We create benefit for industry

Pathways to Decarbonize the Metal Production Industries

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Background: climate goals

Sweden's Net Zero Goal (2045)

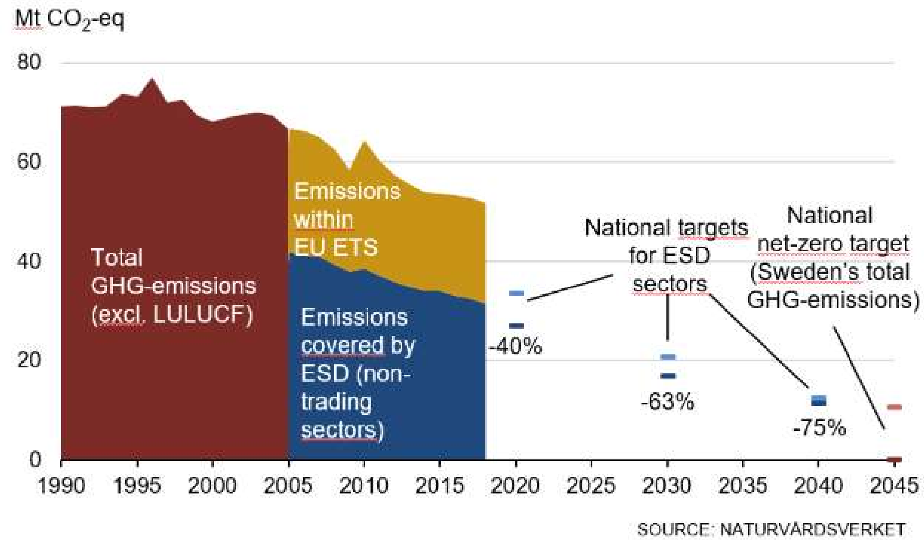
- Sweden aims for net emissions of greenhouse gases by 2045.

EU Climate Targets (2030 & 2050)

- EU countries commit to a 55% greenhouse gas reduction by 2030.
- EU climate neutrality by 2050.

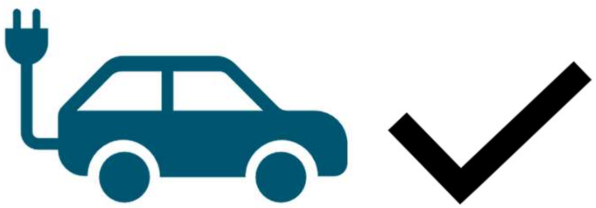
Paris Agreement Goals

- Below 2°C above pre-industrial levels.
- Pursue efforts for 1.5°C.



The milestone targets are visualized in the graph. Note that these targets do not include emissions and uptake in the land use and forest sector. Source: Naturvårdsverket

Climate goal and its implication to the metallurgical industries: Green metal production



Shift in fuels: from fossil fuels to CO2-lean energy sources

Shift in production process(es)

Key enablers for green metal production

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Green or fossil-free energy

Replacing fossil fuels like coal and coke

Disruptive process & technology(es)

Replacing the existing process & technology(es) based on fossil fuels

Integration of the green energy into the disruptive process(es) & technology(es)

Improving the productivity, energy efficiency, materials efficiency, etc.

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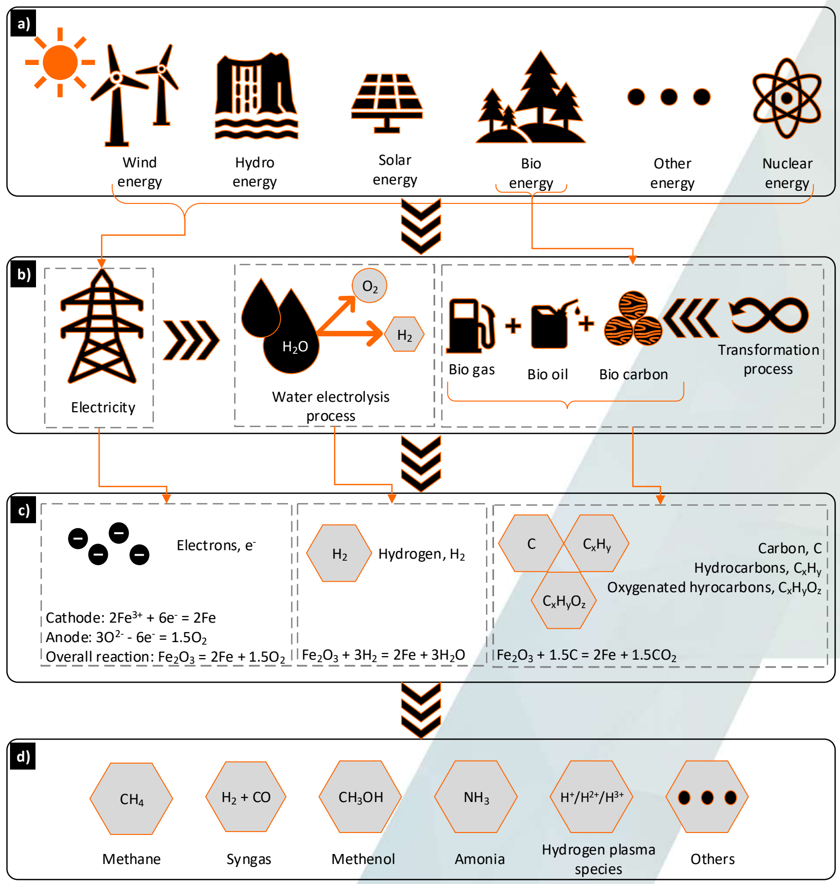
Green or fossil-free energy and possible technical pathways for green transition

