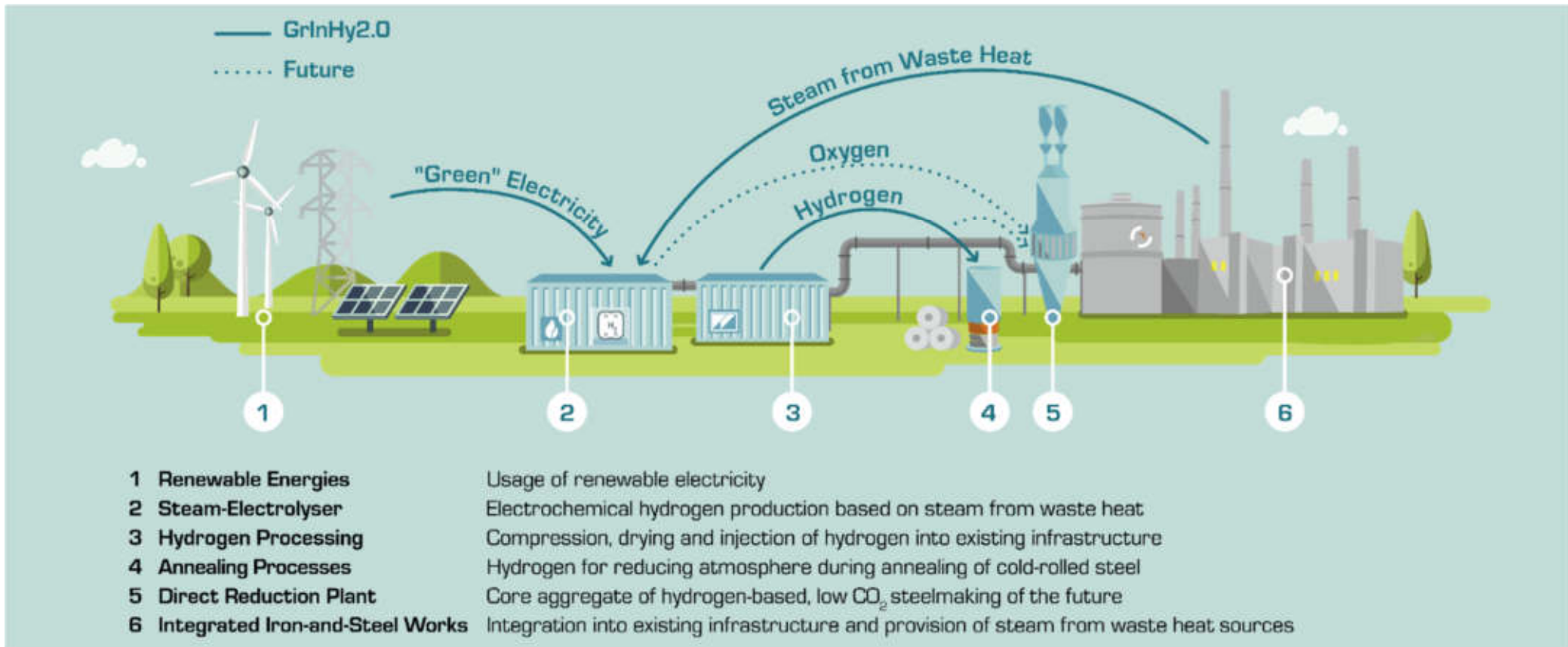
- Project start: January 2019
- Project duration: 4 years
- Idea: Realization of a steam electrolysis in an industrial relevant size integrated in an integrated iron & steel works to support the most promising Carbon Direct Avoidance (CDA) approach by substituting the reducing agent carbon by green hydrogen to significantly reduce carbon dioxide emissions in the steel production
- Consortium consists of six partners from four different EU countries and is characterized by its interdisciplinary expertise.

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (JU) under Grant Agreement No 826350. This Joint Undertaking receives support from the European Union's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe Research.



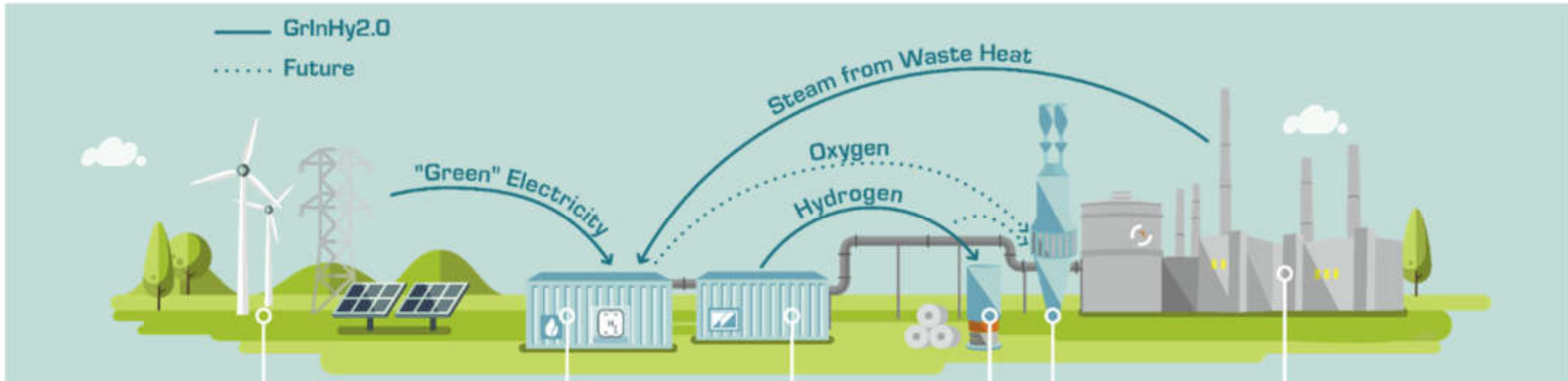
The GrInHy2.0 project - concept

THE TRANSFORMATION PROCESS OF AN INTEGRATED PLANT



The GrInHy2.0 project - is...

