# Finance for Innovation: Towards the ETS Innovation Fund

# Workshop 1: Ferrous and Non-ferrous metals

**17 February 2017 2016**

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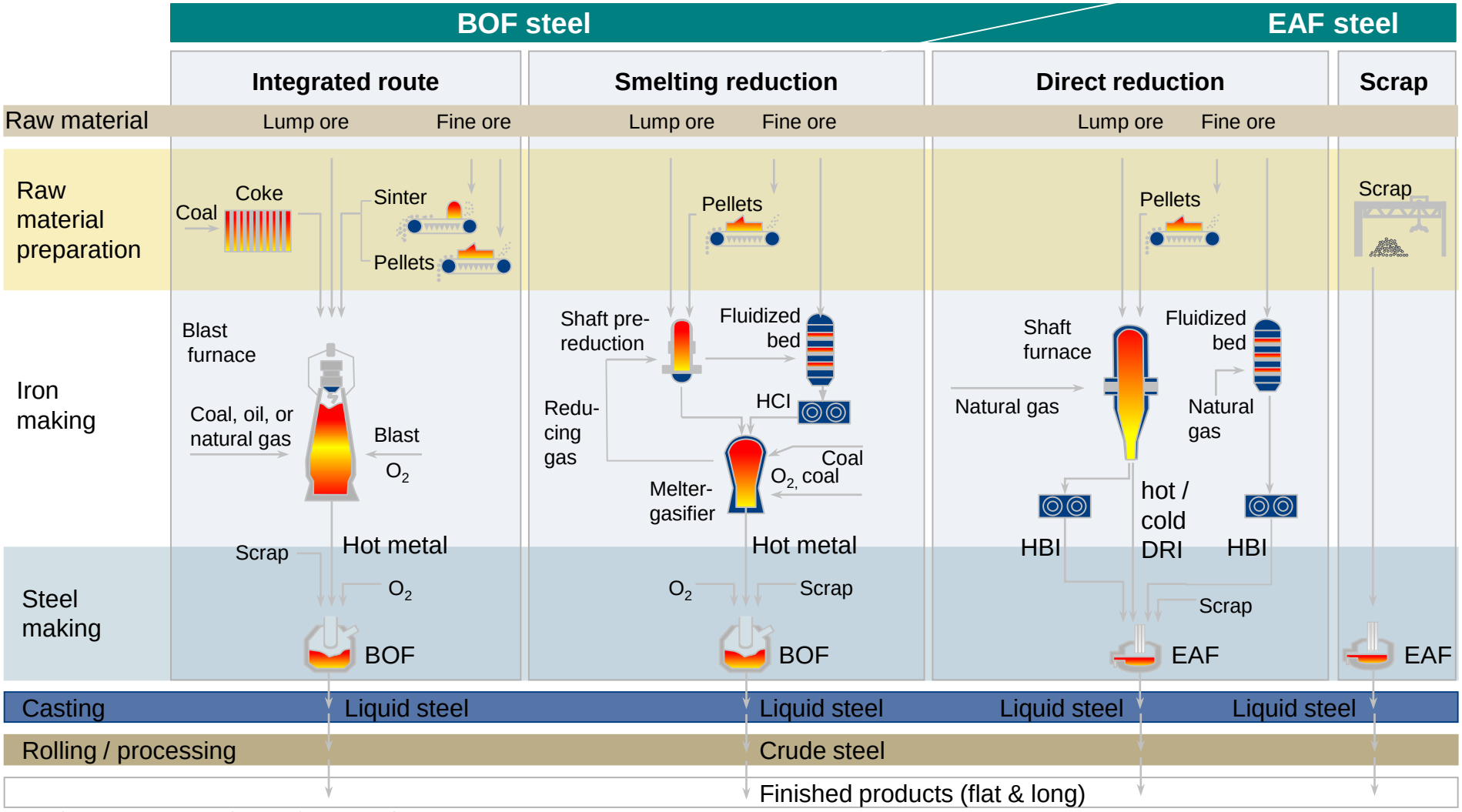
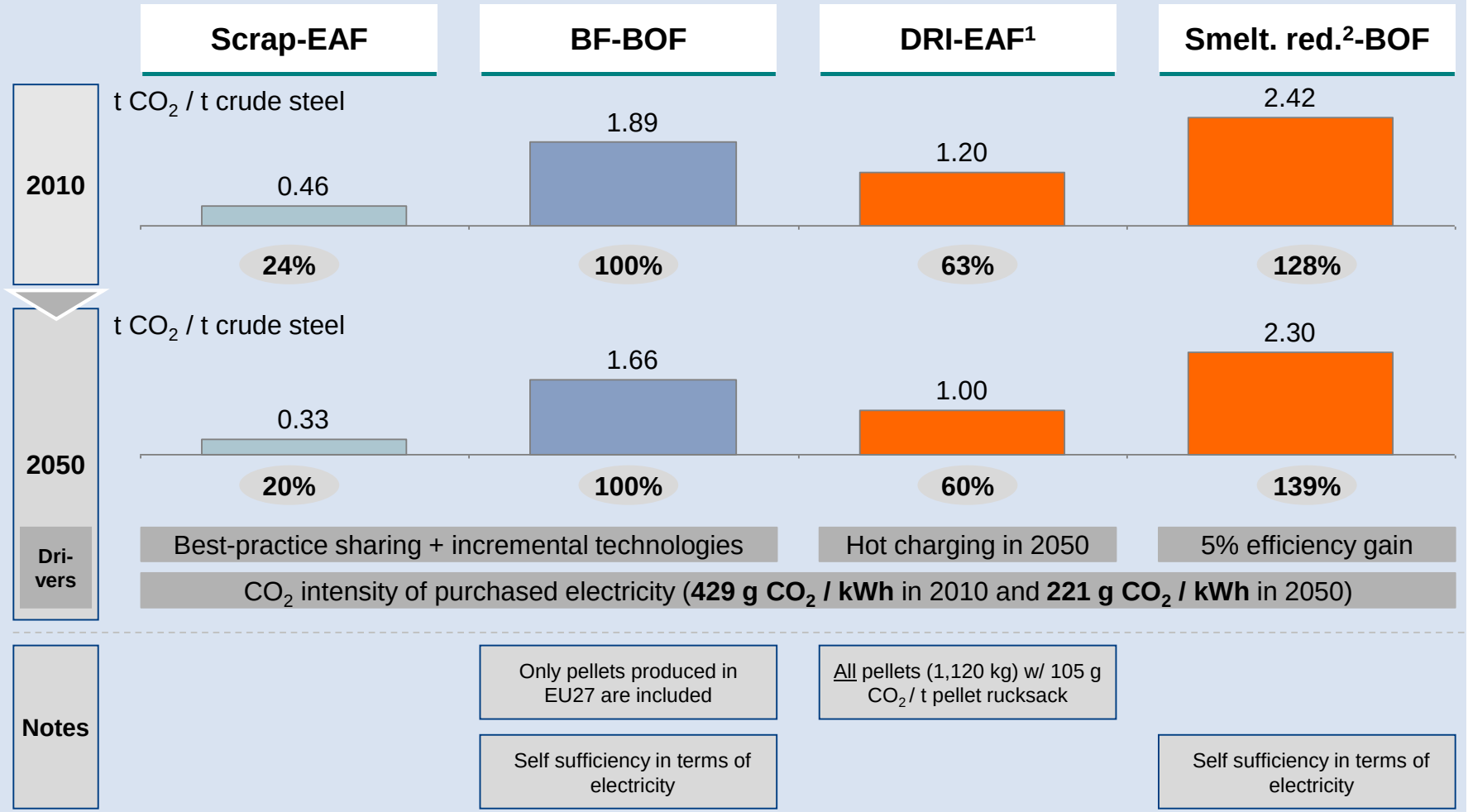
EUROFER
The European Steel Association