Green or fossil-free energy

Available energetic species

Use of the energetic species and their derivatives



H2, biomass, and electricity: potentials and limitations

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Hydrogen:

- A clean option but limited by thermodynamic constrains.
- Unsuitable for reducing Cr-ore, Mn-ore, Si-ore, and sulfide ore.

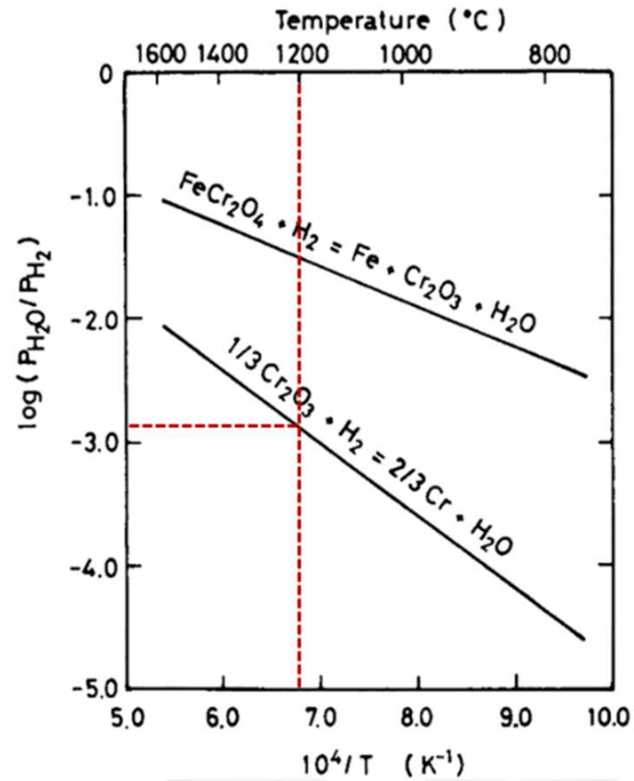
Biomass:

- Regional availability restricts its usage.
- Primarily caters to specific metal producers.

Electricity (Electrons):

- Effective in certain circumstances.
- Offers flexibility and efficiency in electrolysis-based processes.

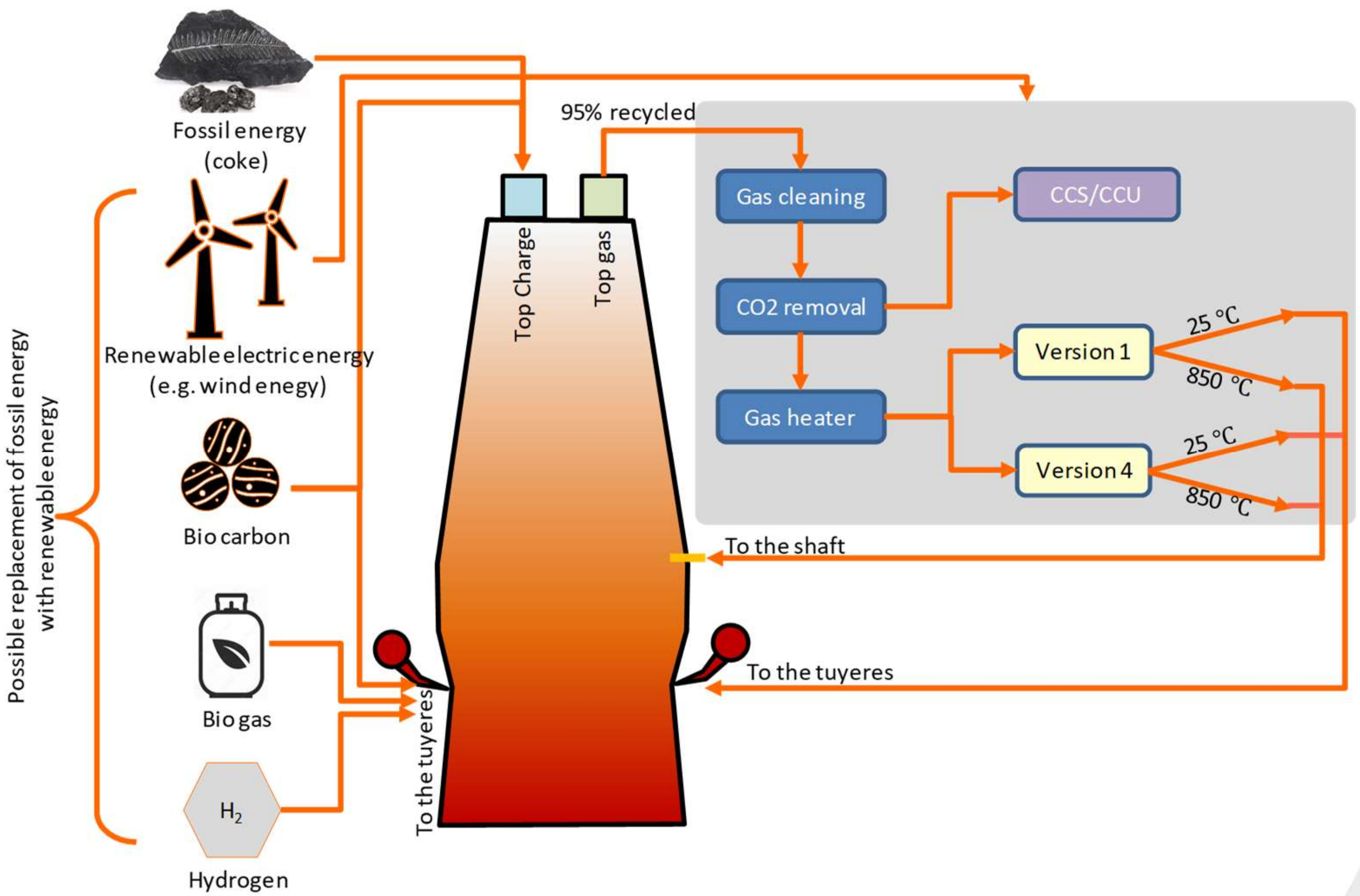
Hydrogen has its thermodynamic limitations.



