

SCRAP SUPPLEMENTS & ALTERNATIVE IRONMAKING 10



HYBRIT Pilot Project: New sponge iron product with unique properties

Scrap supplements and alternative ironmaking 10
Conference

March 11, 2026

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HYBRIT FREE STEEL



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SSAB



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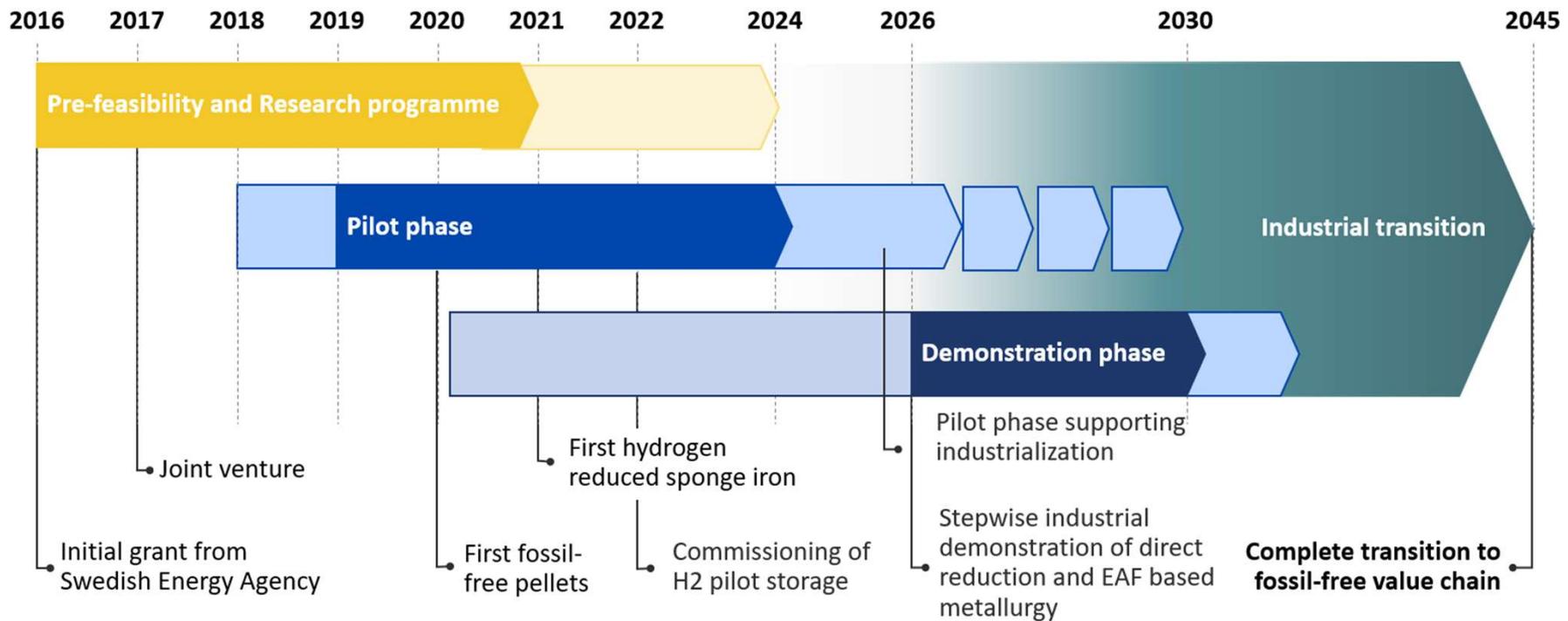
HYdrogen Breakthrough Ironmaking Technology