THE TRANSFORMATION PROCESS OF AN INTEGRATED PLANT



- Demonstrating the first Steam Electrolyser (StE) in the Megawatt-class in an industrial environment,
- the most energy-efficient hydrogen production using green electricity and steam from waste heat sources of the steelmaking processes,
- the optimized integration of the system into an existing infrastructure and operation via Salzgitter's energy management control system,
- producing 'green' hydrogen for today's steelmaking processes while assessing the technology's potential for a hydrogen-based, low carbon European steel industry in the future,
- setting new standards in long-term stack validation of the Solid Oxide Electrolysis Cell technology.

The GrInHy2.0 project - the way to green steel



THE TRANSFORMATION PROCESS OF AN INTEGRATED PLANT

- ✓ Electrolyser scale-up to 720 kW_{el,AC} producing 200 Nm³/h (18 kg/h)
- ✓ Electrical electrolyser efficiency up to 84 %_{el,LHV} (< 40 kWh_{el,AC}/kg H₂)
- ✓ > 13,000 operating hours at system level with a proved availability of > 95 %
- ✓ > 20,000 operating hours at stack level
- ✓ Demonstrate hot start from minimum to maximum power in < 5 mins

- ✓ Produce >100 tons of green hydrogen
- ✓ Reduce electrolyser CAPEX to < 4.500 €/(kgH₂/d)
- ✓ Provide techno-economic studies for further market deployment

- ✓ Create viable technology by demonstration in a complex industrial environment
- ✓ Assess CO₂ avoidance potential of a hydrogen-based European steel industry
- ✓ Provide significant share of green hydrogen to the iron-and-steel works
- ✓ Evaluate situation on purchasing renewable electricity and green H₂ certification

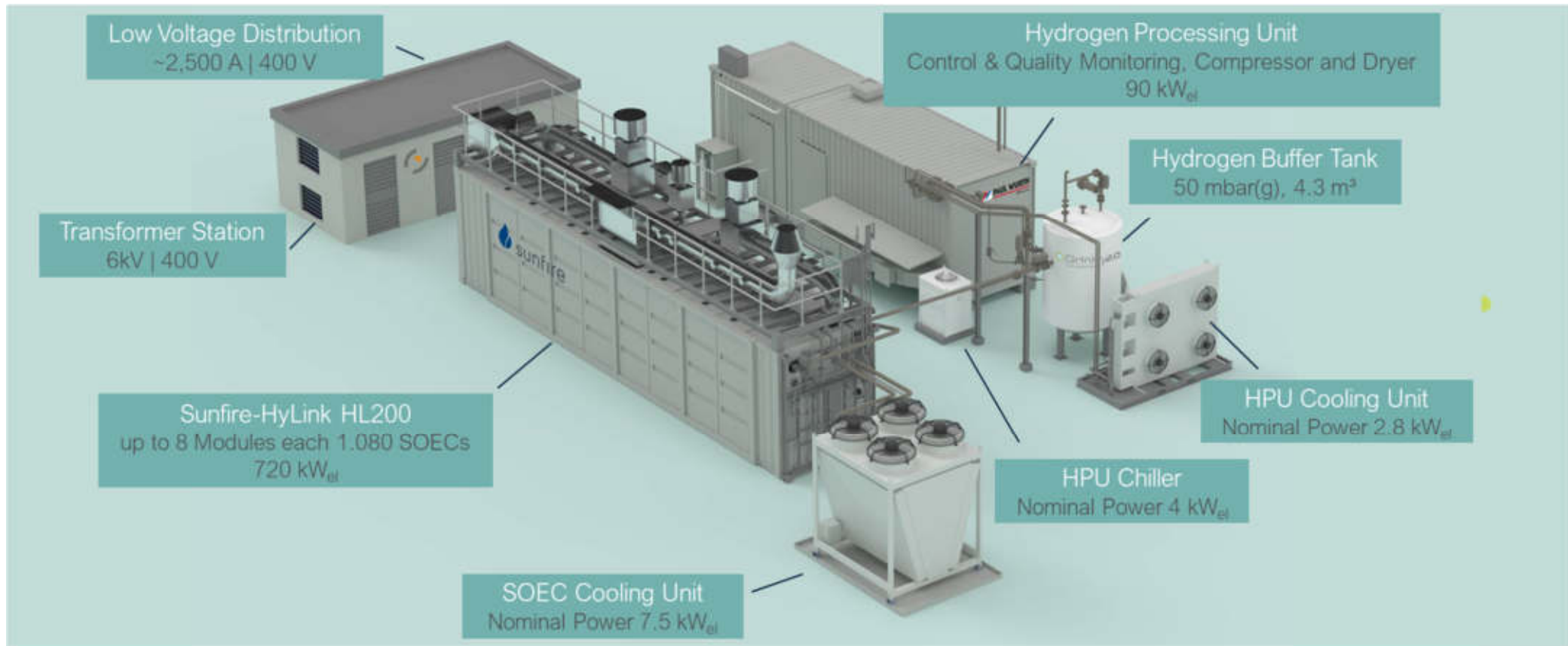
Technical

Economical

Socio-
Political

The GrInHy2.0 project - layout

THE TRANSFORMATION PROCESS OF AN INTEGRATED PLANT



The GrInHy2.0 project - Tenova's contribution



THE TRANSFORMATION PROCESS OF AN INTEGRATED PLANT

- ✓ Study on hydrogen's CDA potential for integrated iron-and-steel works
- ✓ Identification of optimal system dimensions based on mass and energy balances
- ✓ Evaluation of indispensable process transformation to perform with maximum efficiency