Relation between equilibrium P_{H2O}/P_{H2} ratio and temperature (Ref. 1).

Ref 1.: H.G. Katayama, Reduction Kinetics of Synthetic Chromite Pellet With Hydrogen, Tetsu-to-Hagane(J. Iron Steel Inst. Jpn.). 72 (1986) 396–402

Minimal CO2 emissions by enhancement in the BF-based green steelmaking process



- Biomass injection
- H2 injection
- Top gas recycling
- …

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Areas of expertise

Biocoal in the blast furnace for reduced climate impact

31 August, 2017

Use of biocoal in blast furnace-based steelmaking could reduce fossil carbon dioxide emissions by as much as 30 percent in the short to medium term. In a recently started research project under the direction of Swerea MEFOS the methods will be developed and tested at SSAB.

Biocoal application in the blast furnace can reduce up to 30% CO2.

To meet the climate goals, the BF-based steelmaking route must be phased out.

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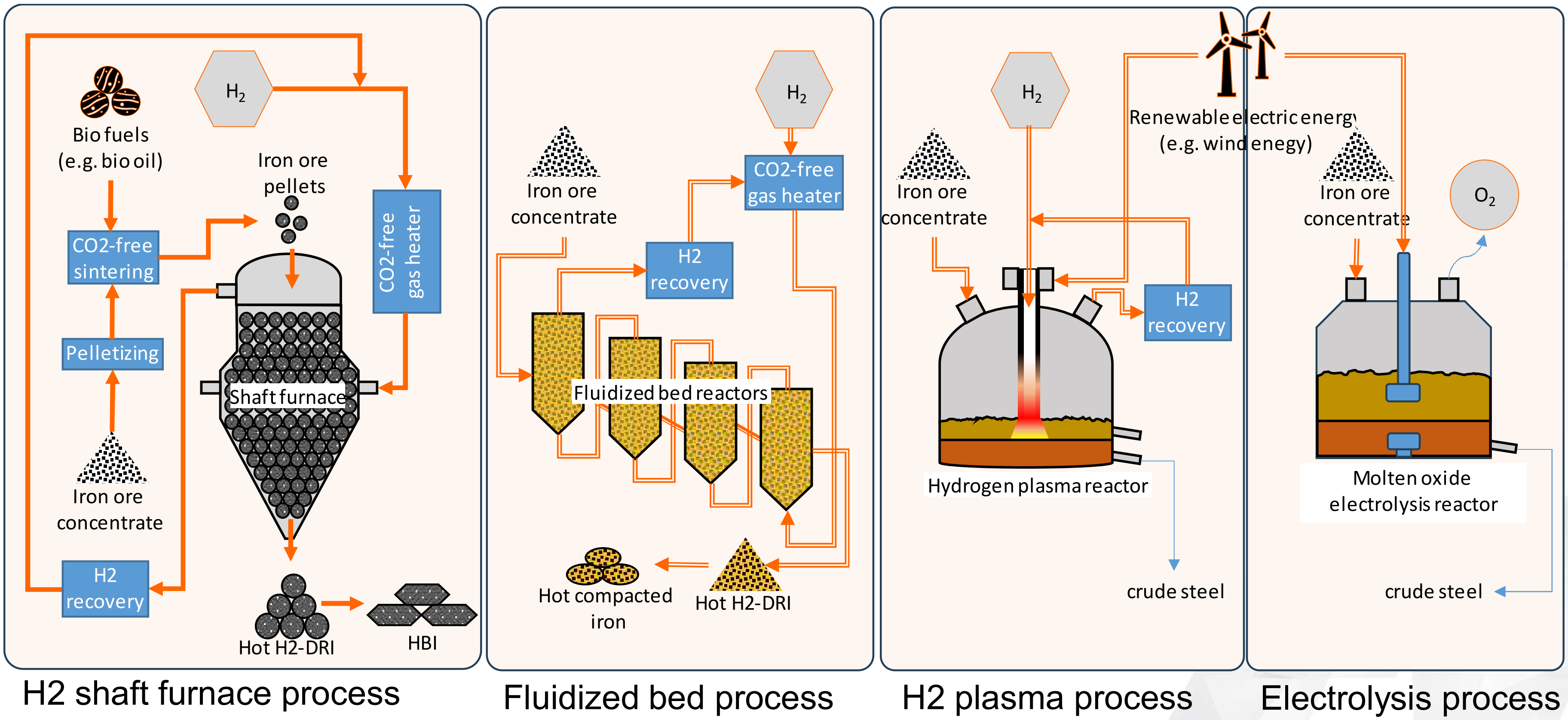
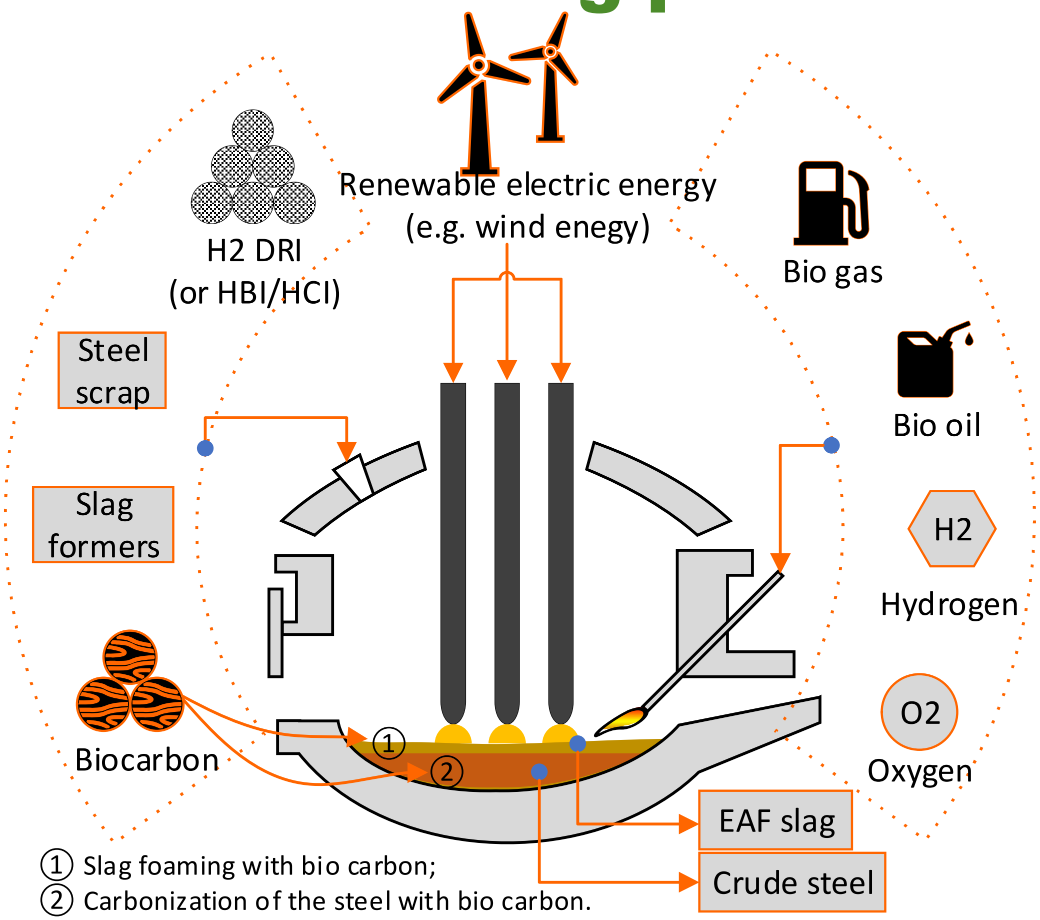
Emerging disruptive technologies for green ironmaking



Improvement in electric-based green steelmaking process



- Melting DRI/HBI/HCI in the EAF.
- Using renewable fuels in the EAF.
- Biocarbon is crucial in the process.

Direct or indirect carbon emissions:

- Graphite electrode: CO_2 emissions 4-7 kg/ton steel
- Lime consumption
- Refractory consumption

