

# The HYBRIT demonstration of a fossil-free iron- and steelmaking value chain

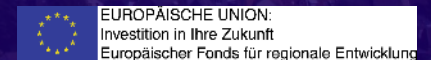
Christer Ryman, HYBRIT Development AB  
12 May 2022



**Process<sup>4</sup>  
Sustainability**

**Cluster for climate-neutral  
process industries in Hesse**

Supported by:



A large industrial building with a grey facade and a tall chimney stack. The word 'HYBRIT' is written vertically in blue on the left side of the building. A sign on the lower part of the building reads 'FOSSIL-FREE STEEL' in green, with a logo of three colored triangles (blue, yellow, blue) to its left. The sky is blue with some light clouds.

# The HYBRIT Demonstration of a fossil-free iron- and steelmaking value chain

**HYBRIT**  
FOSSIL-FREE STEEL

A JOINT VENTURE BETWEEN SSAB, LKAB AND VATTENFALL

# Content of this presentation

- What is HYBRIT
- Development path
- HYBRIT Demonstration project
- Value-chain effects

# What is HYBRIT

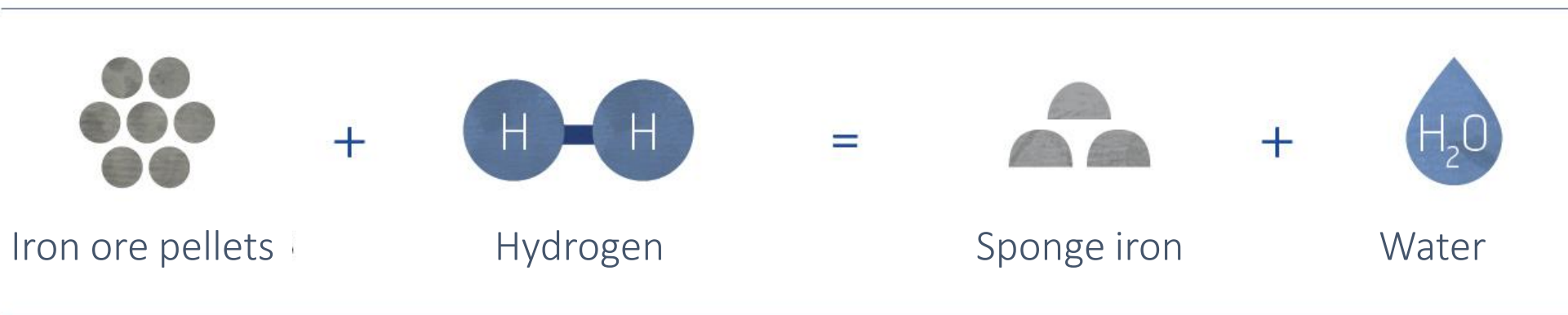


THE HYBRIT TECHNOLOGY

# HYBRIT

## Hydrogen BReakthrough Ironmaking Technology

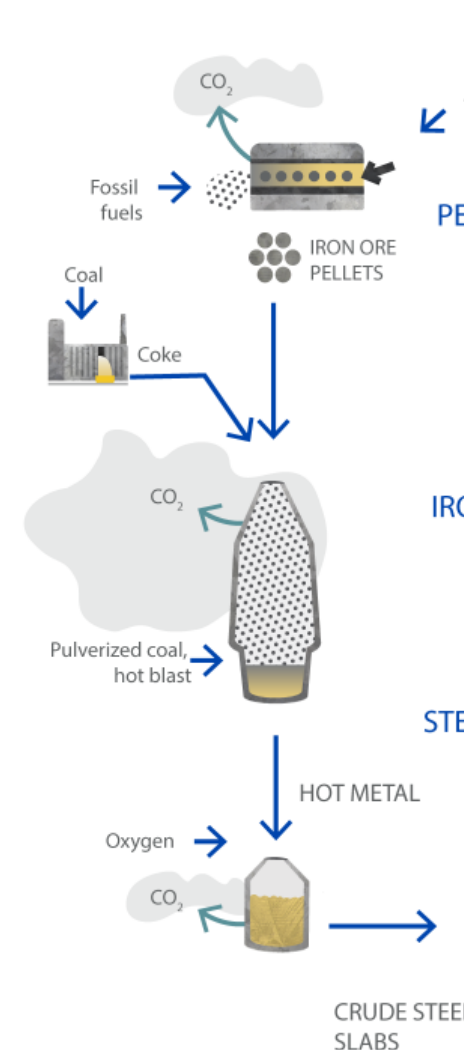
- *Easy to understand path to decarbonisation*



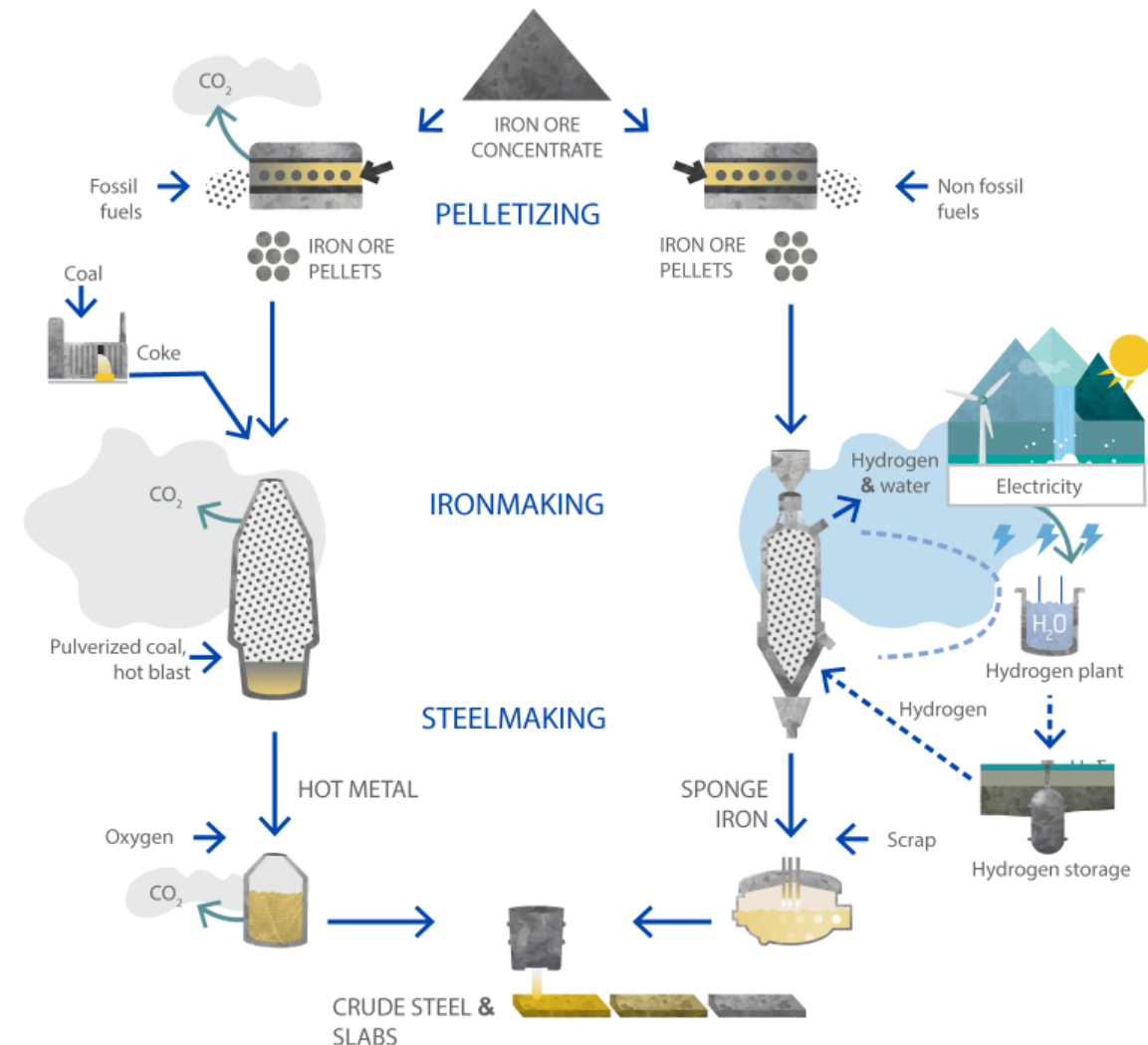
# HYBRIT technology to replace thousand year old blast furnace process