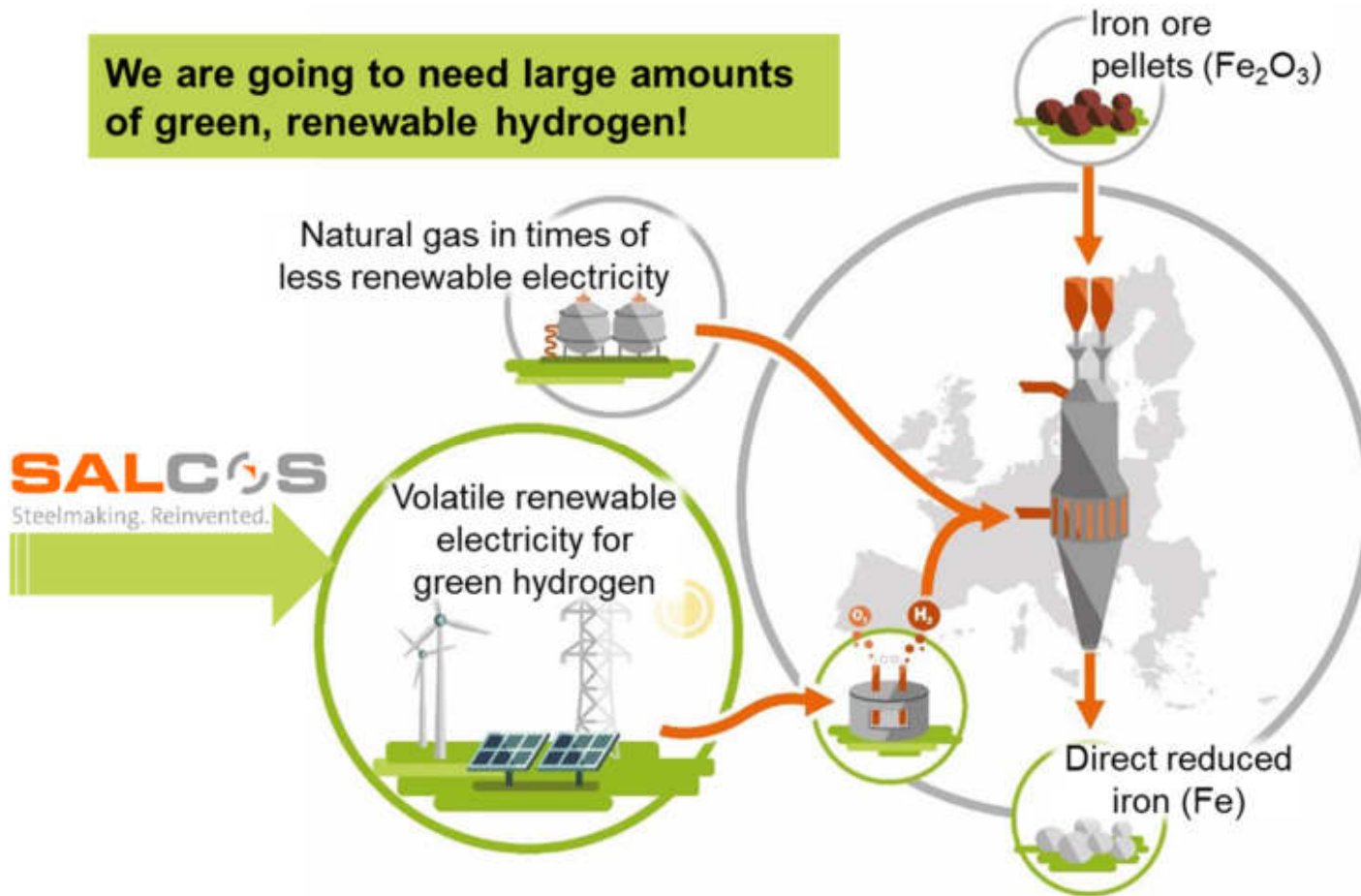
- ✓ In detail (1st phase):
 - ✓ Description of the ENERGIRON-ZR process scheme as potential BAT for hydrogen usage in iron making processes
 - ✓ Investigation of a stepwise transformation process towards direct reduction and electrical energy based processes and calculation of related CO₂ emission reduction potentials based on SZFG
 - ✓ Modelling of different levels of H₂ usage in the DR Plant (based on the ENERGIRON ZR Process)
 - ✓ Investigation and evaluation of the usage of DRI / HBI in Blast Furnaces (BF) and correlated effects on CO₂ emission reduction
 - ✓ Further H₂ use up to 100% modelling and experimentation for DR plants, in combination with BF-BOF mills.

- ✓ Outlook: Upscaling effects and CAPEX/OPEX estimations for European steel works

The SALCOS approach - a summary

THE TRANSFORMATION PROCESS OF AN INTEGRATED PLANT

We are going to need large amounts of green, renewable hydrogen!



SALCOS is...

- pairing already **established** technologies with **hydrogen** technologies and an **innovative** operational concept
- a **step-wise transformation** of the integrated steelmaking route **supporting** the transition of the **energy system**
- reducing today's CO_2 emissions by more than **95%**
- a **sustainable "Carbon Direct Avoidance"** approach: Reducing instead of recycling!