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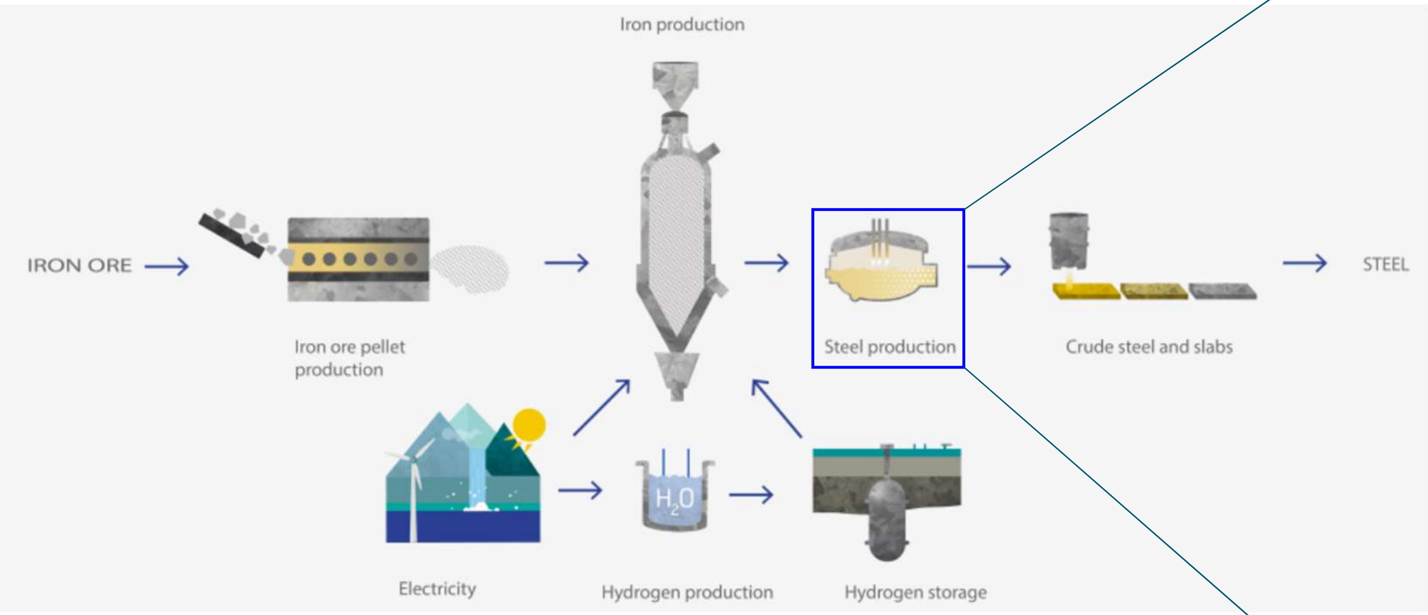
Green steelmaking pathway I: H2 DRI - EAF

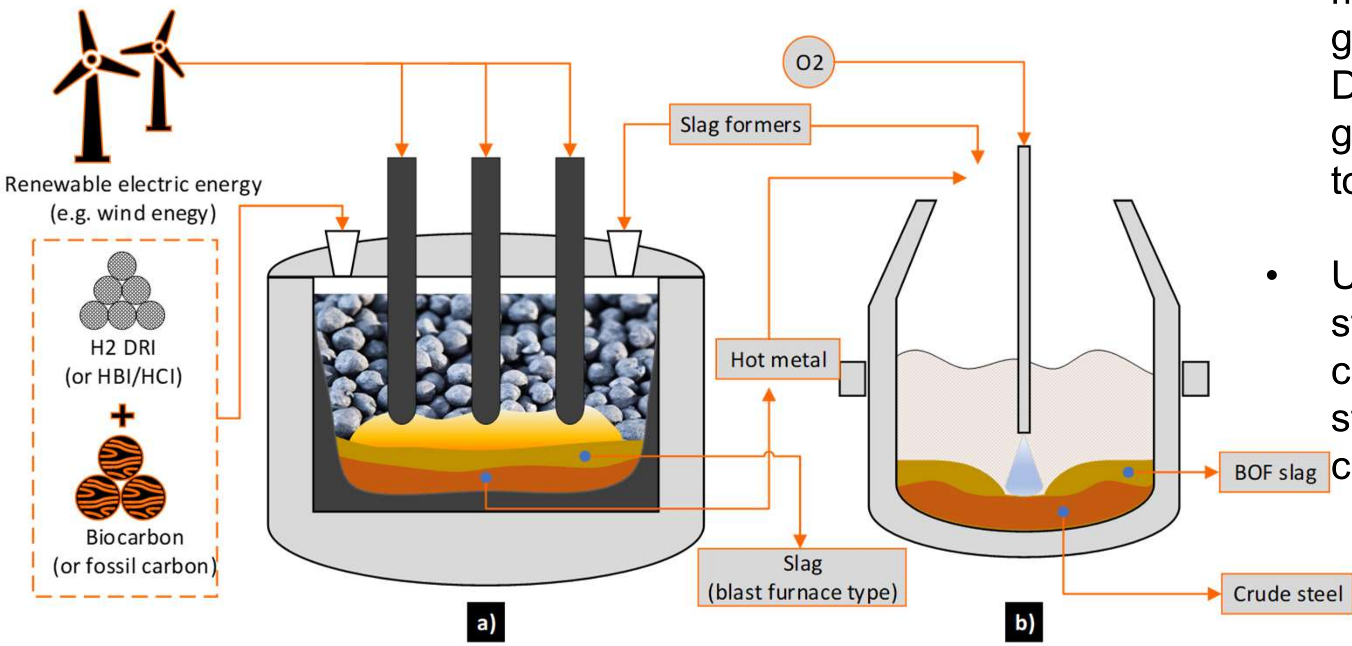


HYBRIT project

DRI melting at Swerim pilot EAF

Hybrit (hybritdevelopment.se)

Green steelmaking pathway II: H2 DRI – SAF – BOF



- Limited availability in DR-grade iron ore; majority of the iron ore is blast furnace grade. Using BF-grade iron ore in the H2 DRI-EAF green steelmaking process will generate a large volume of slag and lead to high iron loss.
- Using H2 DRI – SAF – BOF green steelmaking process, BF-grade iron ore can be used for green steelmaking. BOF steelmaking can be retained; SAF slag can be used for cement production.