# Overview of iron- and steel-making routes



# Overview of $CO_2$ intensity per route for 2010 and 2050

EUROFER The European Steel Association




1. Based on Midrex direct reduction technology 2. Based on Finex smelting reduction technology
Note: Differences between routes in production of the by-product slag not considered in analysis
Sources: VDEh; Project team analysis

Source: BCG/Stahlinstitut VDEh

# Introduction

- The EU steel industry is committed to contribute to the EU's climate objectives.
- The EU steel industry is a world leader in $CO_2$ emission reductions and is today very close to the physical limits of conventional steelmaking technologies.
- Currently, there is no steelmaking technology available that could even come close to $CO_2$ emission reductions target set out by the EU
- Only innovative, so-called "breakthrough" technologies may deliver emission reductions set out by the EU ETS. The EU steel industry is since many years at the forefront of R&D into breakthrough technologies (e.g. ULCOS programme).
- Currently, a number of emission reduction approaches are being explored within the EU steel industry.
- Whilst initial funding for the first technology upscaling steps for these projects is available until 2020, it is of absolute importance that support for follow-up projects is also provided in the period from 2020 to 2035
- The effectiveness of these various concepts and potential technologies will entirely depend on their commercialisation and general deployment in the market - meaning definitely not before 2035

# $CO_2$ emissions reduction approaches

**The low-carbon projects and initiatives currently being explored within the EU steel industry can be classified into several groups:**

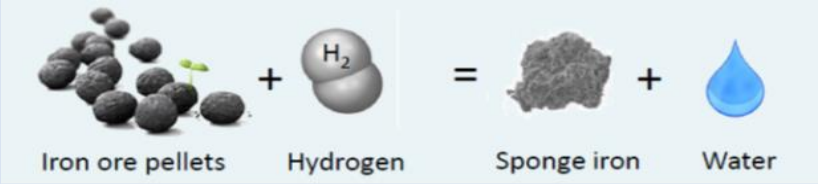
- Carbon Direct Avoidance (so called CDA), directly avoiding $CO_2$ emissions through an increased use of renewable electrical power in basic steelmaking (e.g. hydrogen replacing carbon in metallurgical processes), directly avoiding $CO_2$ emissions.