The ENERGIIRON scheme - the BAT for SALCOS



THE INNOVATIVE HYL DIRECT REDUCTION TECHNOLOGY JOINTLY DEVELOPED BY TENOVA AND DANIELI - UNIQUE FEATURES

REMOVAL OF CO₂

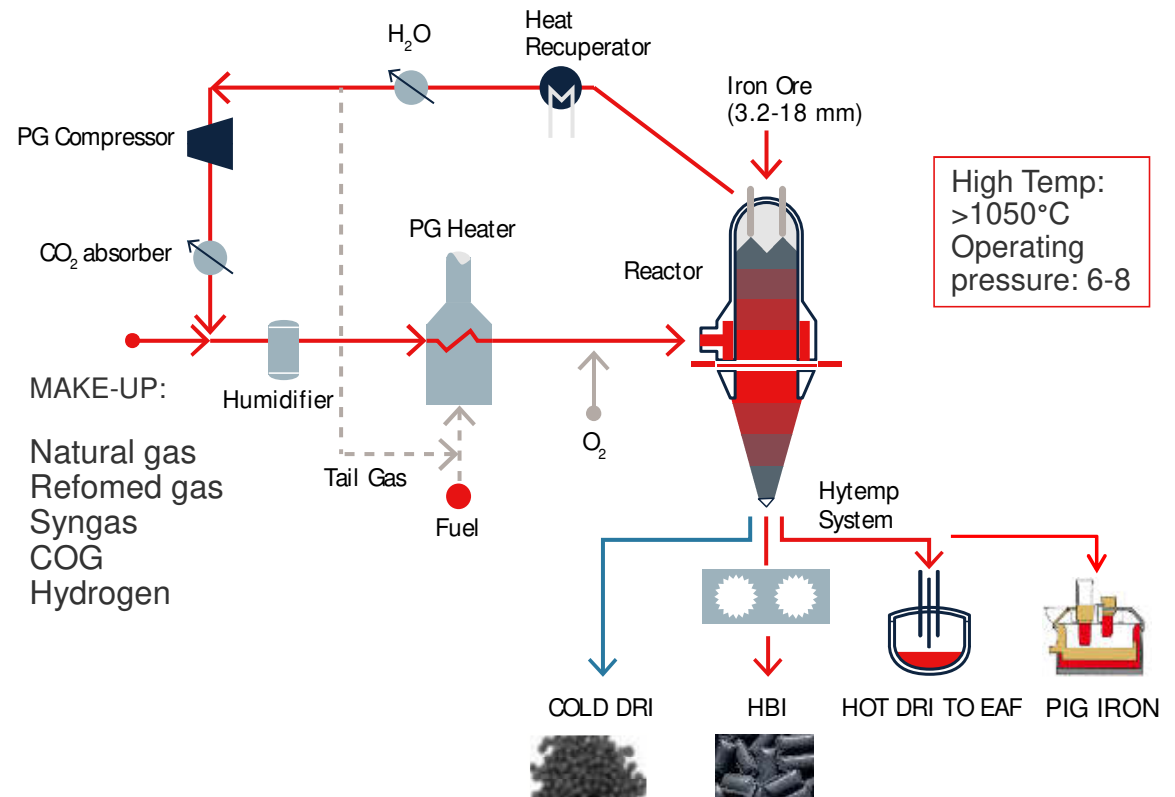
- ✓ Selective removal of CO₂
- ✓ Intrinsic capability for CCU and CCS

DRI QUALITY

- ✓ >94-96% Mtz;
- ✓ 1,5%- 5,0% Carbon (as Fe₃C)
- ✓ High-C CDRI, High-C HDRI, High-C Briquettes

FLEXIBILITY

- ✓ Same scheme for any energy source
- ✓ Energy recovery from the top gas
- ✓ Scheme overall efficiency 83-87%



The ENERGIIRON scheme - the BAT for SALCOS



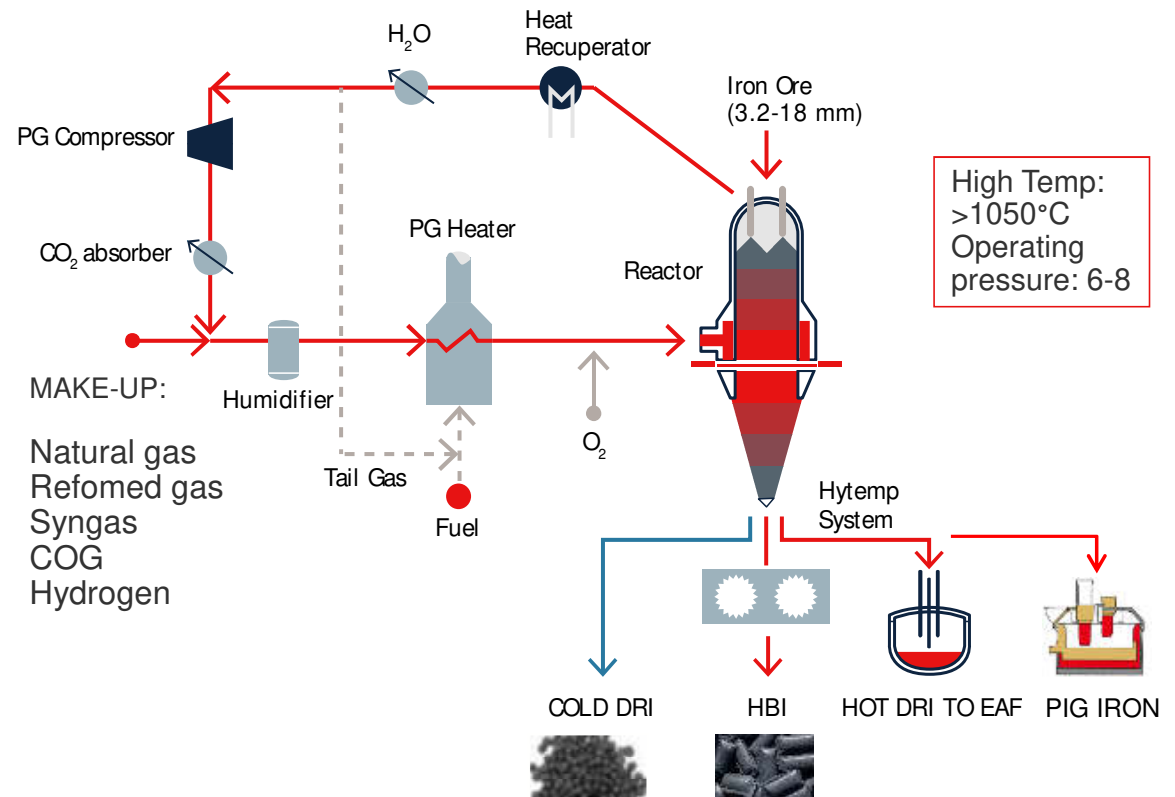
THE INNOVATIVE HYL DIRECT REDUCTION TECHNOLOGY JOINTLY DEVELOPED BY TENOVA AND DANIELI - UNIQUE FEATURES

ENVIRONMENTAL

- ✓ Lowest Nox emissions:
0,030 kg_{NOX} / t_{DRI}
- ✓ Selective removal of iron ore reductions by-products: H₂O & CO₂
- ✓ Use of gas implies that coke/coal is no longer needed as in blast furnace

OPEX

- ✓ Highest overall Energy efficiency
- ✓ < 9,5 GJ/t; < 80 kWh/t
- ✓ High yield: < 1,4 t IO/t_{DRI}