for a fossil-free future

SCRAP SUPPLEMENTS & ALTERNATIVE IRONMAKING 10



HYBRIT timeline – From technical development to complete transition 2045

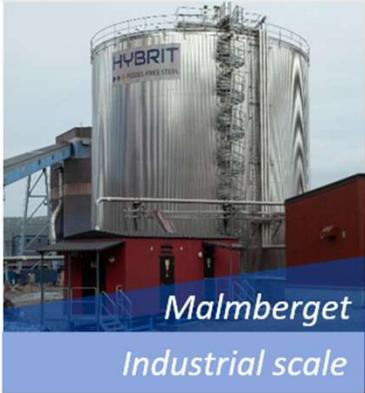


Verification across the value chain

- From ore to steel



IOP production
with bio-oil



H2 sponge iron
production



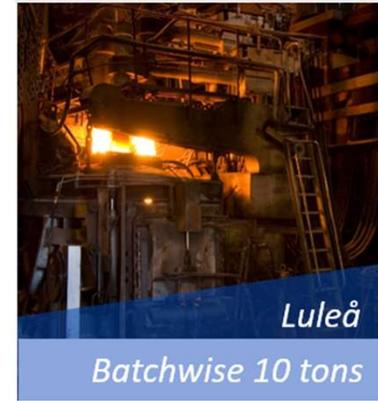
Hydrogen
production



Hydrogen storage
in lined rock cavern



Melting in electric
arc furnace





Extensive testing in pilot-scale

- Focus on process settings for **hydrogen based direct reduction**
- Including testing of different kinds of **carburization**
- Ingoing **reduction gas temperatures** between 550 – 1030 °C
- **Operating pressure** between 2 to 4 barg
- **Production rate** between 0.8 to 1.4 tonnes DRI / h
- **Residence time** for reduction has been varied over a wide span
- **175 process points** with hydrogen reduction have been evaluated



Mechanical properties

- DRI – studies on strength and mechanical degradation
 - Drop testing
 - Tumbling
 - Compression
 - Sieving analysis
 - Method development



Development of Drop testing

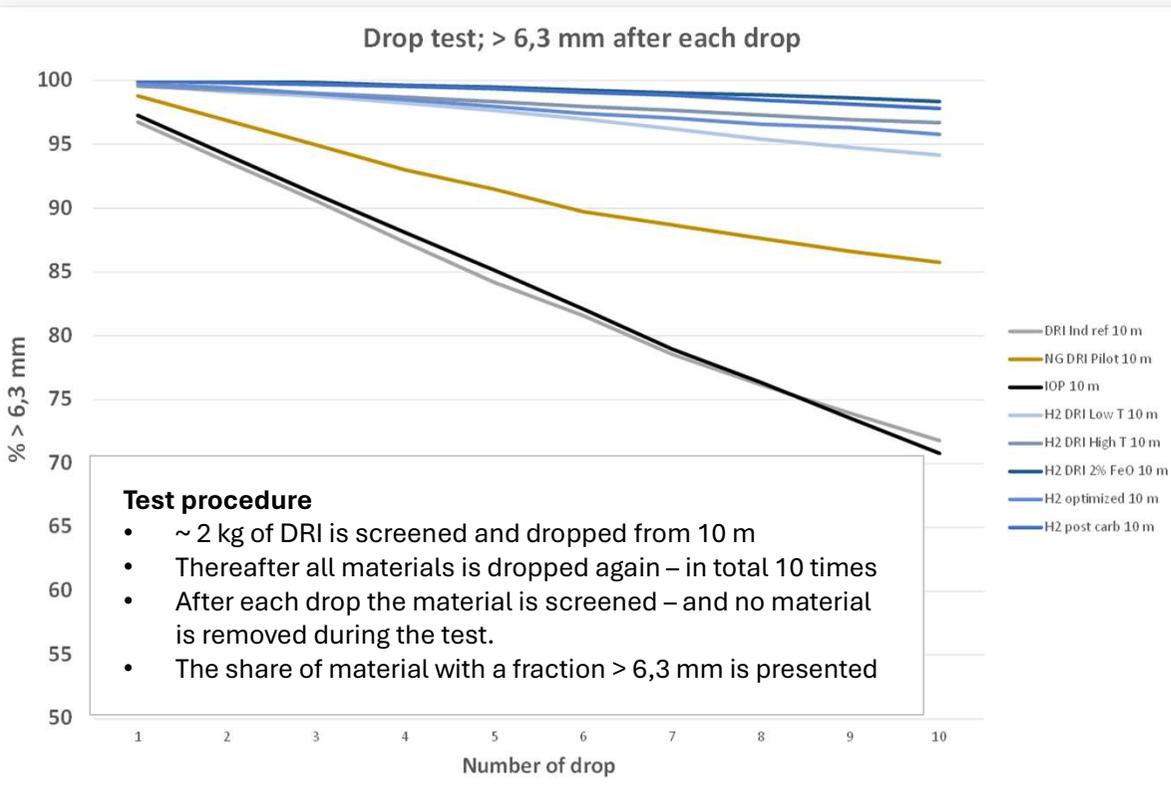
Drop testing provides an indication of the susceptibility of DRI pellets to break when dropped from a height – such as during handling in material silos.