- Significant technical developments
- High CO<sub>2</sub> mitigation potential
- Large scale hydrogen production by electrolysis
- Optional underground hydrogen storage
- H-DR (hydrogen reduction) is the core technology under rapid evolution
  - 2022 - TRL 6-7 => expected => 2030 - TRL 9

## BLAST FURNACE PROCESS



## HYBRIT PROCESS

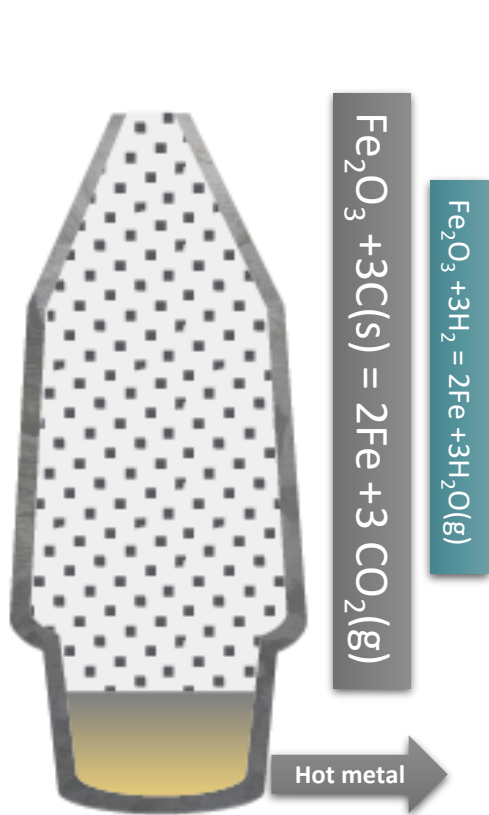


# What sponge iron (DRI / HBI) looks like

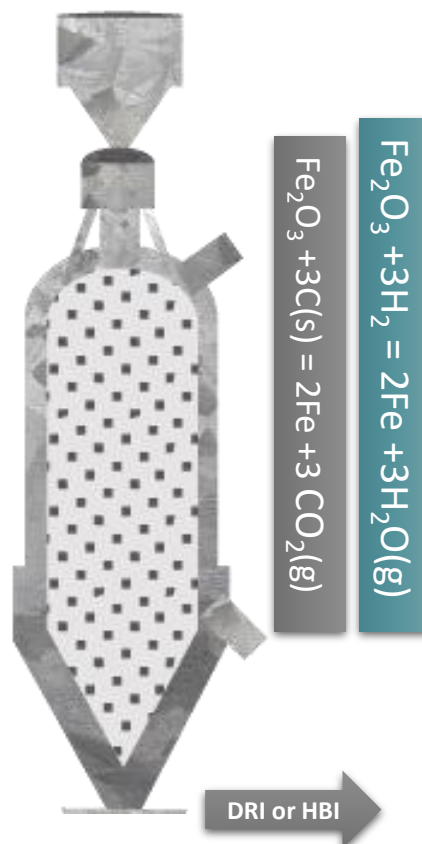


# Evolution (Revolution) of pellet based ironmaking

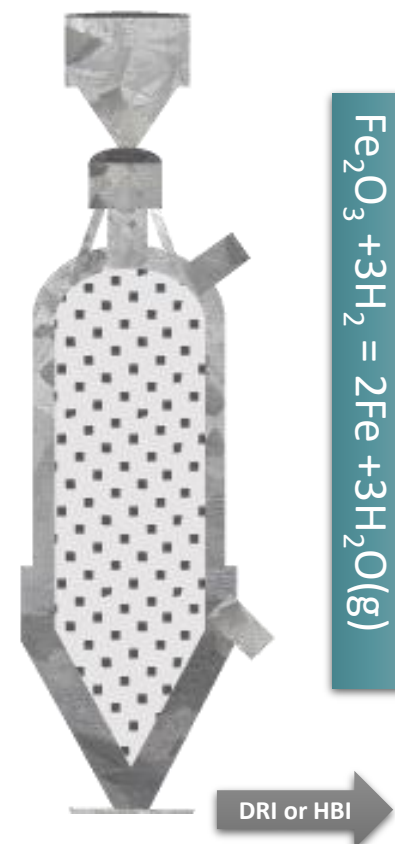
## BF => DR => H-DR



Blast Furnace  
1600 – 2000 kg CO<sub>2</sub> / t Fe



Direct Reduction with fossil gas  
600 – 800 kg CO<sub>2</sub> / t Fe

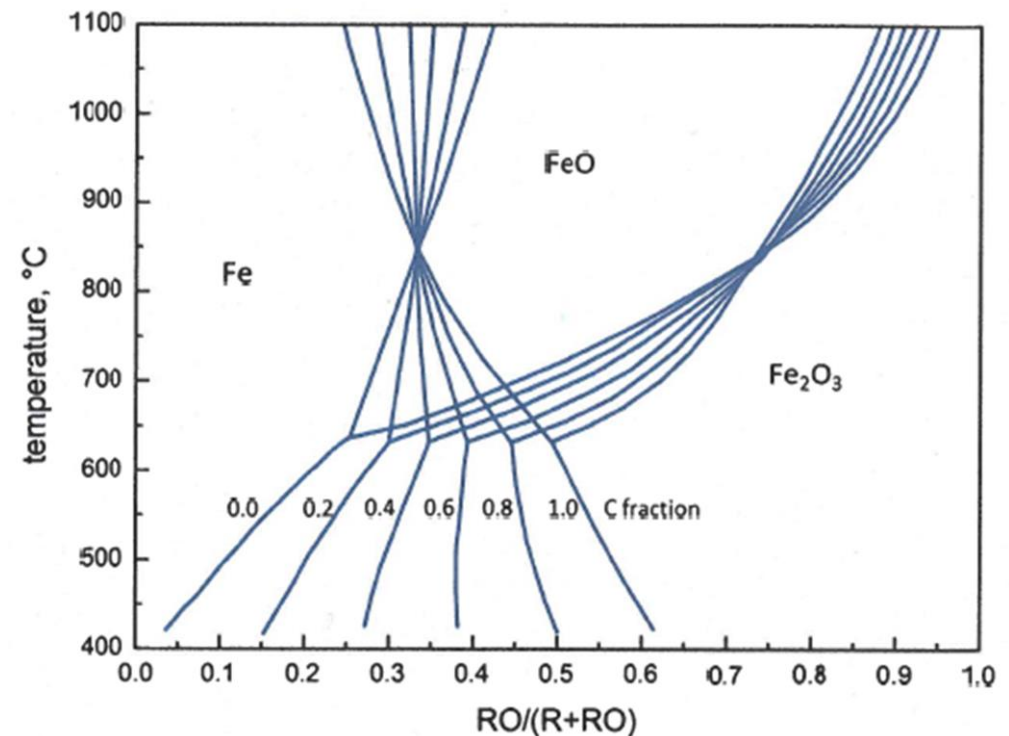


Hydrogen Direct Reduction  
Theoretical 0 kg CO<sub>2</sub> / t Fe



# Reduction of iron ore by H<sub>2</sub> and/or CO gases

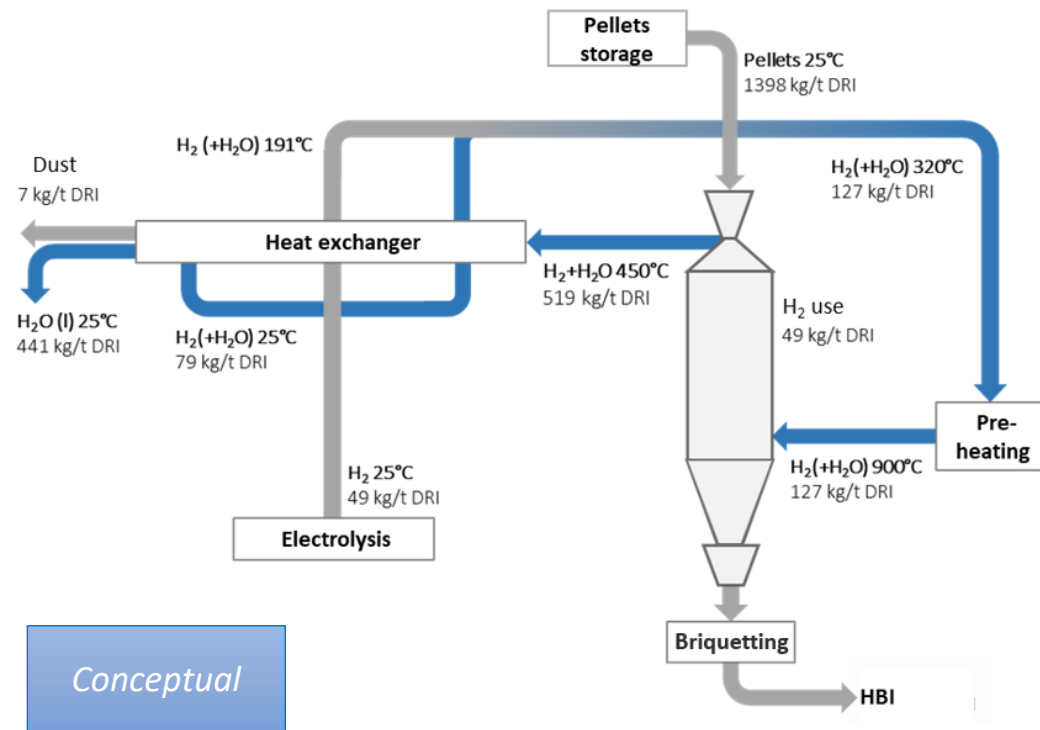
- The driving forces of H<sub>2</sub> and CO reduction varies with gas temperature
- Hydrogen utilization increases at higher temperatures
- H<sub>2</sub> reduction is endothermic while CO reduction is exothermic
- Hydrogen molecules are smaller which also has an impact on how fast the reactions take place
- Experimental development in pilot scale has been deemed necessary within HYBRIT