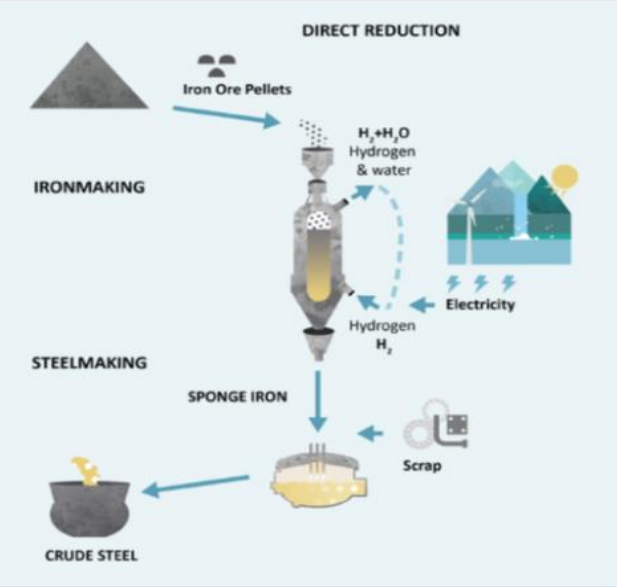
- Process Integration with reduced use of carbon and with or without Carbon Capture and Storage (so called CCS)

- Carbon Capture and Usage (so called CCU), meaning the chemical conversion of $CO_2$ captured from industrial processes, using the $CO_2$ as a raw material

# HYBRIT

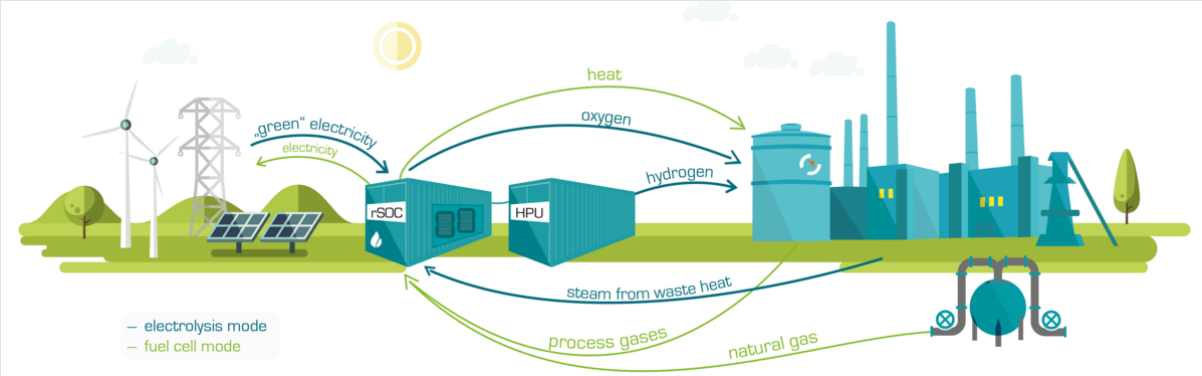
- Reduction carbon dioxide emissions from ironmaking by eliminating the need of using fossil fuel for iron ore reduction. The idea is to use hydrogen produced from “clean” electricity. This means that the by-product from ironmaking would be water rather than carbon dioxide.
- The project was launched in 2016 by SSAB, LKAB and Vattenfall.
- **Investment cost:** funding 1.5 M€ for ongoing pre-feasibility study (Swedish Energy Agency). Est. costs for pilot scale trials and demo: 1-2 bn€
- **Timing**: Pre-feasibilty study (ongoing), Feasabilty study (2018-2024), Demo plant trial 2025-2035
- **Potential savings of $CO_2$**: about 10% of total CO2 emissions of Sweden



# Green Industrial Hydrogen via reversible high-temperature electrolysis)

- The GrInHy project aims to integrate reversible electrolysis technology into industrial processes at a steelworks - efficient and cost effective production of green hydrogen with the aid of regenerative energy.