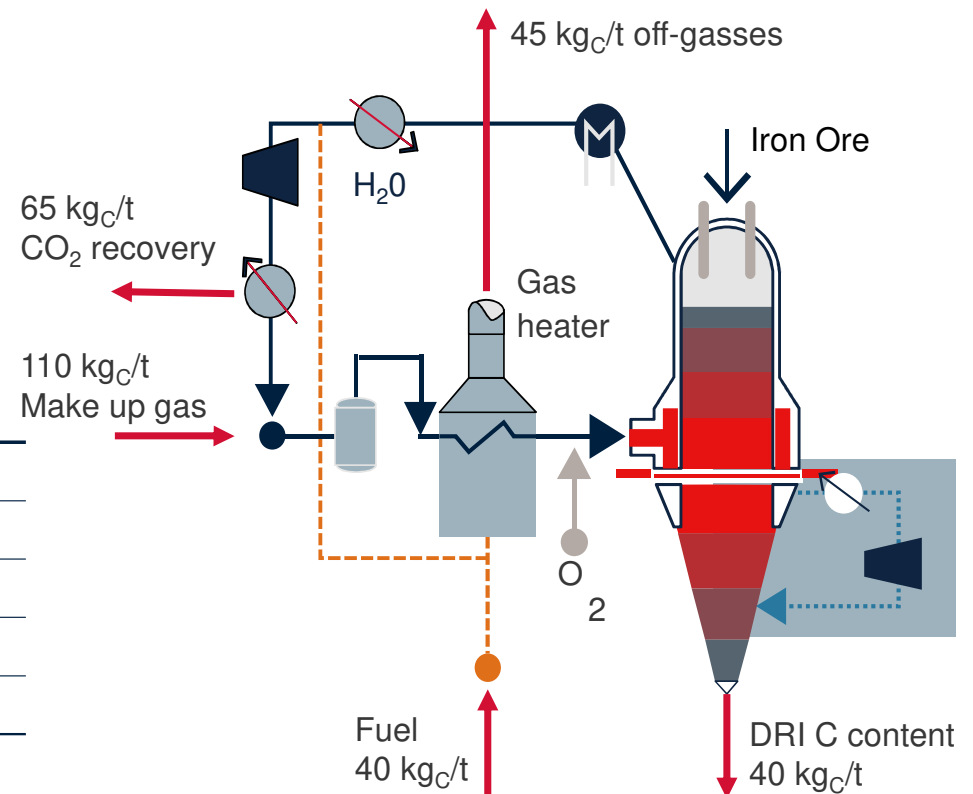
Selective CO₂ removal

CAPTURE AND UTILIZATION OF THE CO₂

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

For the mass conservation law, the total carbon used in the ENERGIRON process ends up as:

- Captured CO₂ Emissions (45% of C input)
- Free CO₂ Emission to Atmosphere (30% of C input)
- Carbon in DRI/HBI product (25% of C input)



Reference Plant	Country	Use	Offtaker
Ternium Monterrey	Mexico	Food & Beverage	Linde
Ternium Puebla	Mexico	Beverage industry	Cryolnra
PTKS	Indonesia	Food industry	Janator
PSSB	Malaysia	Food industry	Air Liquide/MOQ
JSW Salav	India	Dry Ice	Air Liquide
Emirates Steel	UAE	Enhanced Oil Recovery	Masdar/ADNOC

Optimum carbon content in DRI / High-C DRI

FLEXIBILITY FOR SPECIFIC APPLICATION AND STEEL GRADE

- ✓ Reduction of the residual FeO without graphite injection into EAF, that has lower efficiency
- ✓ Feeding to EAF C in cementite form, provides thermal energy (from Fe₃C dissociation) to the **EAF 36 - 40 kWh/t** DRI per each 1% Carbon in the DRI
- ✓ C in DRI reacts with O₂ injected into EAF, providing thermal energy, better stirring, foamy slag
- ✓ Higher C content in DRI provides longer electrode's life
- ✓ Higher C content in DRI provides longer EAF refractory's life
- ✓ Feeding DRI with correct C content allows to reduce the tap-to-tap time

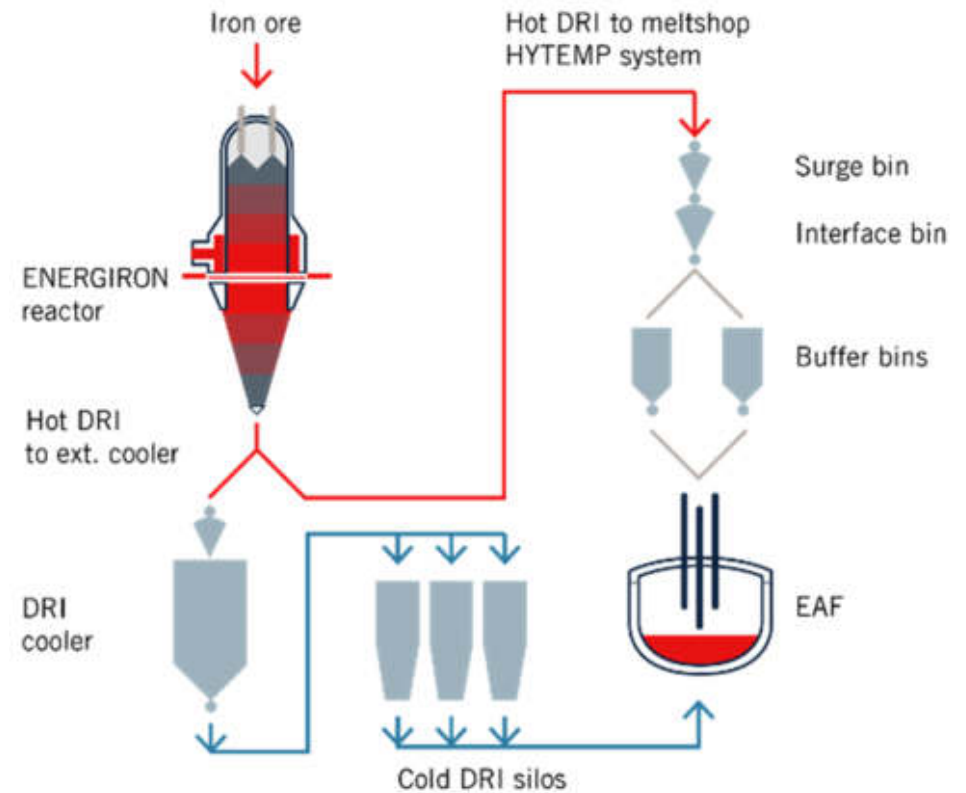


High temperature DRI

THE FIRST, WITH THE MOST RELIABLE SYSTEM



- ✓ Thermal energy of **HOT DRI** can be recovered by transporting it at high temperature directly from the reactor to the EAF
- ✓ DRP & SMP at the same site
- ✓ Savings for every 100°C in DRI T
- ✓ Electric energy **-26 kWh/tls**
- ✓ Productivity increase **+5%**