. 8.29 Baur-Glaessner type diagram for mixed gases depending on fraction, C, of carbonaceous molecules. R denotes unoxidized gas species (CO + H<sub>2</sub>), and RO denotes the oxidized gas species (CO<sub>2</sub> + H<sub>2</sub>O)

Diagram source: Cavaliere, Clean Ironmaking and Steelmaking Processes, Springer 2019

# Direct reduction of iron ore pellets with hydrogen



- *Hydrogen instead of coal results in water instead of CO<sub>2</sub>*
- In the process, iron ore pellets are reduced to sponge iron, a metallic iron product suitable as raw material in steel production
- The reduction occurs in a counter-current shaft furnace, where iron ore pellets are charged in the upper part and reacts with the reduction gas on its way down the reactor
- In direct reduction, there is a solid-state reaction at a temperature well below the melting point for iron

# Development path



R&D => PILOT DEVELOPMENT => DEMONSTRATION

# HYBRIT have unique conditions to lead the transition to fossil-free steel



High quality iron ore  
through **LKAB**



Fossil-free electricity and low electricity prices that enable a replacement of imported coal  
through **Vattenfall**

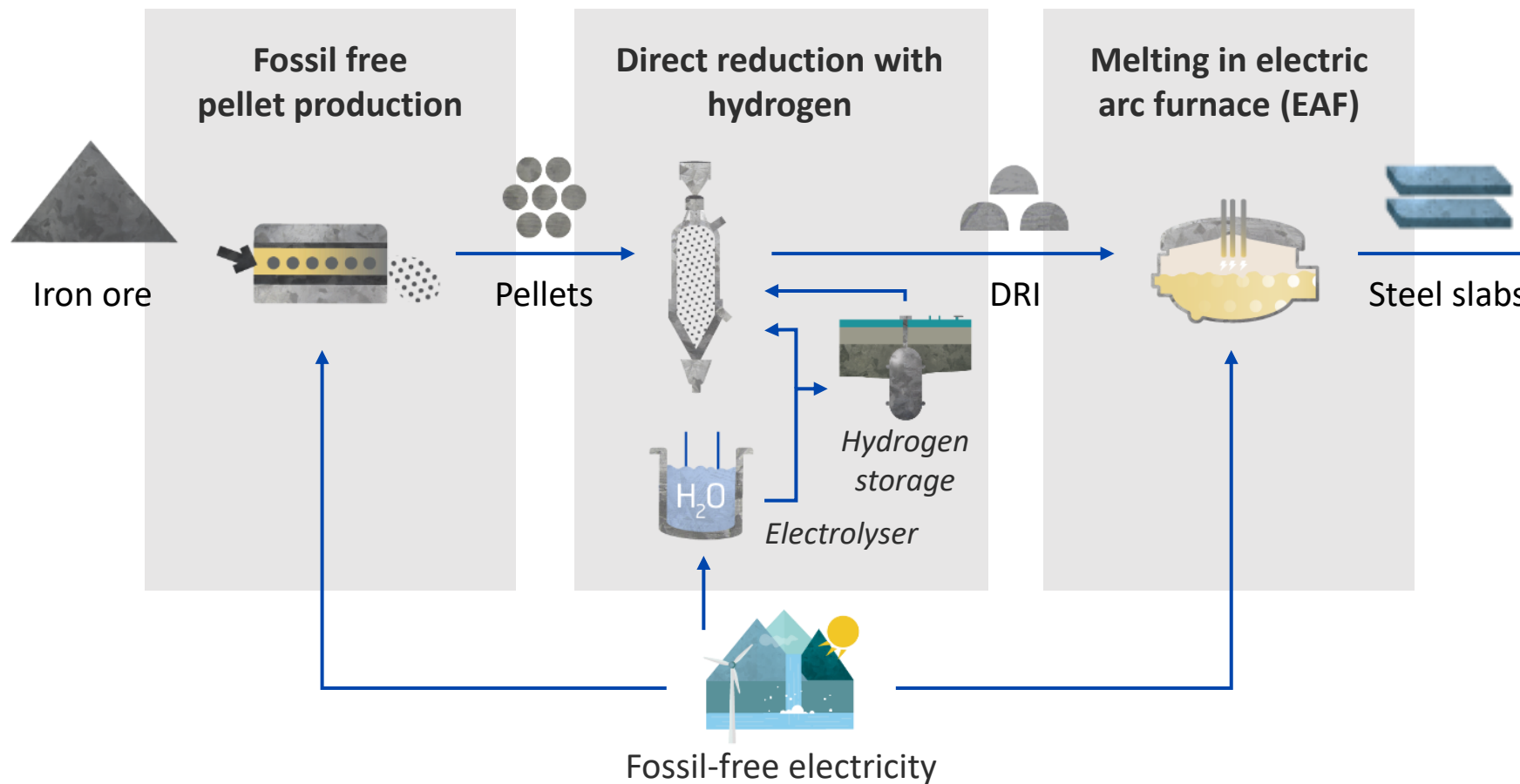


Long tradition and deep knowledge in iron and steelmaking  
through **SSAB**