- Equipment installed in the pilot plant
- Testing of different materials dropped from different heights
- Measurement of disintegration and generation of fines

Hydrogen reduced DRI 0% C after 10 drop at 30 m



Results from Drop Testing

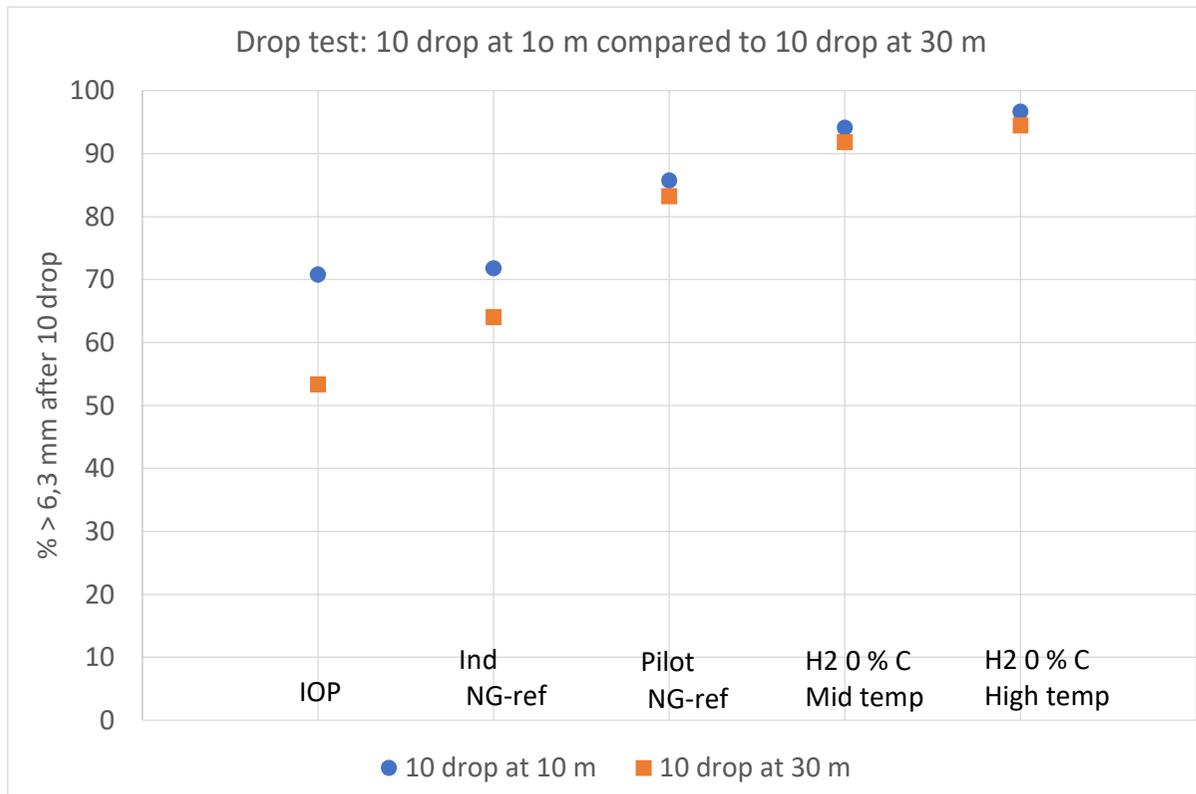


Summary of observations

- H2 reduced DRI has a high strength - only ~ 5 % break to < 6,3 mm after 10 drops at 10 m
- Higher reduction gas temperature improves the resistance to break for H2 reduced DRI
- NG-reduced DRI with carbon and IOP has a lower strength