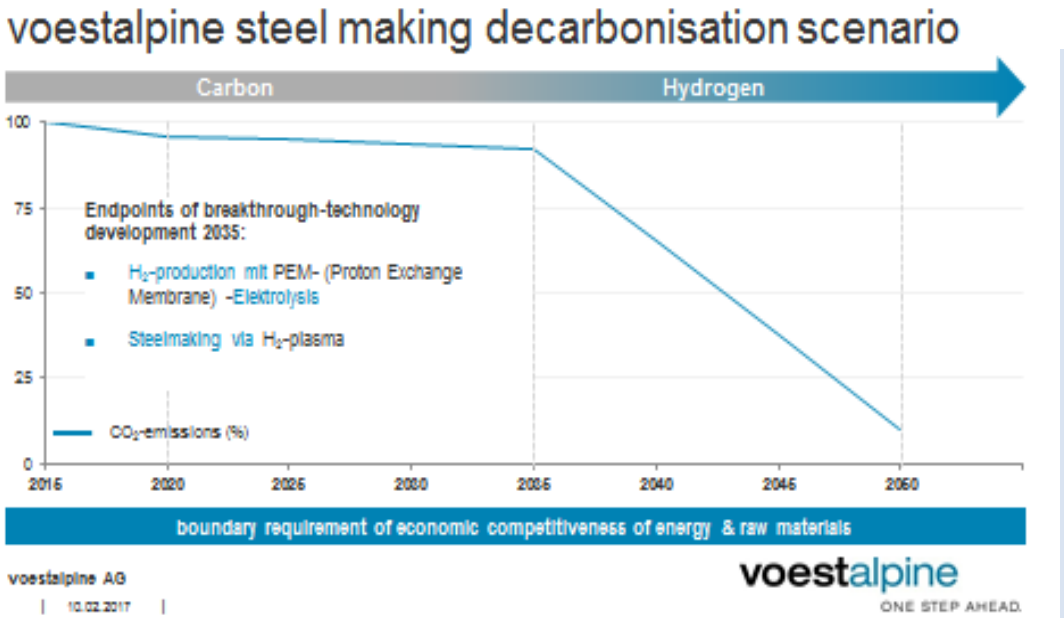



- The recovery of a proportion of the waste heat from industrial companies increases the efficiency of steam electrolysis to about 80%. In addition the avoidance of $CO_2$ emissions supports the EU Commission's push for a competitive, low-carbon economy.
- GrInHy involves eight project partners from Germany, Italy, Spain, Finland and the Czech Republic. It is being implemented at Salzgitter Flachstahl GmbH.
- **Investment costs:** To be investigated during the GrInHy project.
- **Timing**: GrInHy project (2016-2019), Scale-up project (not decided yet) 2019++
- **Potential savings of $CO_2$**: To be investigated during the GrInHy project.

# Voestalpine initiative



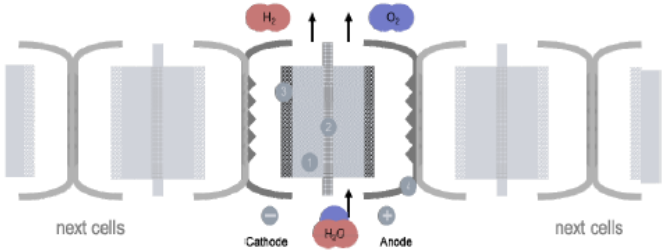
- The aim is in the long term to successively substitute coal in steel making by hydrogen.
- **Timing:** If both technology development and boundary conditions are favourable, roll-out of the hydrogen based steel making technology within voestalpine is expected for 2035.




- With the objective of tackling the task of successfully integrating hydrogen into the steel making processes, a Horizon 2020 co-funded project called **H2Future** started in 2017. With the objective of tackling the task of the development of hydrogen based steel making technologies a nationally co-funded project called **SuSteel** started in 2016. If successful, both need to be followed up after 2020 with upscaling projects. Additional development activities with regard to the raw material base need to be established as well.
- **Potential costs:** There is a need to go beyond H2Future and SuSteel and expand scope of trials on raw material; overall costs 60 M€ (2021-2030). Final upscaling to full industrial demonstrator will follow.
- **Potential savings of $CO_2$**: reduction of 80% of emission intensity of iron ore based steel making

# H2Future

## $H_2$ generation by PEM electrolyzer



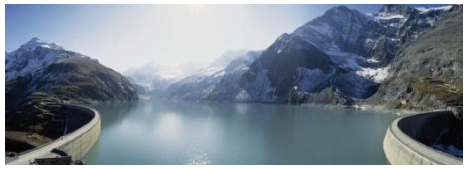

| Electrolyzer type | PEM |
|---|---|
| 1 electrolyte | polymer membrane |
| 2 separator | |
| 3 catalyst | platinum + others |
| 4 frame + bipolar plate) | metal sheet |

**PEM reactions**

**Anode:** $H_2O = 2H^+ + 0{,}5O_2 + 2e^-$

**Cathode:** $2H^+ + 2e^- = H_2$

**Strategic cooperation of voestalpine and Verbund for the installation of the world largest PEM electrolysis unit with 6 MW power and min. 1.200 $m^3/h$ $H_2$ production at voestalpine Linz for full scale demonstration of $H_2$ production and grid balancing.**

