HYBRIT

A case study

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Innovation:	**Fossil-free steelmaking through direct reduction of iron ore using hydrogen as reductant (H-DR) and fossil-free mining and pelletisation of iron ore.**
Intervention:	**The HYBRIT project**
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Methodology:	7 interviews, 1 site visit, desktop research. Limited access to interviewees due to reported time constraints and secrecy.
Case Study Overview	
Sector(s):	Steel (Encompassing mining and energy for hydrogen production)
Value Chain Stage(s):	Resource and production
Type of Intervention:	Technical
Date & Duration:	The HYBRIT initiative was publicly announced in April 2016. The pilot phase started on 1 January 2018 and will last until 2024. The whole initiative is planned to last until 2035 when commercialisation is planned.
Location:	Sweden
Initiating Actors:	SSAB
Actor Constellation:	HYBRIT Development AB, a joint venture by SSAB, LKAB, and Vattenfall. HYBRIT Development AB is the 'project leader' and the actor responsible for the H-DR pilot. SSAB and Vattenfall have been the two parties mainly responsible for communication and public relations. LKAB is responsible for the pelletisation trials. Vattenfall is responsible for the hydrogen production and building new capacity for electricity generation and distribution. The Swedish Energy Agency has been the main funding body. The research programme which is part of the initiative involves several actors: Swerim/Mefos, Sandvik, SEI, RISE, Luleå technical university, KTH and Lund University.
Short Description of Intervention:	HYBRIT, acronym for Hydrogen Breakthrough Ironmaking Technology, is a development project with the aim of implementing fossil-free steelmaking in all stages of production; from iron-ore extraction, through pelletisation and reduction (iron-making), to the final steelmaking (in electric arc furnaces). For this to be possible, fossil free electricity production is needed, which will be used for hydrogen production (for the direct reduction of iron ore), for the electric arc furnaces (for melting of sponge iron and adding materials, most notably carbon, to make steel), and for parts of the mining and processing of iron ore (pelletisation). The HYBRIT project consists of several parallel parts. Two pilot plants are being built at the moment, one for direct reduction using hydrogen with steelmaking in an electric arc furnace and one for fossil-free heating technologies for the pelletisation of iron ore). Both pilot plants are run as separate projects from RP1, partially financed by the Swedish Energy Agency with HYBRIT Development AB as the recipient. A research project, called RP1, involving several research institutes and universities (listed above), is studying the potential side-effects and possibilities of implementing fossil-free steelmaking in Sweden as well as specific technological solutions (such as hydrogen storage or the handling of vanadium contamination in the electric arc furnaces). RP1 covers the resource and production stages of the value chain, including system integration and policy strategies.
Research Theme Summaries	
1. Innovation History & Dynamics:	If fossil-free steelmaking as a whole is to be seen as the innovation, this has never been done before. Most of the processes build on established technology and earlier research, including hydrogen production and storage, plasma-heating, and direct reduction of iron ore using hydrogen (which is currently not in commercial use). The innovative aspect of the HYBRIT project is ensuring that all processes rely on fossil-free electricity generation or renewable sources of carbon (biomass) and the scale on which these technologies are being implemented. SSAB and LKAB had earlier been involved in the ULCOS programme where direct reduction using natural gas and CCS had been trialled. In the light of Swedish climate policy and the Paris agreement the ambitions of these tests (to reduce carbon emissions by about 50%) did not 'solve the issue'. The first step of HYBRIT was a pre-feasibility study, which concluded that fossil-free steelmaking would be possible in Sweden, meeting few major difficulties. Large-scale hydrogen production and storage is also planned to be built and following the pilot plants,