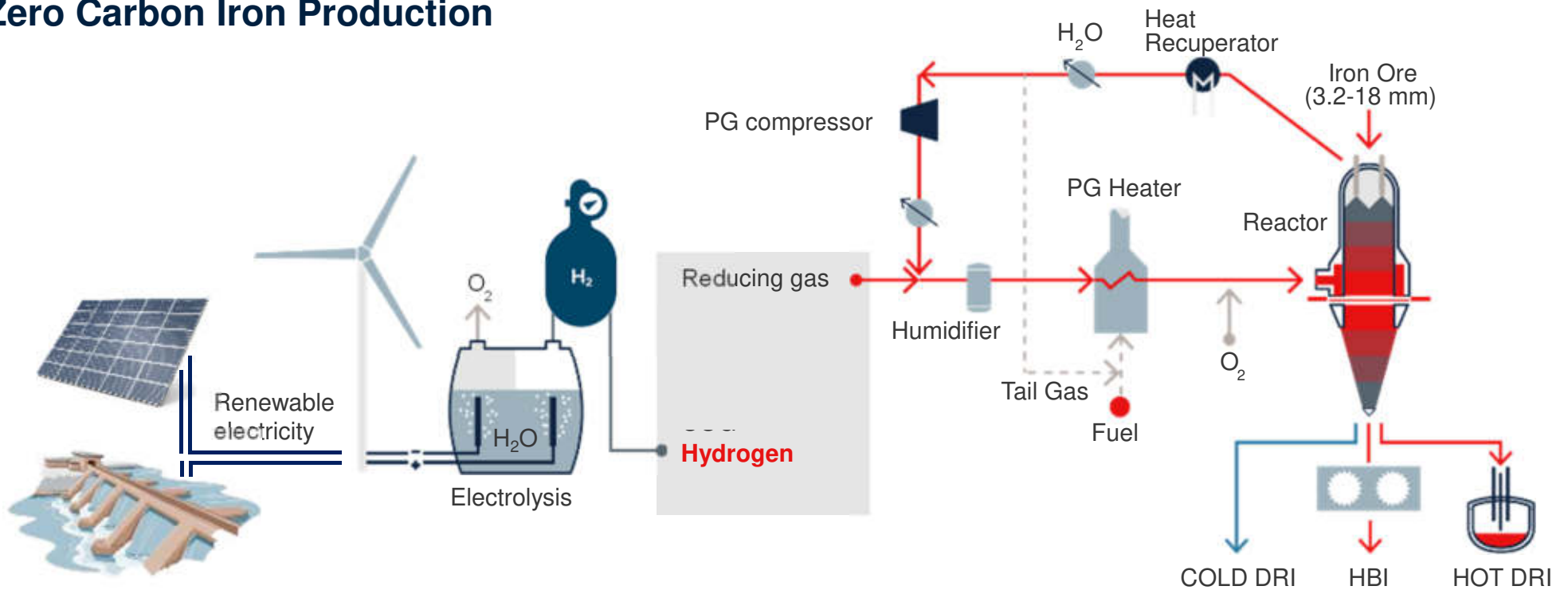


From CCU to Carbon Direct Avoidance (CDA)



HYDROGEN AS ENABLER FOR GREENER STEELMAKING - HYDROGEN BASED DIRECT REDUCTION

Zero Carbon Iron Production

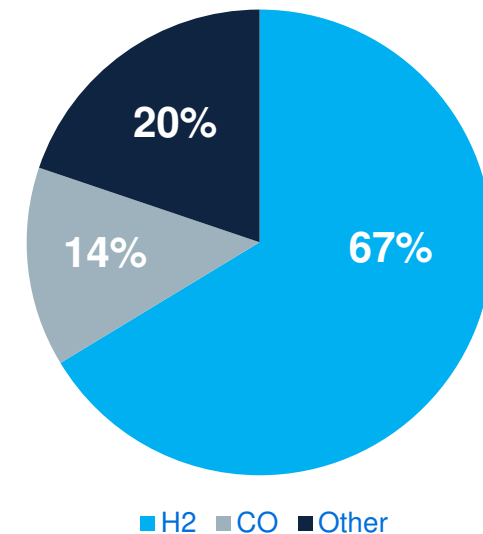


Experience with hydrogen use

ENERGIRON IS READY FOR INDUSTRIAL APPLICATION

- ✓ Experience in ENERGIRON plants with reformer using in **excess of 70% H₂**
- ✓ Scheme natively fitted for direct use of H₂
- ✓ Completion of pilot plant tests with **~90% H₂ since 1990's**
- ✓ Extensive experience and operation with Process Gas heaters and gas sealing valves design, specifically with high percentages of H₂