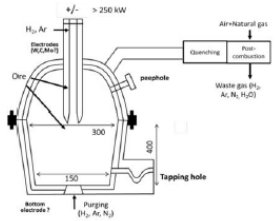


Verbund
Am Strom der Zukunft

# SuSteel

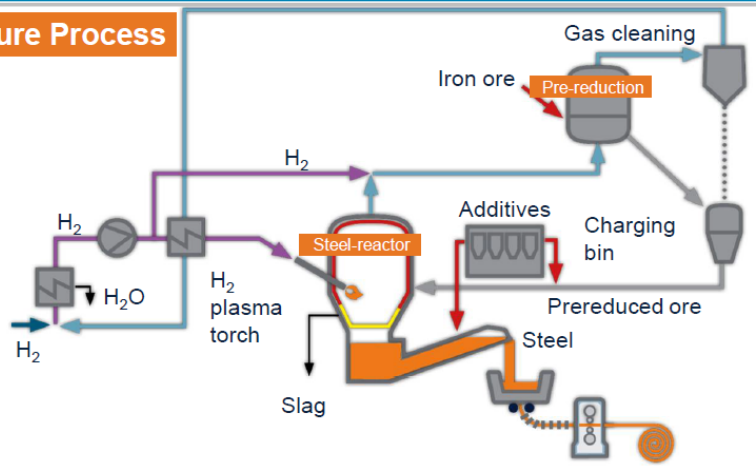
## $H_2$ steelmaking by plasma technology

**1st stage R&D**



- Labscale facility
- Input: Ore or DRI
- Output steel: ~20 kg
- Energy: ~250 kW

**Future Process**




- **Goal**
  Reduction of iron oxide with hydrogen in fluidized bed cascades
- **Second stage**
  Melting of pre-reduced iron ore in steel-reactor within a hydrogen plasma directly to liquid steel

**Fundamental research project for direct steelmaking from iron oxides with $H_2$ plasma at voestalpine Donawitz**

**Project consortium with voestalpine, K1-MET and MUL**

K1 MET metallurgical competence center

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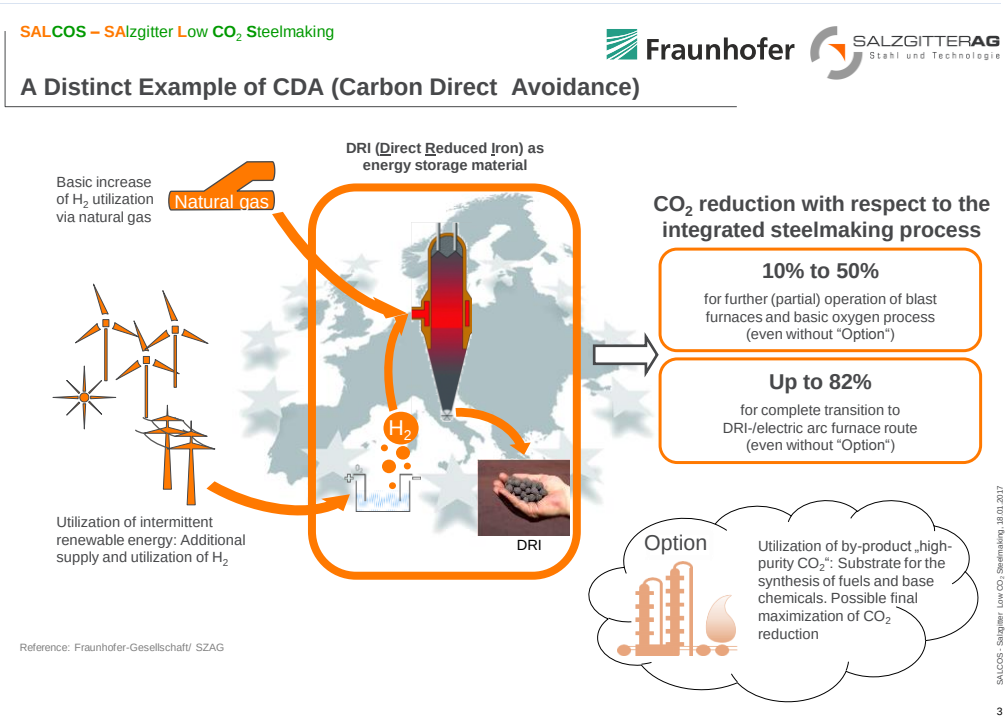
# SALCOS