Drop test at the pilot plant

– Comparison for different heights



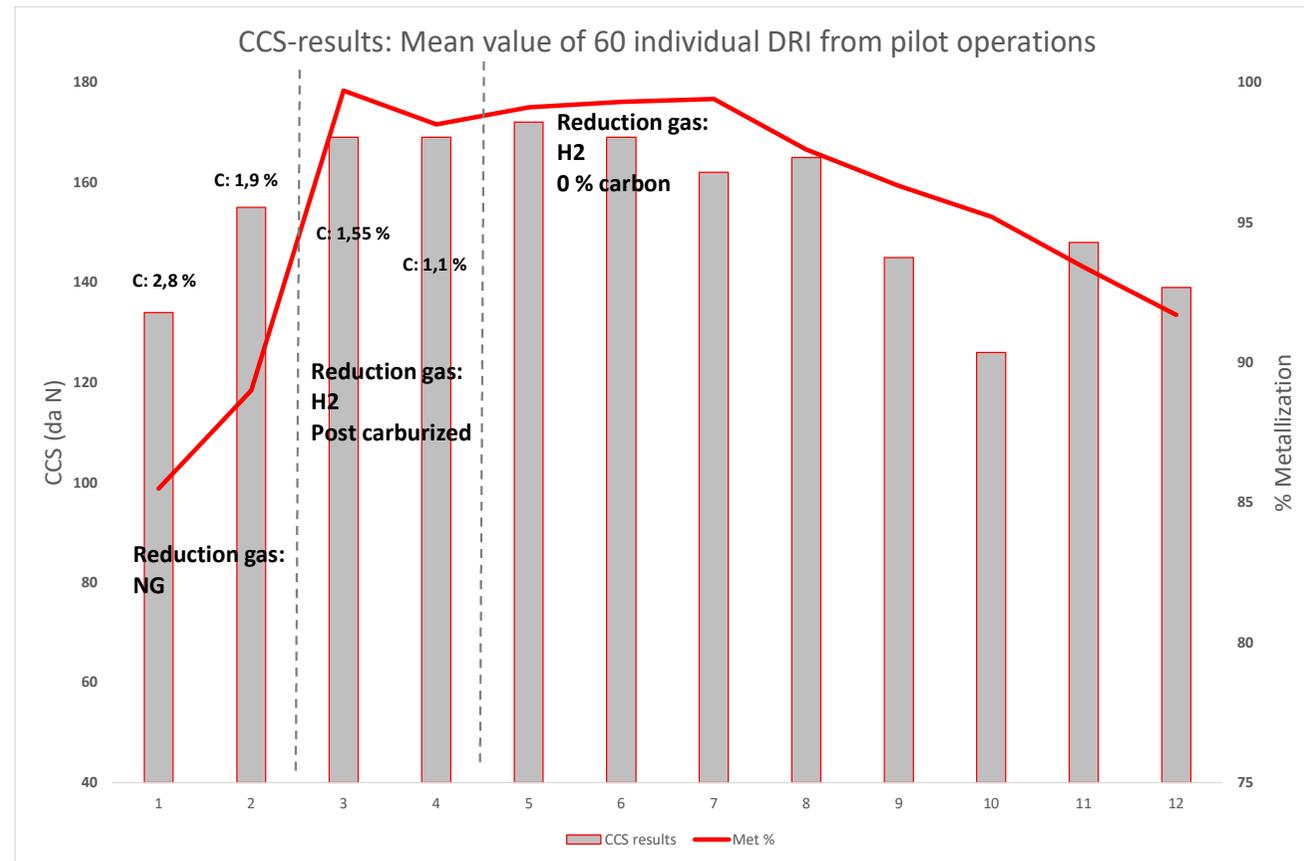
Comparison of different drop heights: 10 m and 30 m

- Increased drop height to 30 m affects different materials in different ways
- H2 reduced DRI 0% C have low breakage after 10 drops at 10 and 30 m
- **H2 DRI 0%C, High metallization: ~95 % of the material > 6,3 mm after 10 drops at 10 and 30 m**