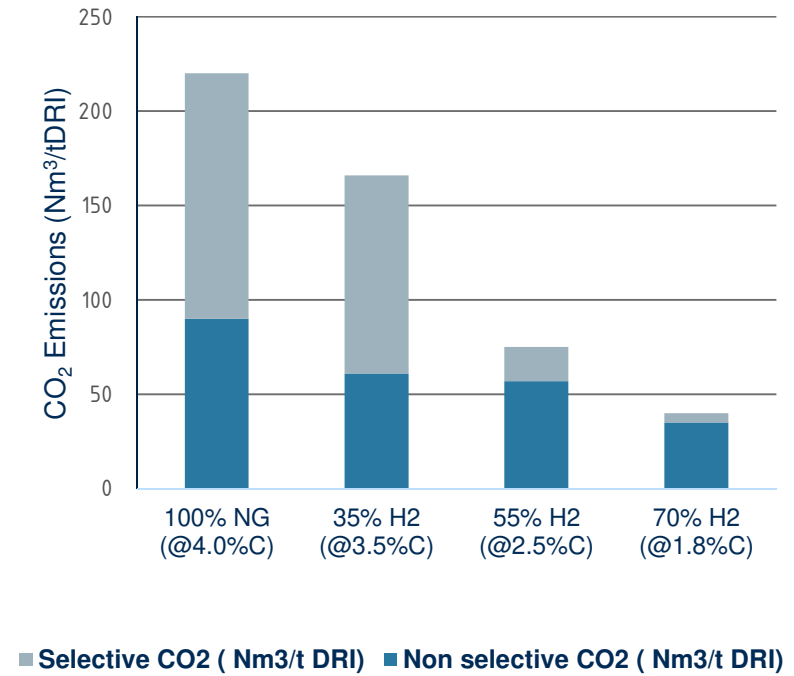
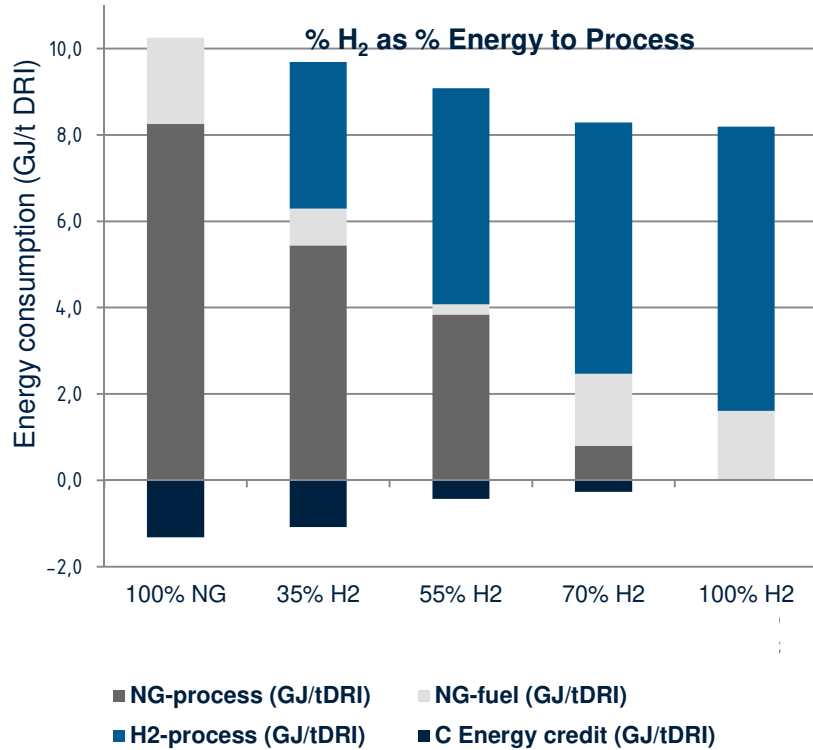
ENERGIRON HYL
DRI TECHNOLOGY BY TENOVA AND DANIELI