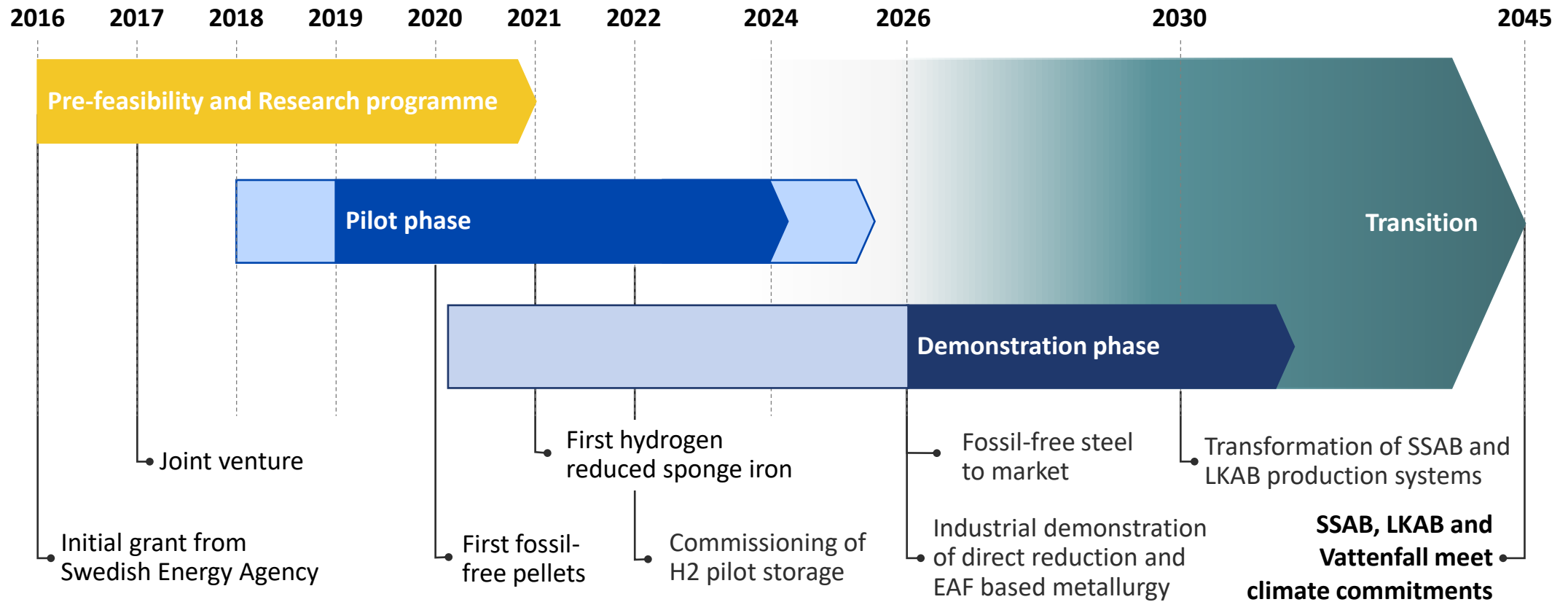


Strong support and a tradition of cross-sectoral collaboration for innovation

# HYBRIT develops with a value chain perspective



# HYBRIT timeline – from technical development to complete transition 2045



# HYBRIT technology development in pilot projects



## Pilot results

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- ▶ Pellet production with bio-oil demonstrated in full scale
- ▶ First hydrogen reduced sponge iron produced (DRI and HBI)
- ▶ Hydrogen reduced sponge iron melted in EAF

## Further pilot tests planned/ongoing

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- ▶ Unique underground LRC hydrogen storage
- ▶ Electric gas heating (strategic cooperation with Kanthal)
- ▶ Fossil-free carburization
- ▶ Further development of hydrogen-based direct reduction process

# SSAB has already produced fossil-free steel





# HYBRIT Demonstration



FOSSIL-FREE PELLET PRODUCTION

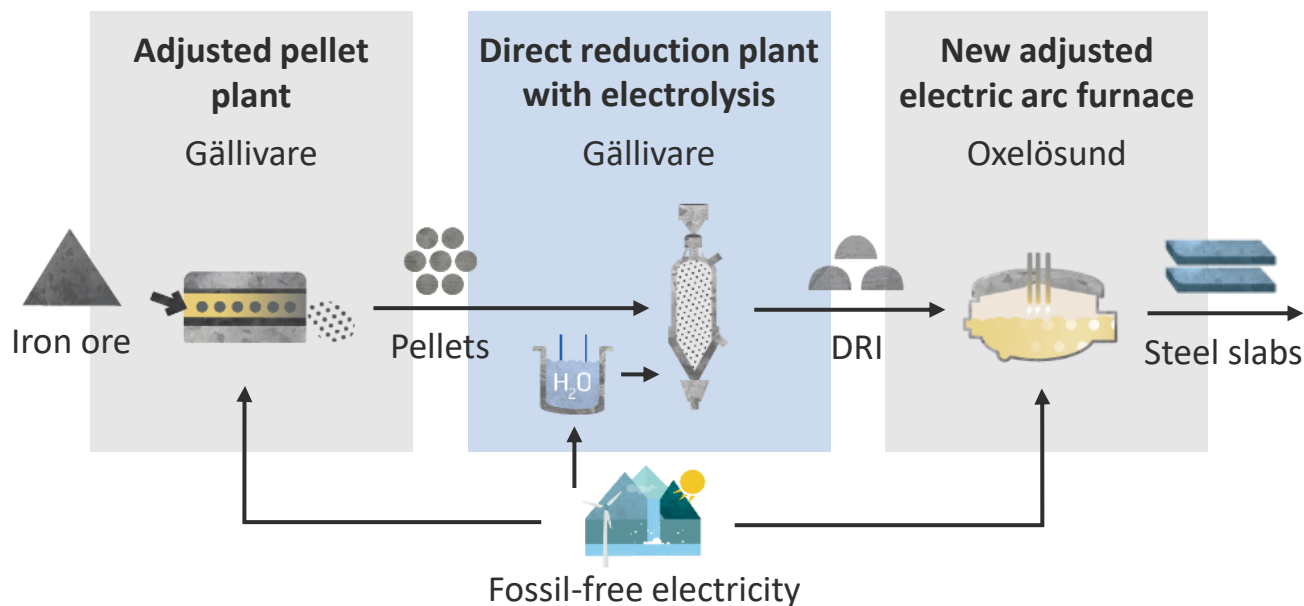
FOSSIL-FREE H-DR PROCESS

FOSSIL-FREE EAF STEELMAKING

# HYBRIT Demonstration: Swedish large-scale steel value chain demonstration of Hydrogen Breakthrough Ironmaking Technology

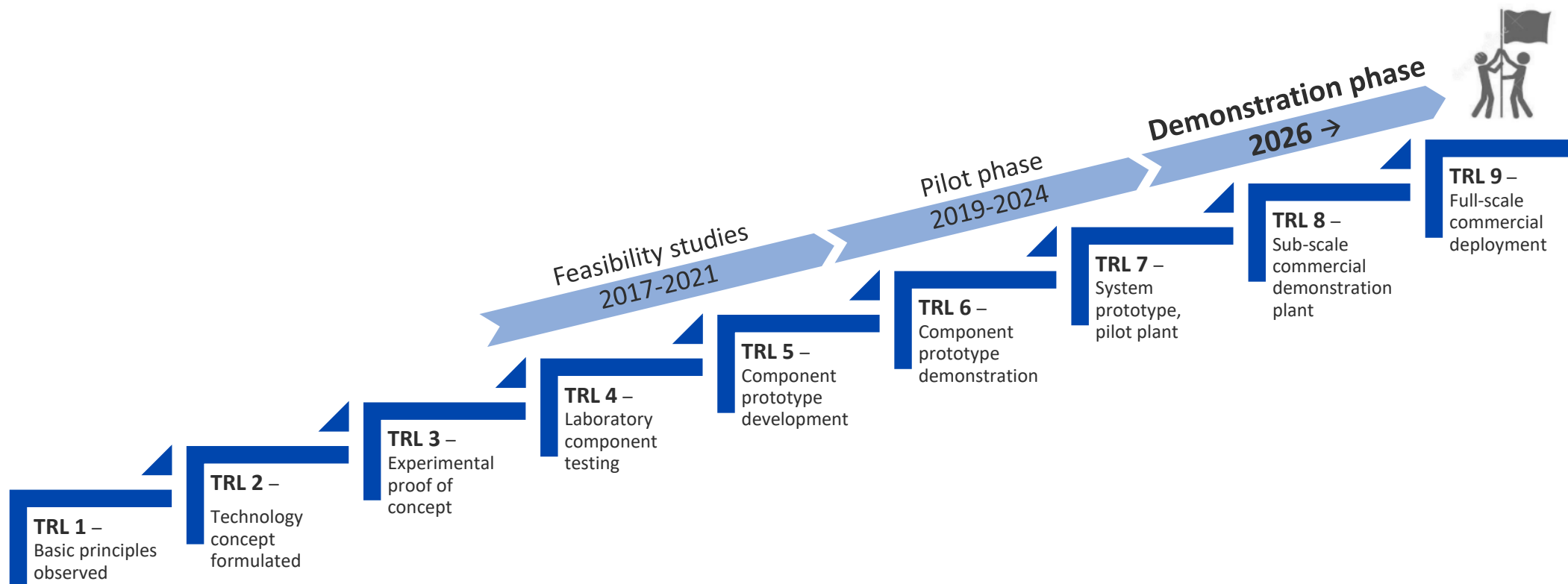
At the core of the value chain is a first-of-a-kind plant for hydrogen direct reduction...