	demonstration plants are envisioned before commercialisation in 2042. The mining and pelletisation is not envisioned to be fossil free until 2045. The main challenge identified is the potential lack of financial support and competitiveness on the market. This innovation is probably only viable under conditions of (global) ambitious climate policies, which require more than 80 % reduction of greenhouse gas emissions before 2050, since that would require that at least CCS be implemented on all primary steelmaking. At this stage of the initiative, no unintended consequences can be identified.
2. Governance Arrangements & Agents of Change:	This initiative is organised as a public-private partnership with substantial governmental support. The project is implemented and governed through the formation of a joint venture, HYBRIT Development AB, which is responsible for recruiting the required competence. Required competence is deemed to exist or will be built through the pilot trials and research project. An overall lack of graduate students in the areas of mining and metallurgy might become a problem in the future. Two of the three companies (LKAB and Vattenfall) with joint ownership of HYBRIT Development AB are state owned. The different projects included in the HYBRIT initiative are funded by the Swedish Energy Agency by on average 50 % per project, with a total sum of 598 838 005 SEK. Most of the funding is done through the programme 'Industriklivet' (The Industry Step) which was initiated in 2018 by the government. Political support, not only through ambitious climate targets, but also through financial support is deemed crucial for this initiative to succeed. Ambitious climate targets (the Paris agreement and the Swedish vision of reaching net-zero emissions by 2045) are referred to as the main drivers for why HYBRIT was initiated.
3. Transformative Capacities:	It is too early to assess the extent to which HYBRIT will be successful in generating skills, knowledge and resources for implementing fossil-free steelmaking. The governance structure with close collaboration and the assessment by interviewees does suggest it has the capacity to do so. HYBRIT builds on the vision by the Swedish steel association, Jernkontoret, from 2013, called 'Stål formar en bättre framtid' (Steel shapes a better future) which states that the Swedish steel industry should only contribute positively to society, reducing waste and emissions. It also builds on the aim taken by Swedish parliament to reach net-zero emissions of greenhouse gases by 2045. Communication of the HYBRIT project is aligned with these visions but the key word is 'fossil free' rather than zero emissions. One reason for that is to show that this initiative solves the 'root problem' rather than fixing the emissions. So far there is unequivocal political support and general acclamation in public discourse (social and established media) and HYBRIT is praised as an example of how the 1.5-degree target can be met.
4. Assessment & Evaluation:	HYBRIT has so far mainly been internally assessed and is assessed continuously, through RP1 and the other projects. Metrics for assessment have not been accessible. Evidence of carbon emission reduction is put forward in the feasibility study, which was done 2016-2018. This shows that close to zero emissions of fossil carbon are possible, with an expected reduction by 99 %. The actual carbon emission reductions will depend on how the electricity is produced as well as the carbon balance of biomass which will be used. Wind power is the envisioned power source for HYBRIT and Sweden already has low carbon emissions from electricity production, so the reduction assessment is reliable. Close to zero emissions of fossil carbon dioxide are possible. The emissions from fossil coal are expected to be reduced by 99 %.
5. Uptake & Consequences:	As the HYBRIT initiative is just at its beginning, it is difficult to assess uptake and potential consequences. There is a growing international interest in alternatives to blast furnace steelmaking and hydrogen reduction in particular. Core to the narrative on HYBRIT is that this is a 'breakthrough' technology, which will address the problem 'at its root' and it therefore seems hard to incorporate in business-as-usual narratives. It still has elements of the latter narrative, however, in that it sustains the idea of primary steelmaking (iron-ore based). Interviewees deemed primary steelmaking to be necessary during this century because of urbanisation, improved material standards of living and a growing global population, but a growing steel stock (the amount of steel present in society) would make secondary steelmaking (scrap based) the largest steelmaking route after mid-century. Potential social and ecological consequences are mainly related to the amount of extra electricity generation needed for hydrogen production where access to land and disturbance of wildlife habitats might create conflicts. This is connected to the growing

	interest in electrification in general among many industries and for transportation.
Conclusion & Outlook	
Key Learnings:	HYBRIT is one of a number of initiatives which show that it is possible to make fossil-free steelmaking a reality. Even if the concept is not proven yet, the narrative itself is challenging because it refutes the (formerly) dominant (but decreasingly so) claim that carbon emission reductions could only be met with CCS for the steel industry. A main factor for explaining the success so far for this initiative is the very close collaboration between companies from different sectors and a joint commitment to align to societal goals of net-zero emissions. This builds on well-developed trust and collaborations, especially between SSAB and LKAB, and the conditions of the Swedish steel industry with a high specialisation and close to zero competition between steel companies which enables a joint undertaking such as Jernkontoret's vision. Timing is another factor to explain the success. One of the two last blast furnaces in Sweden is reaching end of life and with today's climate policies investment in a new blast furnace is not deemed to be a good choice. The Swedish conditions, with low-carbon emissions from electricity generation, iron-ore production, and steel production already focused on specialty steel, provide good opportunity to test fossil-free solutions. All assessments done on the feasibility of HYBRIT and the narrative which it produces builds on political commitment to meeting the Swedish goal of net-zero emissions by 2045. Without this goal, support from politics, and the expectation of continued general commitment to meet this goal, this initiative would be very difficult to implement. SSAB has for many years been identified as the top emitter of greenhouse gases in Sweden. The steel sector has been pointed to as one of the 'problematic areas,' which has to some extent contributed to the change of narrative in the steel industry. The actors do not want to be seen as part of the problem, but part of the solution.
Open Questions & Further Research Requirements:	

For Europe to achieve its long-term climate objectives, carbon-intensive industries have to reduce their emissions.

REINVENT focuses on plastics, steel, paper and meat & dairy – industrial sectors that are key to our daily lives, but where low-carbon transitions are still relatively unexplored.

To gain a broader understanding of the possibilities of transition, entire value chains of the industries are studied. This includes non-technical factors such as supply chains, financing, trade, and social and economic impacts. Together with forward-looking industry leaders and policy-makers, we explore potentials and capabilities for making transitions in these resource-intensive industries.

PARTICIPANTS & FUNDING

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