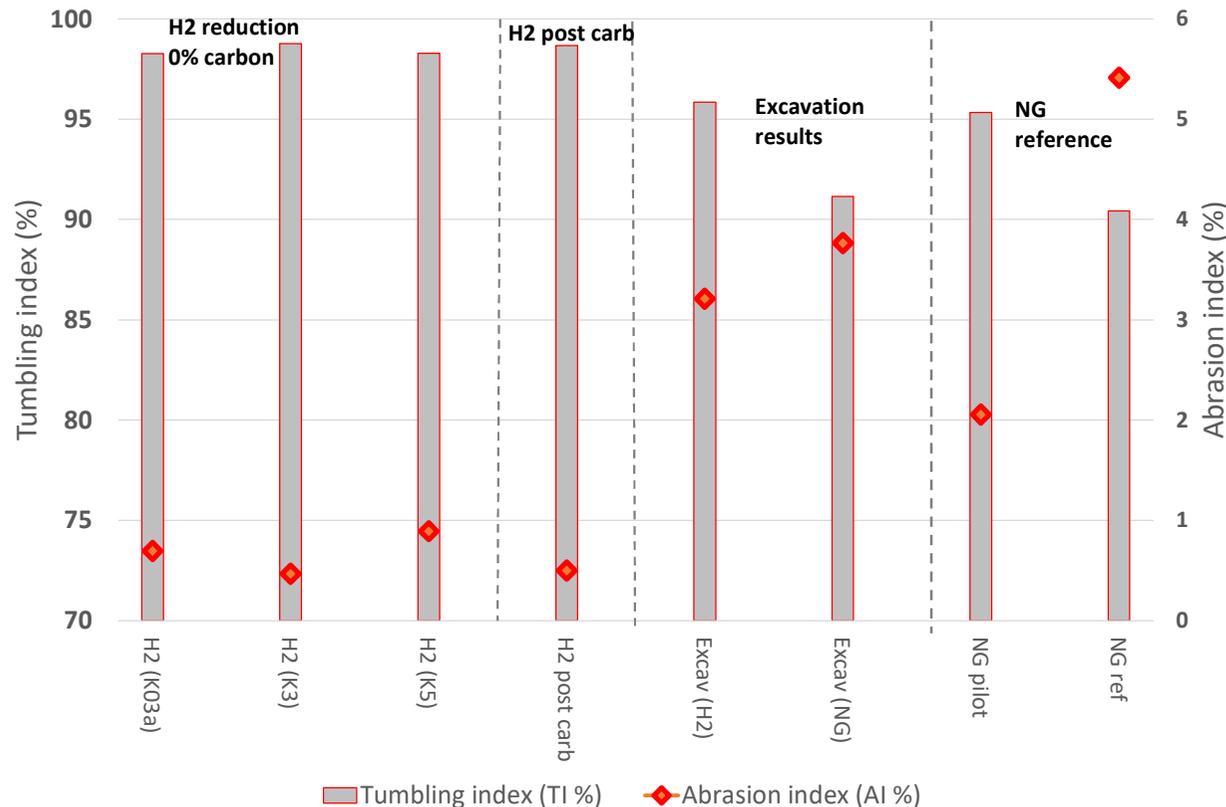
Cold compression strength; ISO 4700-2015

CCS Results on DRI:

- Higher CCS values is obtained with H₂ reduction
- Higher % Met improves CCS for H₂ reduced DRI (> 97%) due to lower iron oxide content
- For NG reduction it seems that higher C and lower % Met has a negative impact on CCS
- H₂ reduced DRI that are carburized after reduction seems to have similar CCS results as H₂ reduced DRI with 0% C



Tumbling indices on DRI; ISO 3271:2015



Tumbling Results:

- H2 reduced DRI, 0 % C and high metallization displays
 - High Tumbling index: ~ 98%
 - Low Abrasion index: ~ 1 %

This indicates that an increasing iron oxide content in DRI and the use of carbon containing reduction gases acts to give a lower TI and higher AI in DRI.