...with large impact on the Swedish steel industry and Swedish CO<sub>2</sub> emissions



- ▶ **1.35 Mton DRI per year**  
Enables ¼ of Swedish steel production to become fossil-free
- ▶ **500 MW electrolyser capacity**
- ▶ **Enables 1.5-2 Mton CO<sub>2</sub> emission reductions per year**  
~3% of Swedish emissions
- ▶ **5 TWh/year fossil-free electricity needed**  
~3.5% of Swedish electricity consumption
- ▶ **Enables fossil-free steel to market 2026**

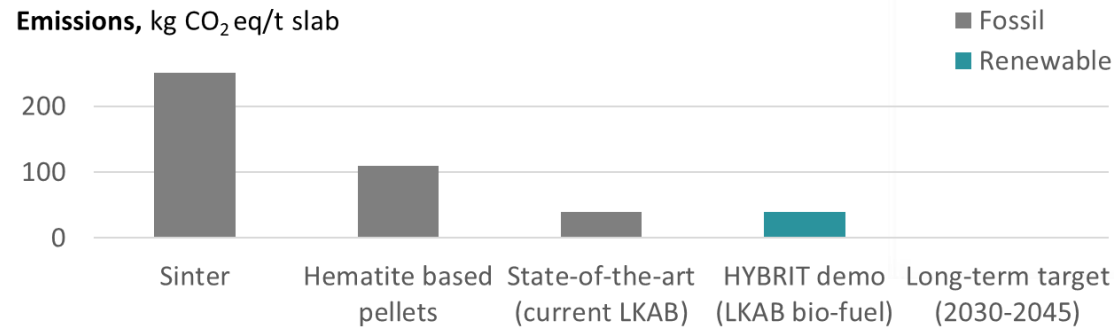
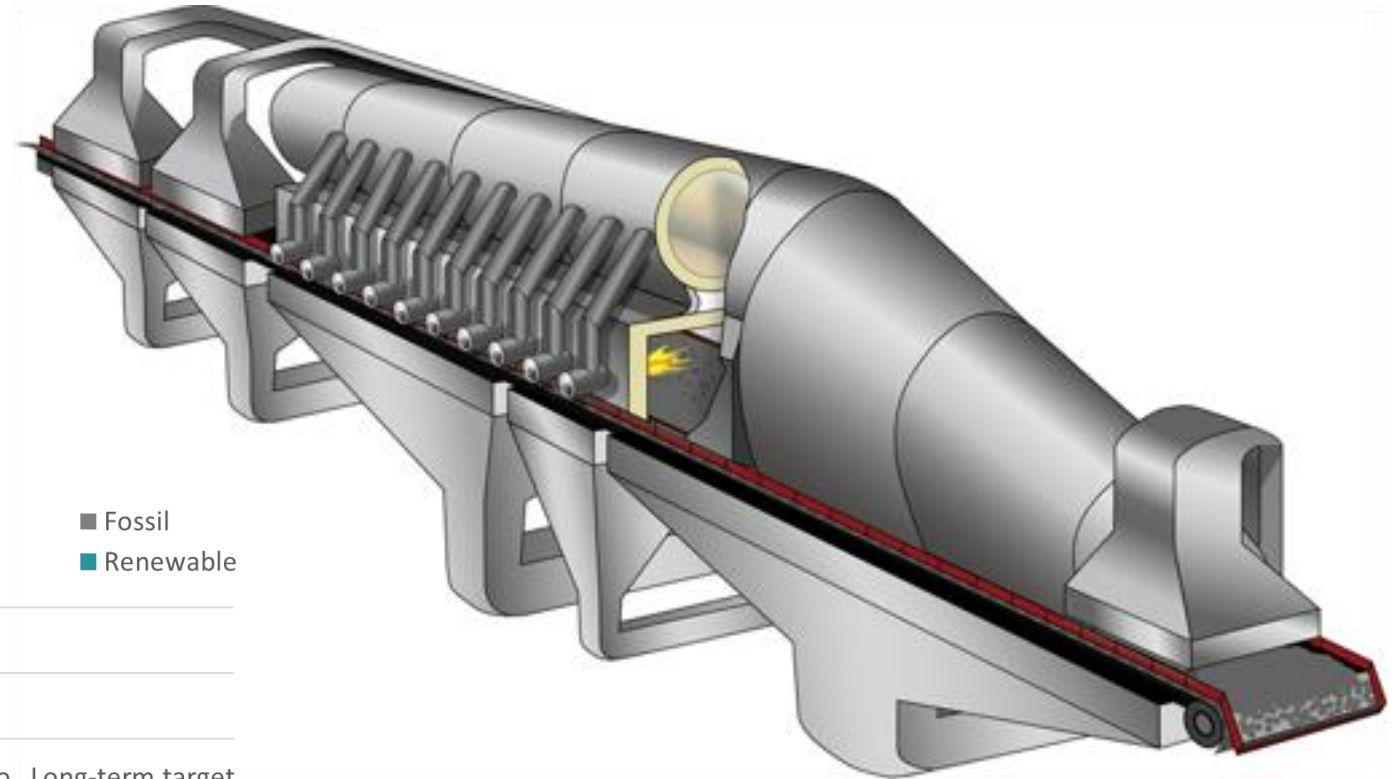
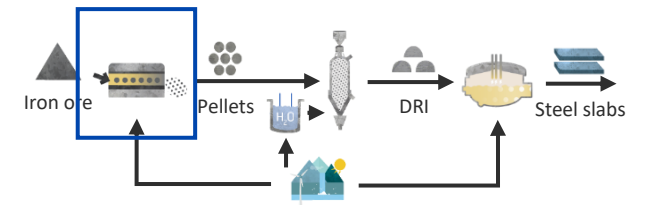
# HYBRIT Demonstration from TRL7 to TRL9



TRL = Technology Readiness Level (Source: Global CCS Institute, 2009)

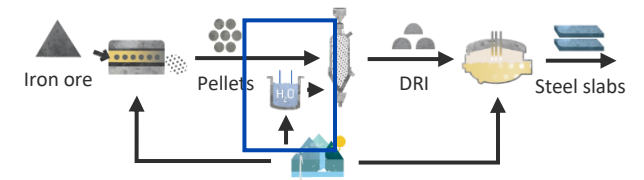
# Fossil-free pellet production at LKAB in Gällivare

Fossil-free agglomeration of iron ore.  
Implementation of bio based heat source in existing pellet plant to enable the induration without fossil emissions.



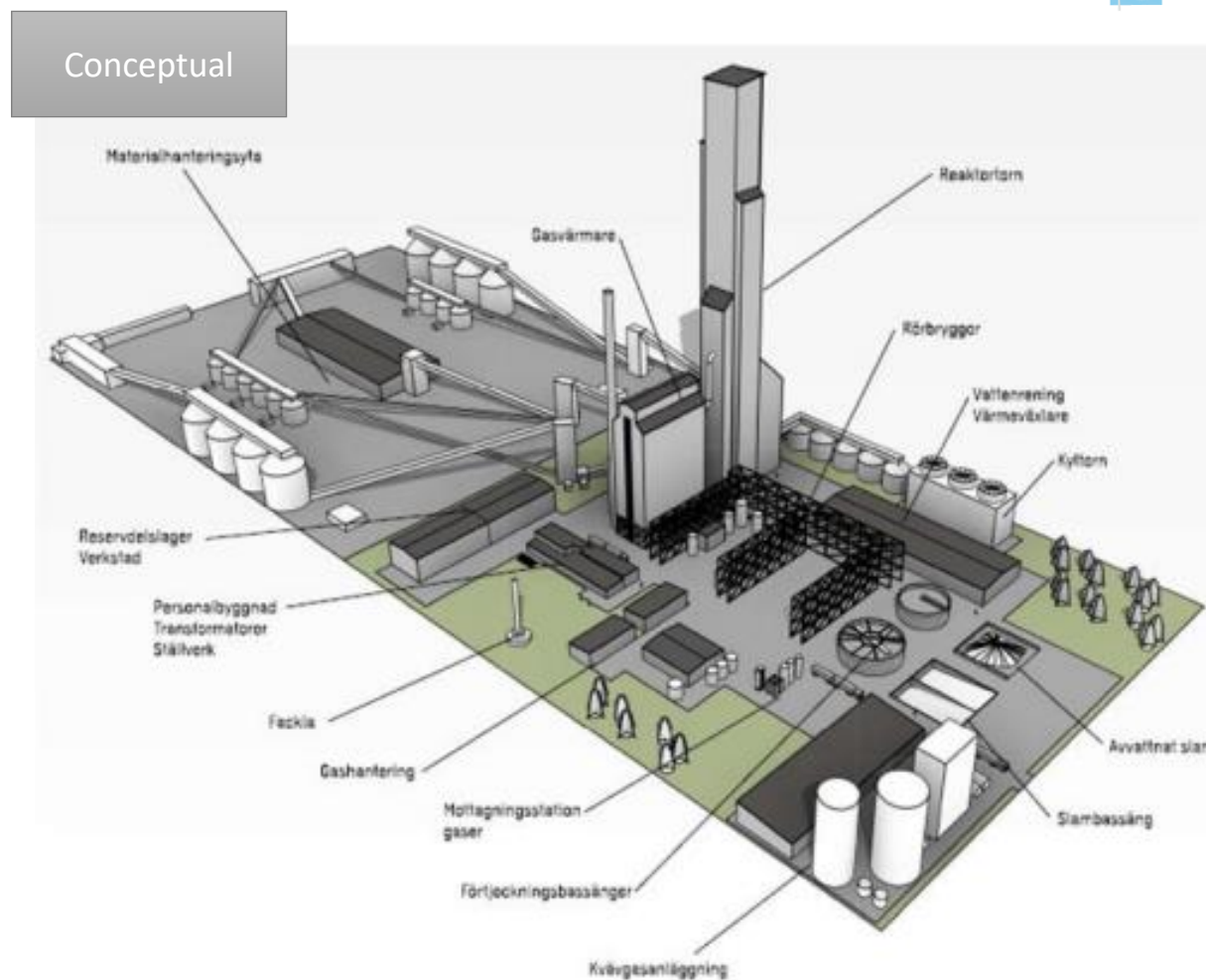
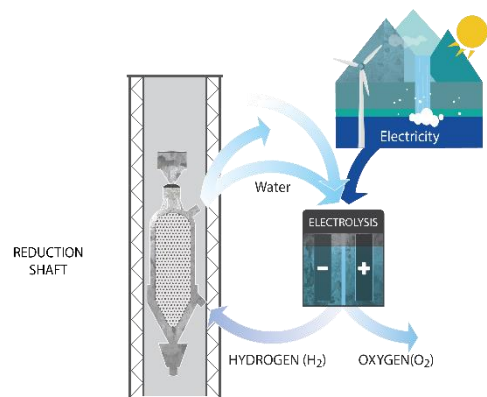
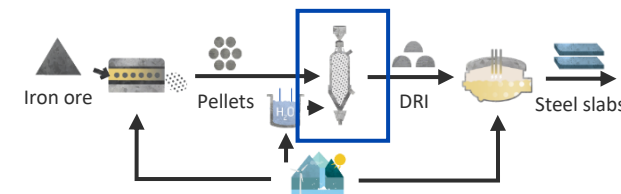
# Demonstration of large-scale hydrogen production through electrolysis