Green steelmaking pathway III: H2 plasma reduction of iron ore (EU Horizon project H2PlasmaRed)

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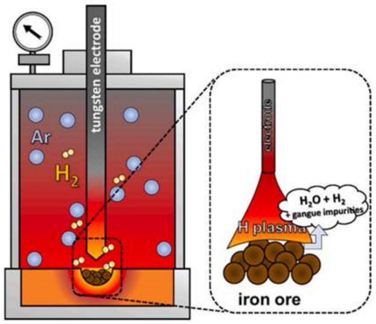
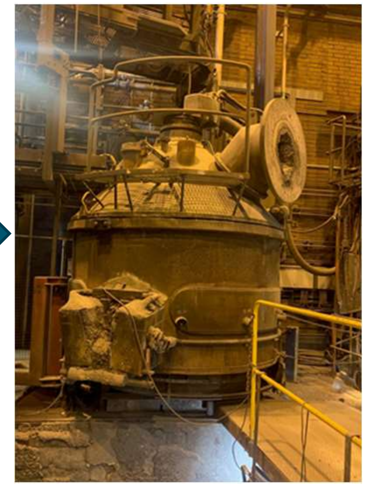


Arc melting furnace for hydrogen plasma-based reduction

Fundamental studies

Demo in hydrogen plasma reduction pilot plant at K1-MET



Demo in tone-scale at Swerim

Project partners

UNIVERSITY OF OULU

voestalpine

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MONTAN UNIVERSITÄT LEOBEN

K1 MET

LUXMET

RWTH AACHEN UNIVERSITY

LKAB

Metso:Outotec

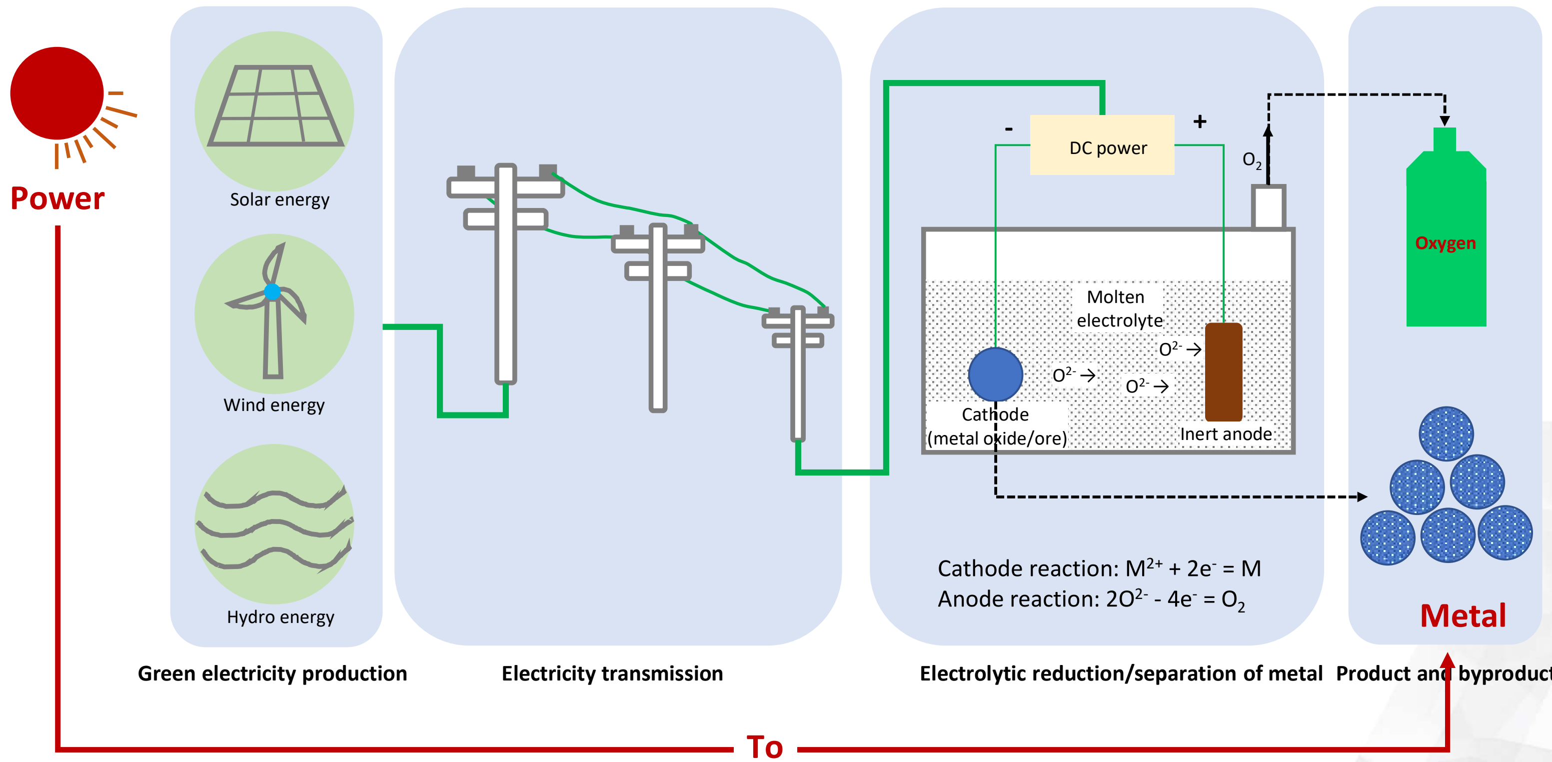
aperam

KU LEUVEN