Chemical properties: studies on reactivity and reoxidation

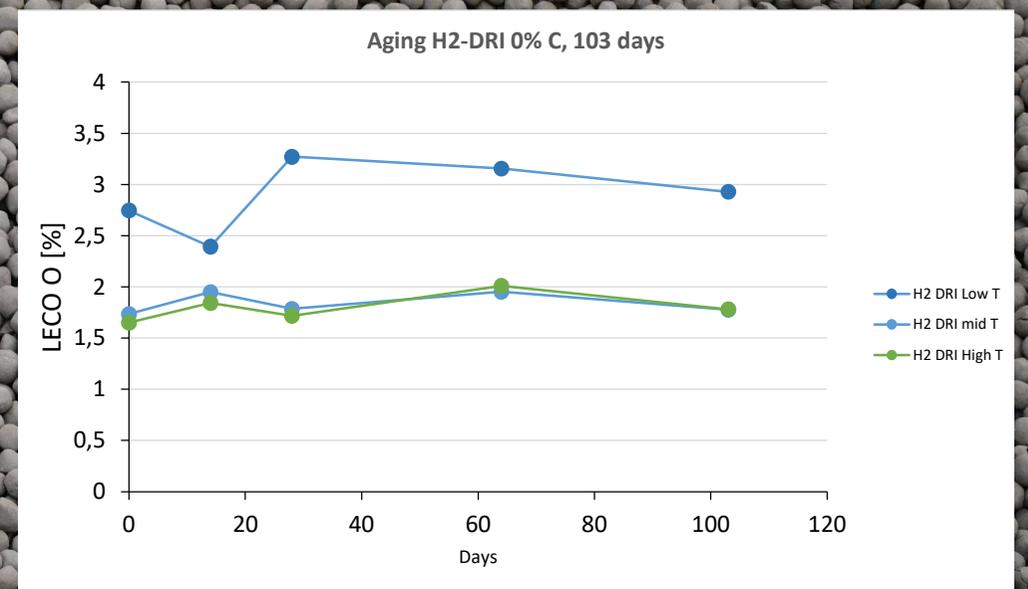
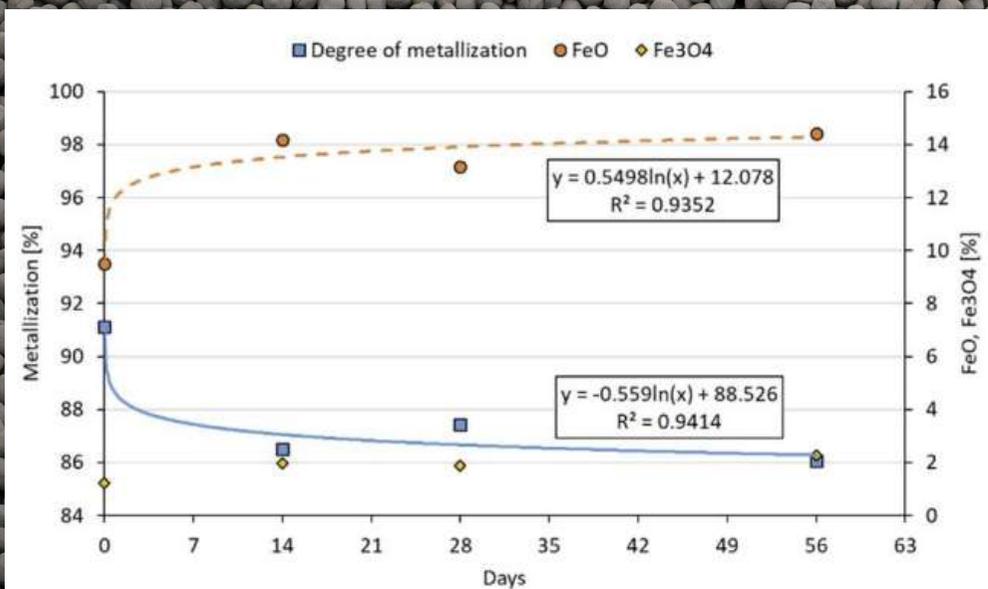
- Passivation studies
- Bulk aging studies
- Accelerated aging in water
- Single pellet aging studies (indoor and outdoor)
- Porosity and surface area measurement
- Microscopy
- Ignition temperature
- Reoxidation test
- **UN-tests for transportation**



Aging of sponge iron

Hydrogen reduced DRI with high metallization is chemically more stable in comparison to pilot NG-DRI

Below diagrams show re-oxidation results in bulk aging tests



UN tests N1 and N4

The aim with the UN-tests is to evaluate if H-DRI is classified as dangerous goods on railway due to the identified risks related to self-heating and flammability.