- Modular technology: largest electrolysis stacks today 600 Nm<sup>3</sup> per hour (~3 MW<sub>e</sub>)
- The HYBRIT demo concept requires a capacity over 100,000 Nm<sup>3</sup> per hour
- ~500 MW electrolyser capacity for demo
- 3-4 TWh fossil-free electricity per year required for hydrogen production
- Electrolysis cells are degraded – reinvestment is likely to be required after ~80 000 hours



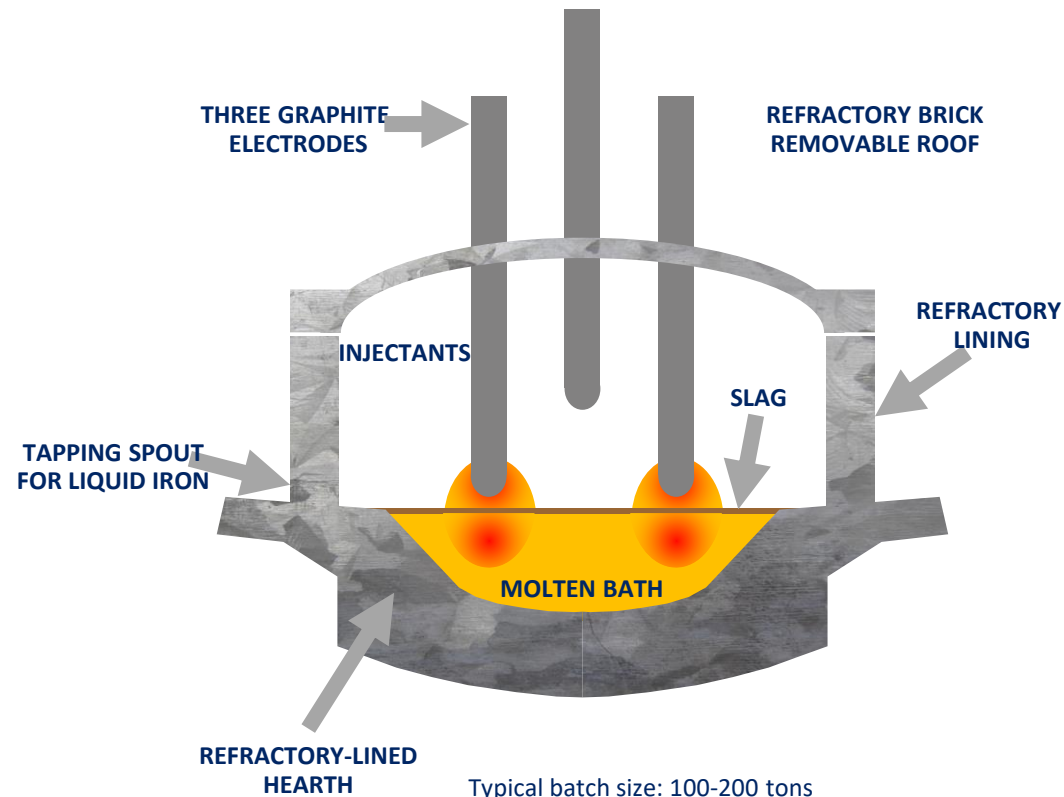
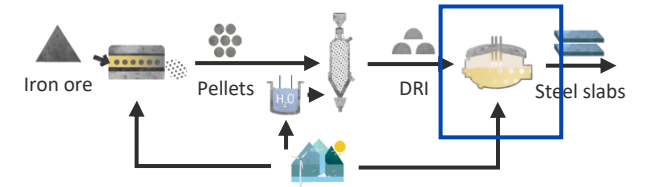
# Demonstration of H-DR technology in Gällivare

- Demonstration H-DR plant in Gällivare-Malmberget, Sweden, on existing LKAB industrial site for pellet production
- Production capacity 1.35 Mton H-DRI per year