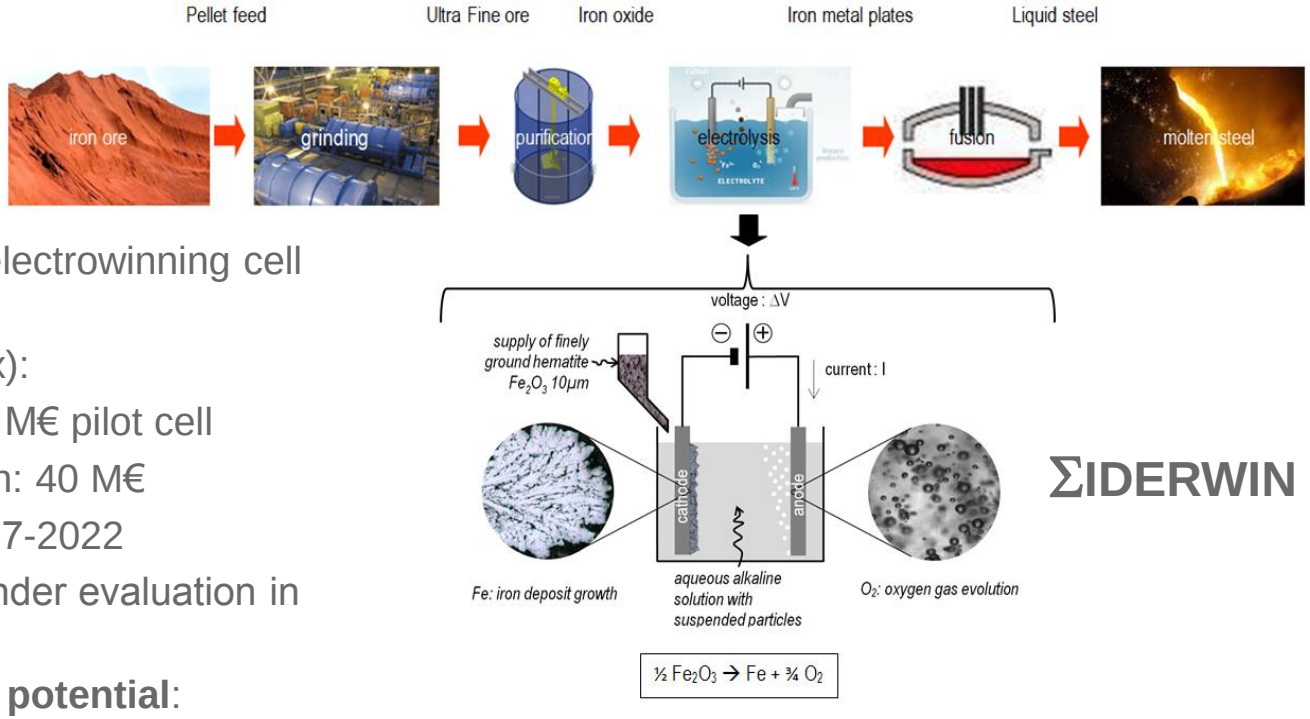
- The project aims at stepwise transformation of carbon based into hydrogen based steelmaking, to be realised in the framework of existing integrated steelworks facility in Salzgitter, Germany.
- **Technology:** implementation of natural gas based direct reduction technology as a substitute for respective blast furnace capacity, additionally offering the potential of integrating significant, variable shares of renewable energy via “green” hydrogen. Long-term successive change to electrical steelmaking and built-up of further direct reduction capacity




- **Potential savings of $CO_2$**: Stepwise $CO_2$ reduction from 10 % up to more than 80 % depending on political regulations and economic feasibility.
- Timeline (up to industrial scale)
  - 2017 -2019 SALCOS feasibility study
  - 2018++ Depending on first outcome of the feasibility study the first steps of SALCOS could be implemented, if the needed political regulations and economic feasibility are given

# SIDERWIN

## Steel production by direct electrowinning of iron ore




ΣIDERWIN

- Development of a fully electricity-based steel production route
- **Technology**:
  Ore purification, alkalie electrowinning cell and EAF melting
- **Investment cost** (Capex):
  - ΣIDERWIN project: 2 M€ pilot cell
  - Further demonstration: 40 M€
- **Timing**: ΣIDERWIN: 2017-2022
- **Funding:** ΣIDERWIN (under evaluation in H2020-SPIRE): 6.8 M€
- **Primary energy saving potential**:
  Improved efficiency in direct energy use: 27% compared to non electrochemical route
- **GHG emission saving potential in percentage :** Based on the objectives set for the integration of RES in EU power grid in 2050, expected reduction of specific $CO_2$ emissions by 70%
  - Participate in the integration of RES (renewable energy sources) by interruptibility
  - Option to recycle iron oxide wastes

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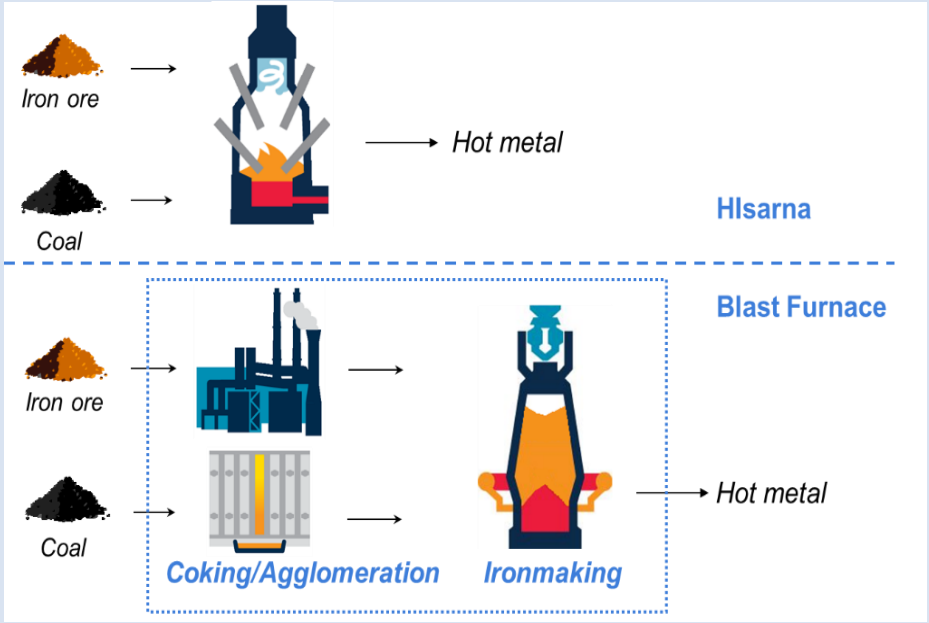
# HIsarna