MAX-PLANCK-INSTITUT FÜR EISENFORSCHUNG GmbH

ESTEP European Steel Technology Platform

Green metal production pathway IV: electrolytic reduction – the power-to-metal concept



Powder-to-metal: the basic concept

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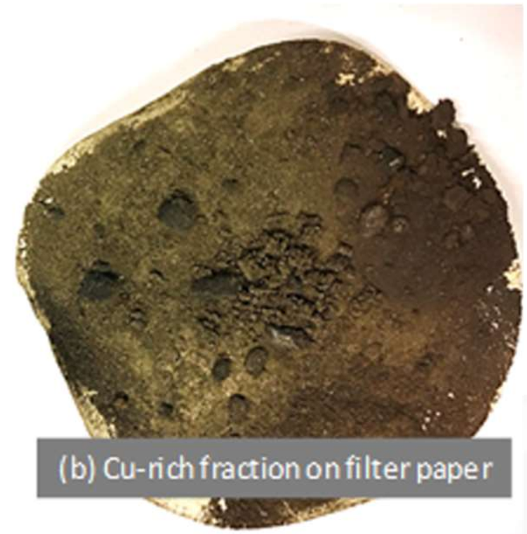
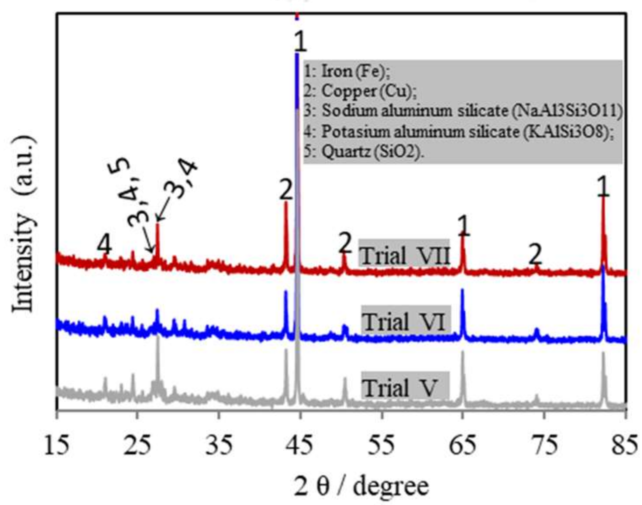
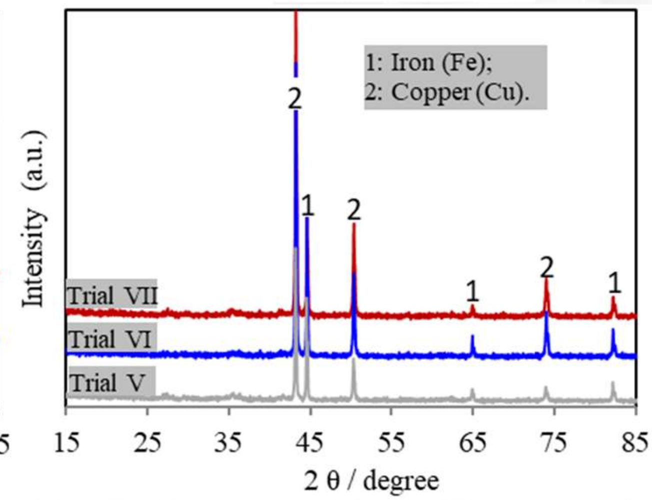
Green metal production pathway IV: Electrolytic reduction of chalcopyrite and pyrite in molten salt

(a) Cu-rich fraction on filter paper



(b) Cu-rich fraction on filter paper





In situ separation of Cu, Fe and S into elements

This project was funded by Hugo Carlsson Foundation via Jernkontoret.