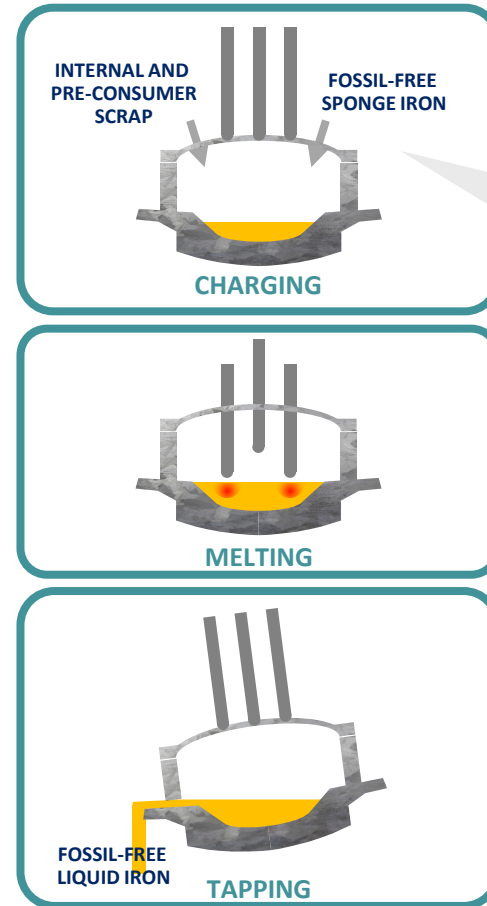


# Demonstration of electric melting

## Electric Arc Furnace (EAF)

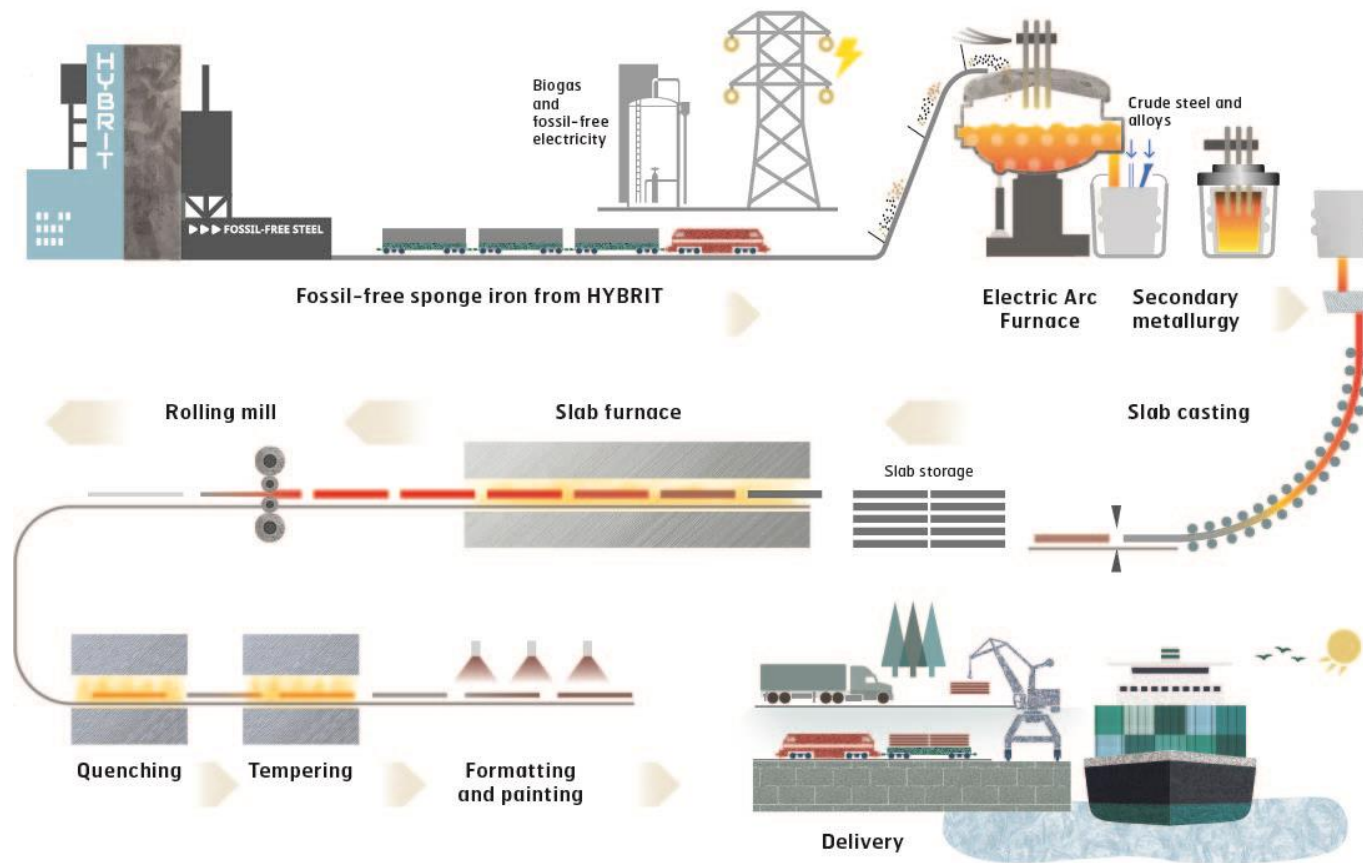
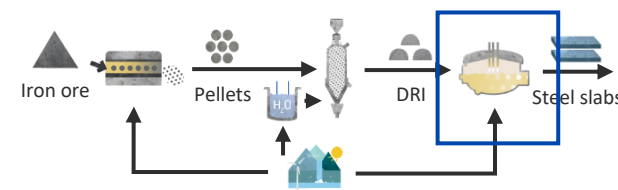


Typical batch size: 100-200 tons  
 Typical tap-to-tap time: 30-60 minutes  
 Typical electricity consumption: 400-500 kWh/ton iron



*This use of sponge iron in the EAF will allow the same crude steel analysis and steel purity as with the BF-BOF route it replaces*

# How to produce fossil-free steel plates at SSAB in Oxelösund





# Value chain effects



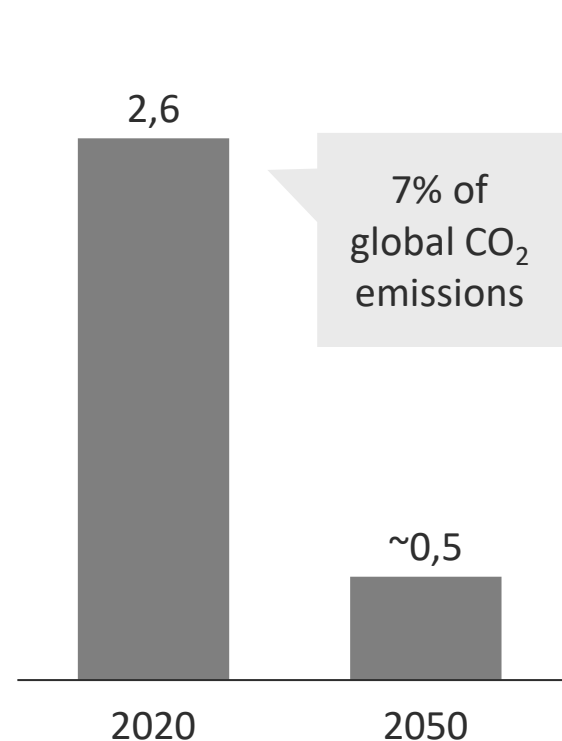
EMISSIONS EFFECTS

TRANSFORMATION

# A new steelmaking process is needed

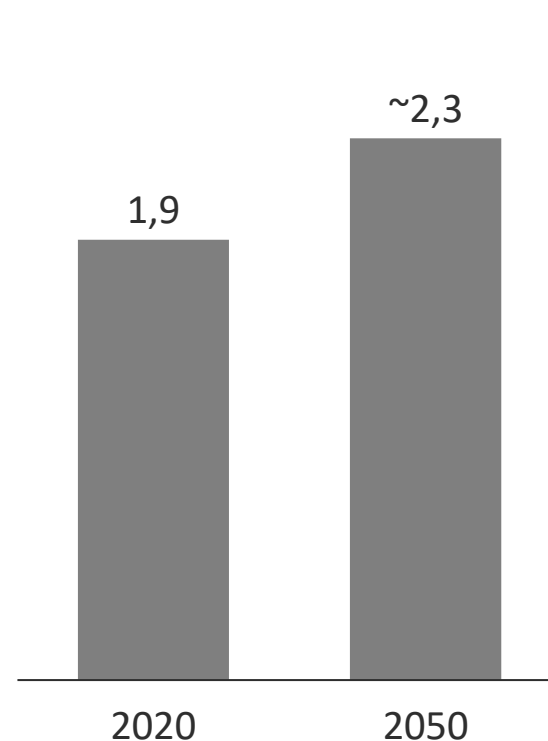
Emissions from the steel sector must be significantly reduced to achieve climate targets<sup>1</sup>...

*Billion tons CO<sub>2</sub>*



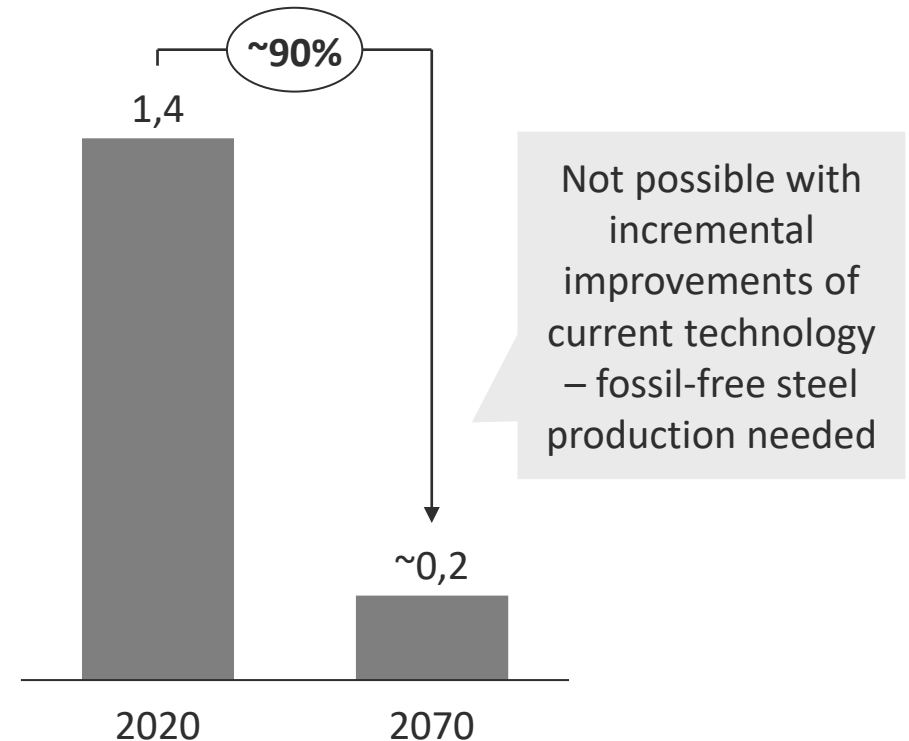
...While the global demand for steel products is increasing...