- HIsarna is an innovative, energy efficient Ironmaking process that can produce liquid hot metal directly from the raw materials iron ore fines and coal – eliminating cokemaking and ore agglomeration
- Possible use of non-coking coals and lower quality iron ore fines
- **Primary energy savings:** 20% compared to BF-BOF route

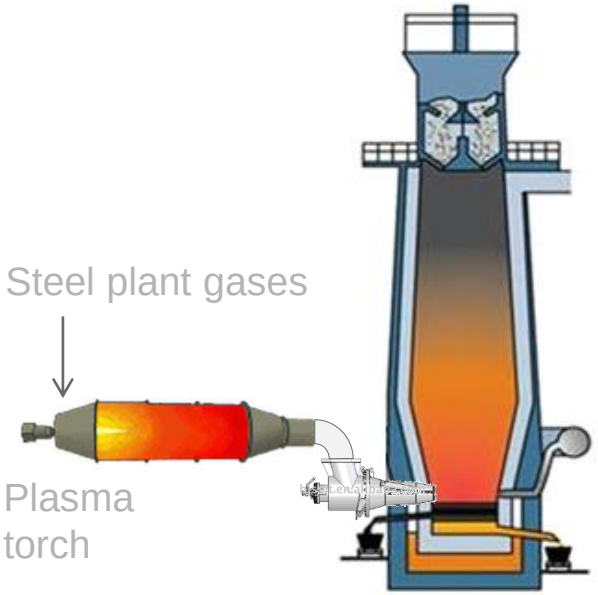



- **Potential savings of $CO_2$**: 20-47 % without CCUS and 80 % with CCUS
- **Timing**: 2017 new campaign is planned to start funded by the industrial partners, with financial support from Horizon2020 (SILC-II). Follow up campaign in 2018/2019. Starting of Demo plant project in 2020
- After campaign E a final campaign on pilot plant scale, campaign F is foreseen in 2018/2019. Parallel to this campaign preparations for the HIsarna Demo plant can take place. Starting of the Demo plant project is considered feasible in 2020.
- **Investment Cost:** 300-350 M € for an industrial scale HIsarna Demo:

# IGAR (Injection de GAz Réformé)

## Injection of reformed steel plant gases in Blast Furnace

- Demonstration of the reforming of steel plant gases and injection in BF tuyeres to reduce coal/coke consumption
- **Technology:**
  - plasma torch and reactor to heat and reform gases
  - Modified BF tuyeres
- **Investment cost** (Capex):
  - Current project: 8,5 M€ for full-scale validation on one BF tuyere in Dunkerque
  - 75 M€ for further BF demonstration
- **Timing**: validation in 2020
- **Funding** (to be confirmed): 5,5 M€ ADEME (FR)
- **Primary energy saving potential:** Coke/coal savings at the BF of 50 to 90 kg/t of hot metal
- **GHG emission saving potential in percentage and in ktCO2eq/a** :
  - 0,1 to 0,3 tonne CO2 per tonne of crude steel
  - For one typical steel plant 500 ktCO2eq/a
  - Total EU scope estimated is 10 MtCO2eq/a.



# PEM (Primary Energy Melter)

## Low Quality Scrap melting for Basic Oxygen Furnace

Pre-melting with gas

Mix with liquid steel or iron

- Development of new metallurgical process based on low quality **scrap melting with metallurgical/natural gas** in two phases: pre-melting process and superheating process
- **Technology**:
  - Scrap melting in shaft vessel with gas burners
  - Additional production of pre-melted scrap to be charged in BOF vessel
- **Investment cost** (CAPEX) is 50 Meuro**.**
- Production **pilot** capacity 200 000 ton scrap/year
- **Timing:**
  - Go live PEM installation 2019
  - Integrated in steel making 2021
- **Primary energy saving potential in percentage and in ktoe/a** : 30% energy reduction compared to other scrap melting processes or 1400 MJ/ton steel.
- **GHG emission saving potential in percentage and in ktCO2eq/a** : 1 ton CO2 per ton melted scrap. For one typical steel plant 200 ktCO2eq/a. Total EU scope estimated is 2500 ktCO2eq/a.