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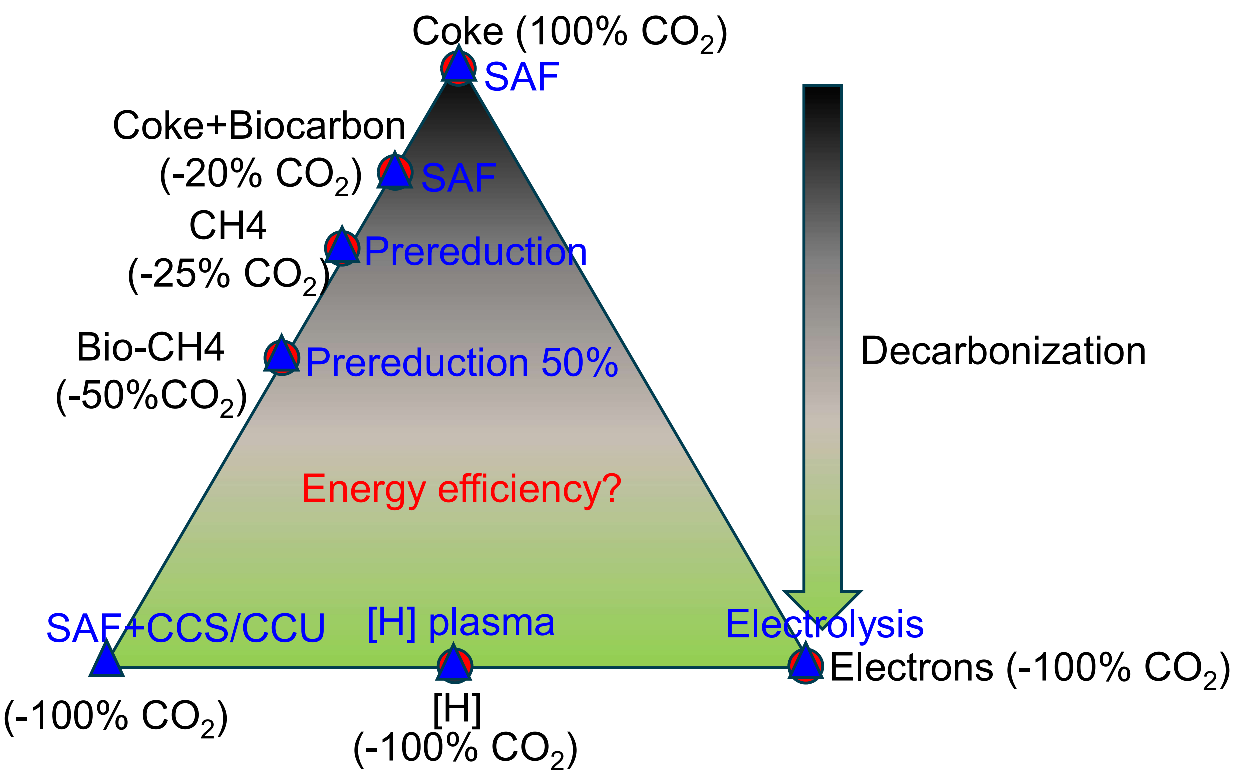
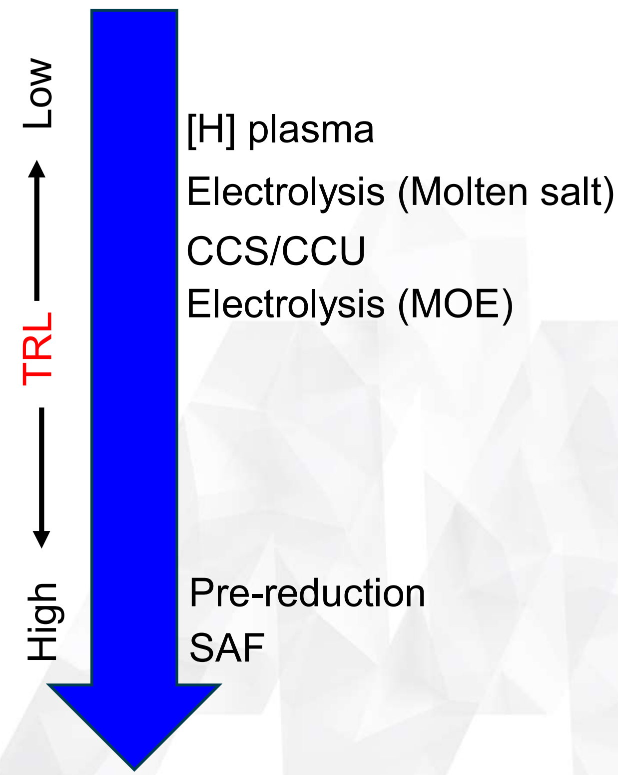
Possible pathways for production of ferroalloys





Green production of flux and refractory materials

- Using renewable energy sources for the heating or firing process
- CCU and CCS

Green Heating

- Heating metallurgical vessels and steel with H_2 burner

Conclusions

- Electricity, hydrogen, and biocarbon are important components in the shift towards sustainable metal production.
- A robust and consistent supply of green electricity, hydrogen, and biocarbon is crucial for the successful transition to green metal.
- Securing high-quality iron ore poses a significant challenge for the production of green steel. H2 DRI – EAF and H2 DRI – SAF – BOF present promising pathways to decarbonize the steelmaking process.
- Hydrogen plasma reduction emerges as a promising technology for the green production of steel and ferroalloys.
- Challenges in green steel production extend to other industries in the value chain, particularly lime and refractory production, as calcination processes in lime and refractory industries release substantial CO2, adding to the challenges of achieving a green steel production.
- Decarbonizing the entire value chain for green metal production is a challenging task for most of the metal producers.

Acknowledgement

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