Use of hydrogen in an ENERGIRON plant



ENERGIRON AS BENCHMARK FOR CO2 REDUCTION



Hydrogen use: projects under execution

THE SELECTION OF CHOICE FOR HYDROGEN USE



SALCOS – SALzgitter Low CO₂ Steelmaking

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

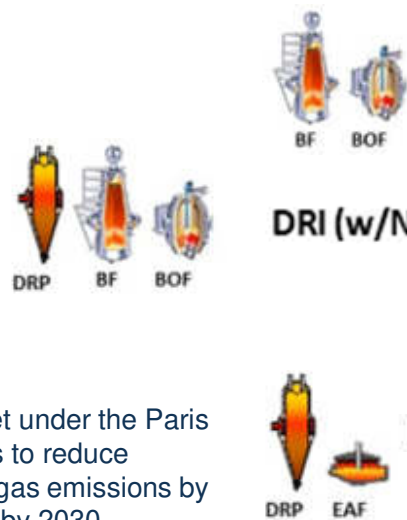


Use of H₂ and impact on CO₂ emissions reduction



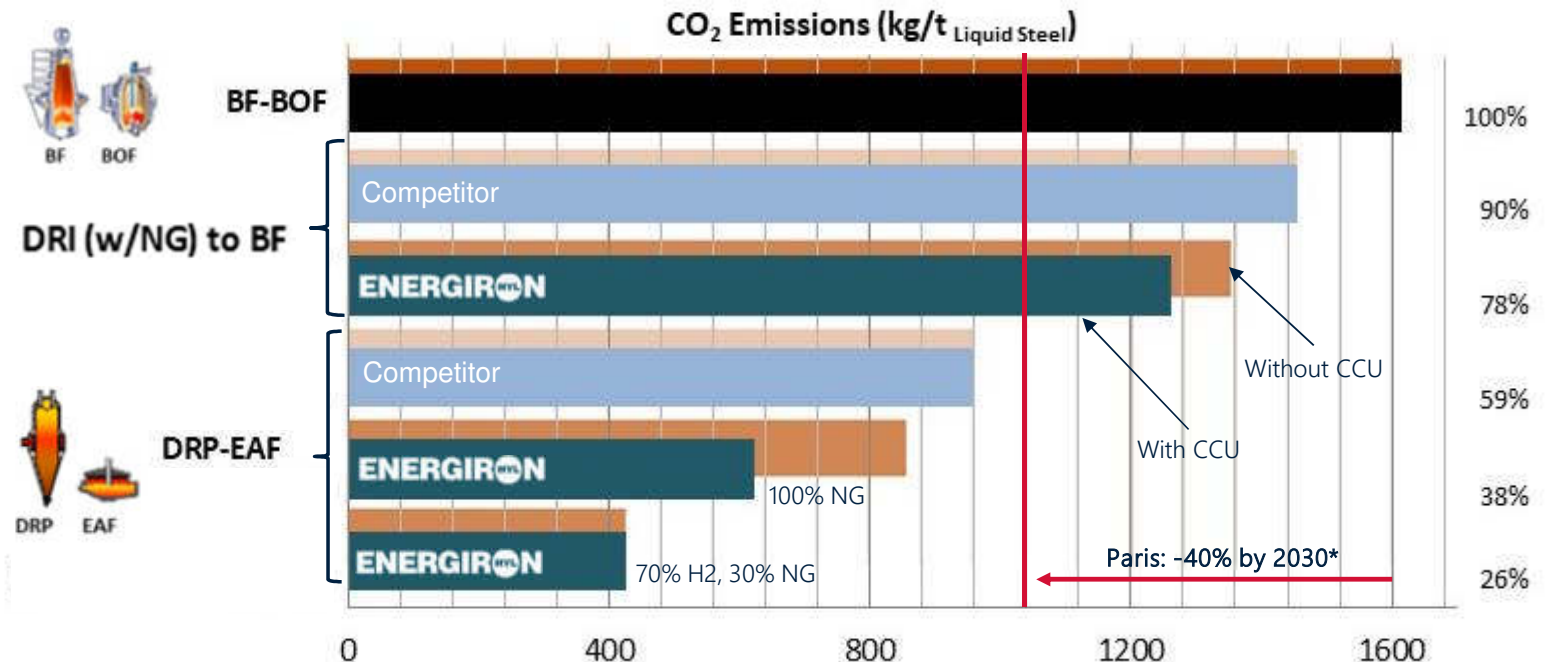
ENERGIRON AS GAME CHANGER FOR THE SUSTAINABILITY OF STEELMAKING

- A sustainable path for the decarbonization of steelmaking
- ENERGIRON DR-EAF route is ~50% less carbon intensive than the BF integrated process, ~60% less with CCU
- Further reduction to ~75% less carbon intensive with 70% H₂ / 30% NG use



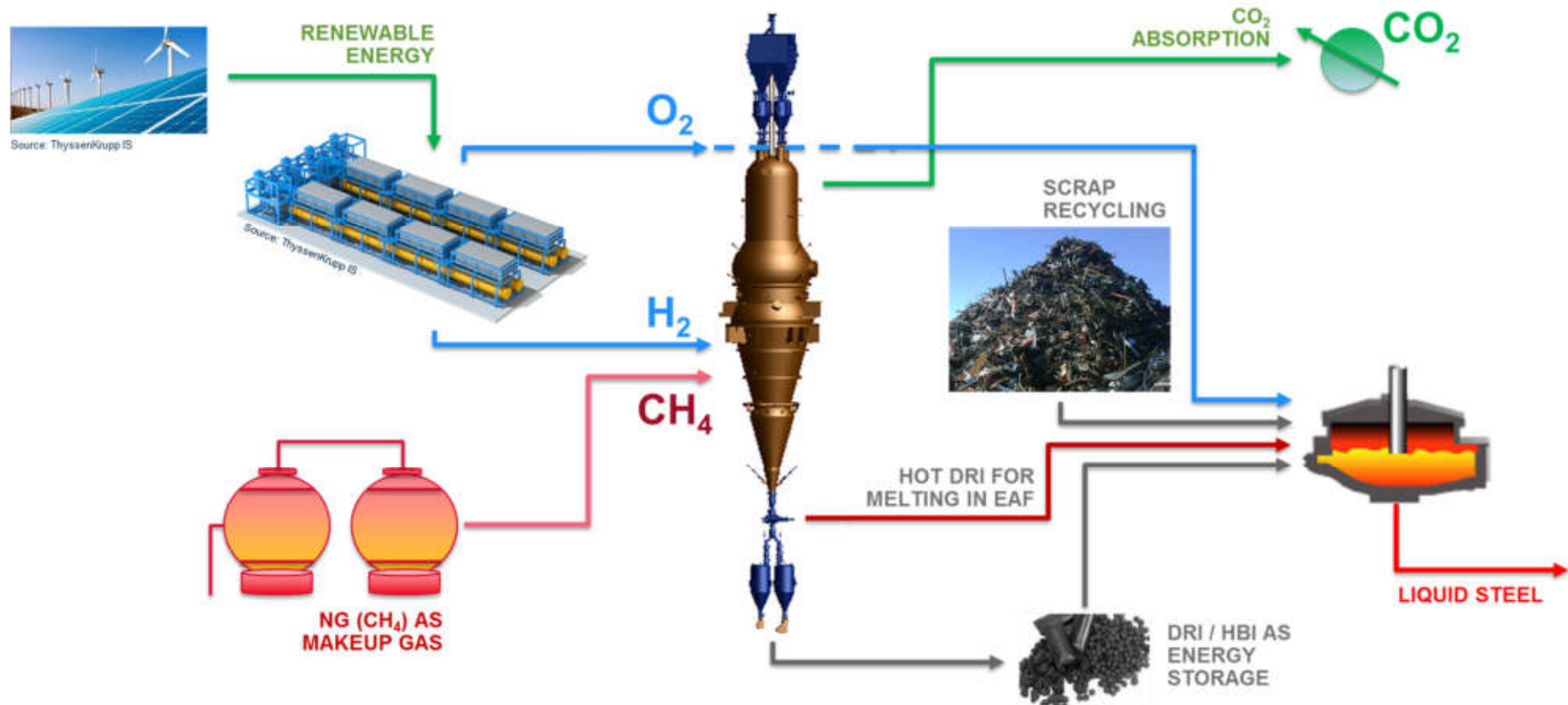
* The goal set under the Paris Agreement is to reduce greenhouse gas emissions by at least 40% by 2030 (<https://ec.europa.eu/>)

** assumed ~0,5 kgCO₂/kWh)



Steelmaking process of the future

THE TRANSFORMATION PROCESS OF AN INTEGRATED PLANT



Sustenovability



SUSTENOVABILITY IS A NEOLOGISM THAT EMBODIES THE PERFECT BLEND BETWEEN THE TENOVA BRAND, ITS ECO-FRIENDLY VALUES AND ITS CAPACITY TO DELIVER SUSTAINABLE SOLUTIONS



sustenovability.

sustenovability.tenova.com is a new web platform featuring stories, best practices and case studies that highlight how Tenova is living up to its commitment towards sustainability



Thank you!

Tenova / LOI Thermprocess GmbH

markus.dorndorf@tenova.com

www.tenova.com
www.energiron.com

TECHINT GROUP