The standardized test methods are described in the United Nations “**Recommendations on the Transport of Dangerous Goods**” and the handbook “**UN Manual of Tests and Criteria**”.

UN N.1 Test method

- A burner is applied to one end of a powder train of 250mm for 5 min.
- If the powder either ignites or propagate combustion over 200mm in 20 min, the sample is not approved.

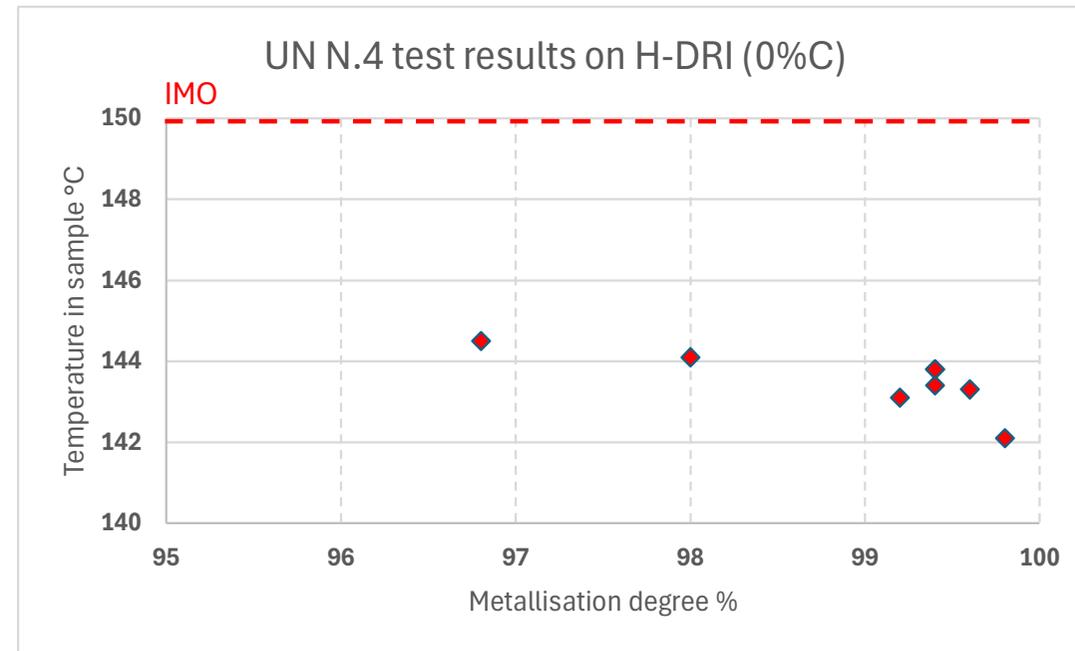
UN N.4 Test method

- A container with 1-liter DRI is placed in a furnace at 140°C for 24h.
- The sample and furnace temperatures are measured continuously.
- If the sample temperature **exceeds 200°C**, the sample is not approved.
- The International Maritime Organization (IMO) - Material should be classified as MHB if the sample temperature reaches **more than 10 °C (150 °C)** above the oven temperature



UN N1 and N4 results on H₂-DRI

- All tests are made on passivated samples
- Tested H-DRI products for UN N.1 were approved
- Tested H-DRI products according to UN N.4 were approved
- UN N.4 tests show very low self heating tendencies
- Ongoing method development to test various size fractions. For example, fines.



Summary of finding for hydrogen reduced DRI

Results from extensive testing in the HYBRIT pilot plant highlight that H2 reduced DRI display different product properties compared to NG reduced DRI.