*Billion tons steel*



...And therefore must the carbon intensity from steel production be reduced by ~90%

*Tons CO<sub>2</sub>/ton steel*

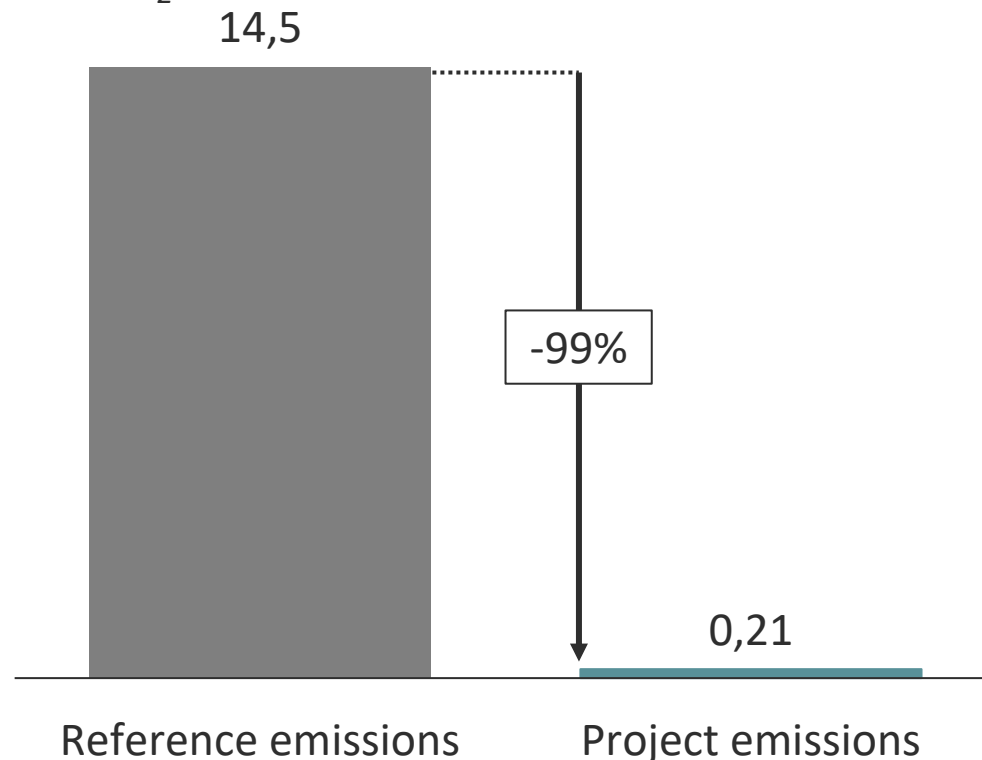


1. Beyond 2 degree Scenario from International Energy Agency (2017), *Energy Technology Perspectives 2017*. Source: IEA ETP; Material Economics (2018), *The Circular Economy – A Powerful Force for Climate Mitigation*

# The HYBRIT Demonstration project contributes to significant and accountable CO<sub>2</sub> emission avoidance

## CO<sub>2</sub> emissions first 10 years of operation\*

Million tons CO<sub>2</sub>e



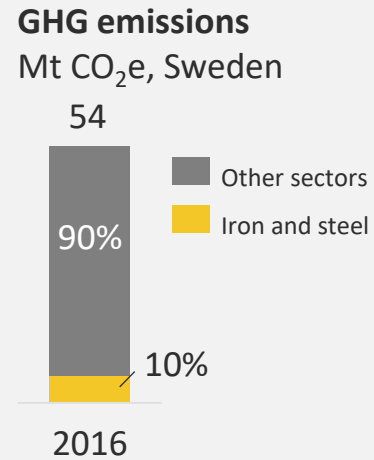
- Replacement of two blast furnaces and one coke plant
- Emissions accounting will take place during a 10 year follow-up
- 14.3 million ton CO<sub>2</sub> emission avoidance
- 3% reduction of annual Swedish CO<sub>2</sub> emissions

\* According to Innovation Fund methodology as defined in Annex C: Methodology for calculation of GHG emission avoidance. Reference emissions based on EU ETS benchmarks

# A successful transition of the iron and steel industry will be beneficial from many perspectives

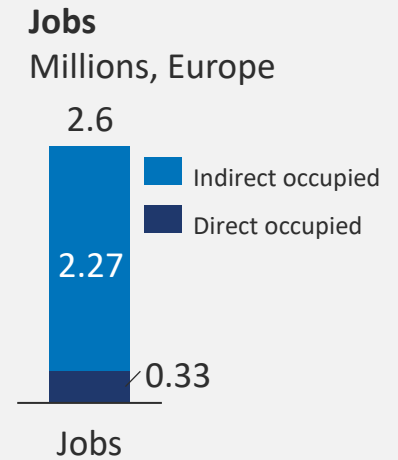
## 1 REDUCED CO<sub>2</sub> EMISSIONS IN SWEDEN BY 10%

- ▶ Iron and steel production accounts for **10% of Sweden's emissions**
- ▶ A rapid ramp-up of HYBRIT could be the **most important climate action for Sweden**



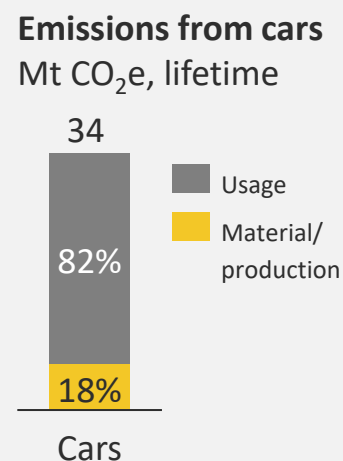
## 2 PRESERVATION OF EUROPEAN COMPETITIVENESS AND JOBS

- ▶ **Critical for European competitiveness** to offer climate positive products when the demand grows
- ▶ The European steel industry is **responsible for over 2.5 million jobs**, direct and indirect



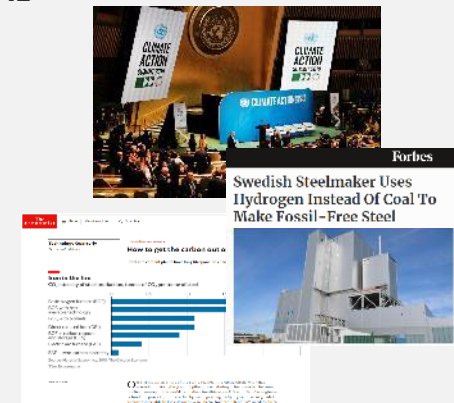
## 3 COMPETITIVENESS FOR EUROPEAN STEEL USERS

- ▶ HYBRIT creates **conditions for other European industries** to be global pioneers in fossil freedom
- ▶ **Increased focus on emissions related to materials**, as the usage of fossil fuels reduces



## 4 HYBRIT AS AN INTERNATIONAL FRONTRUNNER

- ▶ HYBRIT has gained **great international attention**
- ▶ **Many companies are now following HYBRIT** through other low-carbon steel initiatives



Sources: SCB (2020) - Utsläpp av växthusgaser från industrin efter växthusgas, bransch och år; Material Economics analysis; The Economics; Forbes; EUROFER Employment statistics  
 1. Assumption: 95 g CO<sub>2</sub>/km exhaust gas, 25 g CO<sub>2</sub>/km from fuel production, 230.000 km during lifetime; material related emissions based on Ellingsen & Hung (2018) and 30-50% is estimated to be related to steel

# To summarize

- ✓ The use of hydrogen enables conversion of iron ore to sponge iron and to steel in a fossil-free manner.
- ✓ Not all steel can be produced via recycling and melting of scrap, iron-ore based steel will remain of strategic importance for EU as it is the main approach to produce high quality and high strength steel.
- ✓ The HYBRIT Demonstration project will prove the concept of a fossil-free value chain from pelletizing, via sponge iron, to crude steel, and grant proven emissions reductions exceeding 14 million tons during the follow-up period.

# The HYBRIT Demonstration project has been granted €143 million from the EU Innovation Fund



**HYBRIT**  
▶▶▶ FOSSIL-FREE STEEL



**Funded by  
the European Union**

*The contents of this publication are the sole responsibility of HYBRIT and do not necessarily reflect the opinion of the European Union.*

# HYBRIT

▶▶▶ FOSSIL-FREE STEEL

A JOINT VENTURE BETWEEN

**SSAB**

 **LKAB**

**VATTENFALL** 