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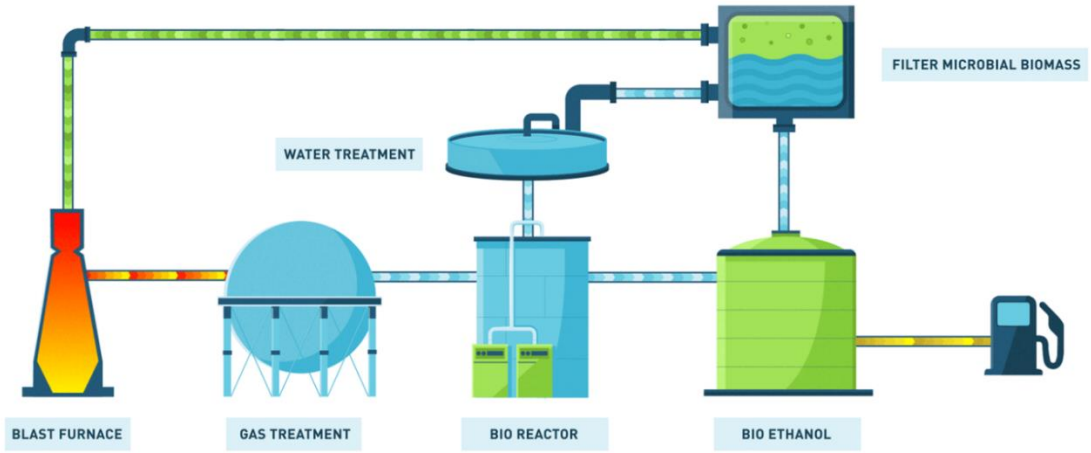
# Steelanol

## Production of bio-ethanol via gas-fermentation of steel waste gases

- Construction of commercial scale production facility to create **bioethanol from waste gases** produced during steelmaking process
- **Investment cost** (Capex): 120 M€ for Steelanol project in Gent, with 65 kton/year ethanol
- **Timing**: go live 2019
- **Funding** 10.2 Meuro H2020

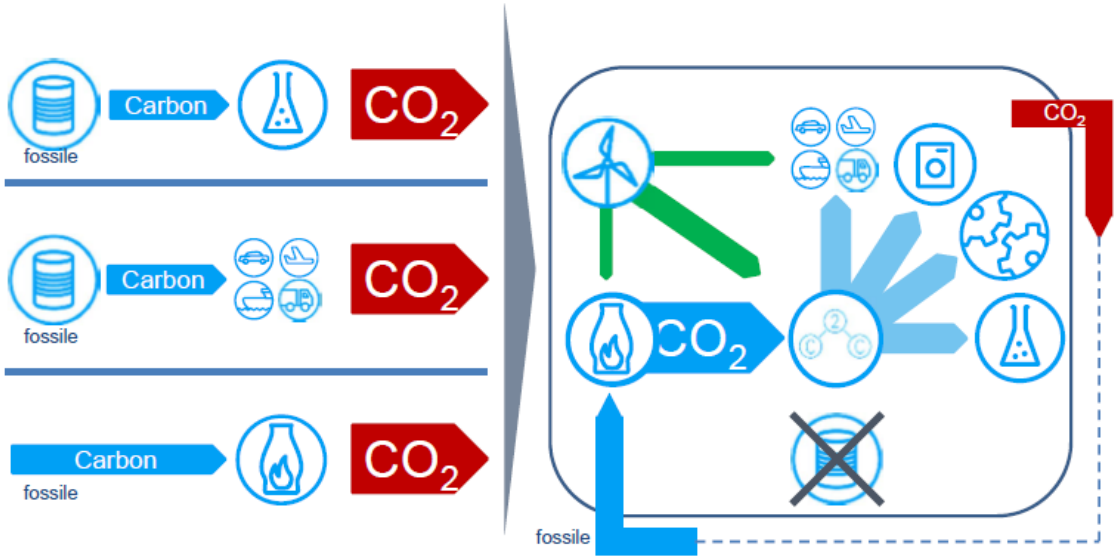



- **Primary energy saving potential**: if all steel mill gasses of the EU-28 conventional steel plants (BF-BOF route) are converted into ethanol the yearly production potential is app. 14,5 million t/y of EtOH. This is the storage of 350 million GJ/y.
- **GHG emission saving potential in percentage and in ktCO2eq/a :** if all steel mill gasses of the EU-28 conventional steel plants (BF-BOF route) are converted into ethanol the yearly production potential of app. 14,5 million t/y of EtOH will reduce CO2 emissions from industry by 33,3 million tons/y.

# Carbon2Chem

- The project aims to convert process gases from steel production – including the $CO_2$ they contain – into base chemicals. The energy required for the conversion process will come from renewable sources.
- $CO_2$ can be used as a raw material by splitting its molecules. This requires hydrogen, which in part is already present in the steel mill gases.

Schematic concept of transformation by Carbon2Chem®:
Cross-industry utilization of $CO_2$ as a valuable raw material




- Additional hydrogen is to be produced using renewable energies.
- The processes in the steel mill will be modified in such a way that part of the process gases are diverted to chemical production when low-cost excess electricity is available from renewable sources.