- ▶ H2 reduced DRI with 0% C and high metallization (98-99%) is very stable.
 - ▶ It shows better physical, mechanical, chemical and aging characteristics compared to conventional NG-DRI.
 - ▶ Low iron oxide content and 0% carbon give the sponge iron robust mechanical properties.
 - ▶ The product has very good stable chemical properties. The material ages very slowly when handled properly and can therefore be stored for longer times.
 - ▶ The results indicate the potential of high metallization H2 reduced DRI without carbon for implementation of a H-DR based value chain.
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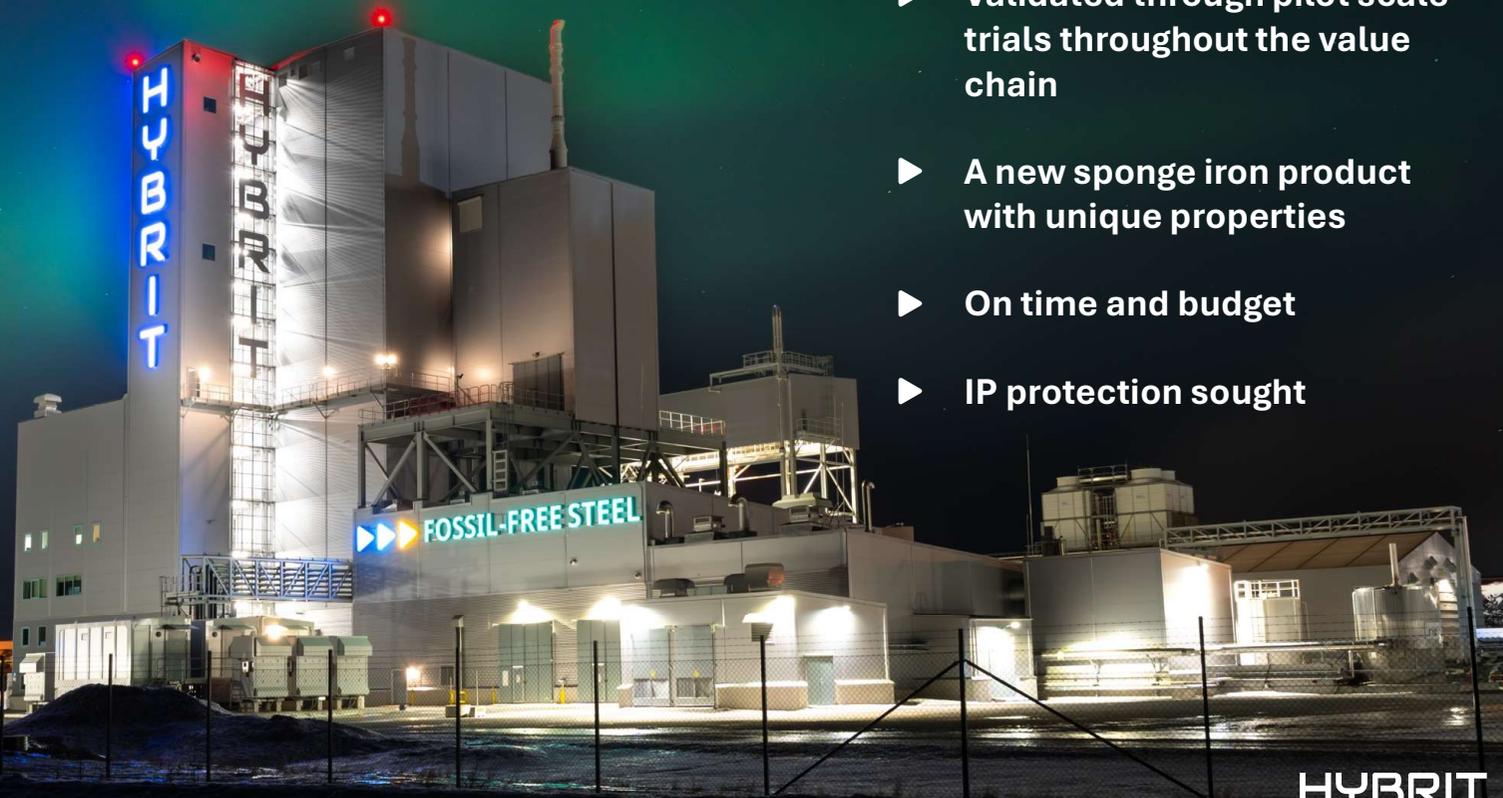
HYBRIT – For a fossil-free future

Developed technology that enables efficient fossil-free steel production

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Tonne CO₂e / tonnes of steel*

- ▶ Validated through pilot scale trials throughout the value chain
- ▶ A new sponge iron product with unique properties
- ▶ On time and budget
- ▶ IP protection sought



A joint venture between SSAB, LKAB and Vattenfall

HYBRIT
▶▶▶ FOSSIL-FREE STEEL