Stirling Infrastructure Partners Ltd

Hydrogen

Steel and Cement Industries

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INTRODUCTION

Metals, stone, and mud have been the key building blocks for the earliest civilisations. Today, however, the most consumed materials such as steel and cement are also the greatest polluters, respectively emitting 1.85 and 0.5 tonnes of CO_2 per tonne of material produced.[1]

To reduce carbon emissions in this industry, companies will be required to switch to alternative "green" materials, seek a method to reduce the environmental impact of the current processes, or become subject to carbon taxation. With the current European average carbon tax of $42.49/tonne of CO_2[2], a European steel company without free allowances or other mitigating measures would be taxed $78.61 per tonne steel produced.

STEEL INDUSTRY, SCIENTIFIC OVERVIEW

Steel is the world's most-used metal. The $2.5 trillion industry produces ~2 billion tonnes of steel per year and emits 7-9% of global CO_2 emissions due to the energy-intensive process of converting iron ore into pure steel. The production of iron and steel requires temperatures up to 2,000 °C, which is difficult to simulate at a low cost without using carbon, a material that helps generate high temperatures necessary to smelt raw materials.

Iron ore and metallurgical coal are currently the two main raw materials used for steelmaking. The mined iron ore must be reduced, meaning that oxygen needs to be removed. This is done by bonding the oxygen molecules with a reducing agent. The carbon intensity of steelmaking largely depends on the type of reducing

1 https://www.sciencedirect.com/science/article/abs/pii/S1350630714000387#:~:text=Abstract,all%20other%20building%20materials%20combined
2 Where Is Carbon Taxed in Europe? | Tax Foundation

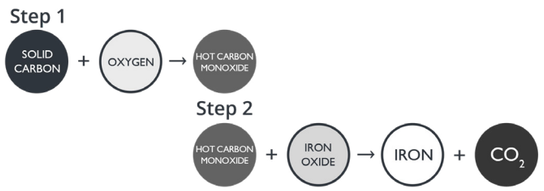
agent and the technology used.

Two of the most popular methods of steelmaking include:

Basic oxygen furnace (BOF) with blast furnace

- 75% of global steel is produced via BOF, with inputs including carbon, minerals, oxygen, iron ore (which is an iron oxide).
- Hot air is injected into a feed of minerals, namely coke, sinter, and lime.
- The reduction process results in liquid iron, which is transported to the basic oxygen furnace, as well as CO_2 and slag.
- In the basic oxygen furnace, oxygen is blown onto the molten iron to reduce its carbon content, creating CO_2 and steel.[3]

Figure 1 - Step-by-step process of iron production



Electric arc furnace (EAF)[4]

- 25% of global steel is produced with the EAF, developed to overcome the difficulties of conventional BOF.
- The EAF uses recycled scrap metal and electrical power via an electrical arc to convert scraps into liquid metal.
- EAF often produces steel from direct reduced iron (DRI), which is created by reducing iron ore pellets with natural gas instead of coke, to reduce emissions.
- The process is more environmentally friendly, as it uses recycled steel scraps and is less carbon intensive than BOF. In addition, EAF are smaller and more efficient.

HYDROGEN OVERVIEW, STEEL

Hydrogen can be used to reduce carbon emissions in the steel industry by replacing coal, coke, natural gas, or any other polluting compounds as a reducing agent. Reducing iron ore with hydrogen would create iron and water vapour as outputs.

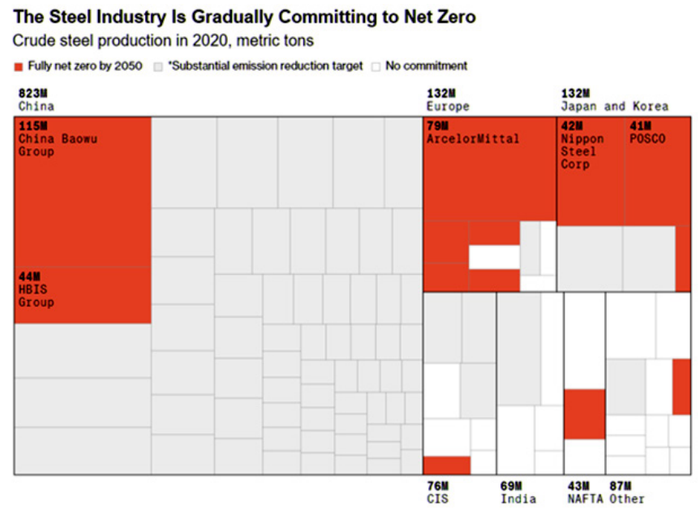
EXISTING INFRASTRUCTURE, STEEL

The top seven of ten largest steel-producing countries have initiated at least one green steel project[5], particularly in regions with ambitious climate change goals. Although China is the largest steel producer in the world, with Chinese companies occupying 12 positions of the top 20 global players in terms of tonnes of steel produced, it has been reluctant to sacrifice growth to achieve climate plans. In the first half of 2021, coal-dependent steelmaking capacity was expanded to 35 million tonnes by constructing 18 blast furnaces and 43 coal-fired power plants[6] in China.

European steelmakers, pressured by stricter environmental rules, account for 31 of 47 existing green steel projects. Sweden, home to the highest carbon tax in the world at $137 per tonne CO_2[7], is investing $22-51 billion in six projects. Hydrogen-reduced steel is currently produced by retrofitting existing steel mines and constructing on-site electrolysers, a methodology that does not require significant infrastructure development.

3 Basic Oxygen Furnace Processing | Thermo-Calc Software (thermocalc.com)
4 Making iron & steel - DRI furnace | ArcelorMittal
5 Green Steel Tracker - Leadership Group for Industry Transition
6 China puts growth ahead of climate with surge in coal-powered steel mills | Financial Times (ft.com)
7 Where Is Carbon Taxed in Europe? | Tax Foundation

Figure 2 - Net-zero goals of companies in China, CIS (Commonwealth of Independent States), NAFTA (North American Free Trade Agreement), and others.



OPPORTUNITIES, STEEL

I) Ease of Development

The limited infrastructure required for constructing small-scale green steel operations smooths the transition from fossil-fuel to hydrogen-based steel. Steel producers are gradually substituting their reducing agent from coke to natural gas, to a mix of hydrogen and natural gas, with an end goal of full hydrogen reduction. For this reason, producers can work towards green steel production and hydrogen facility production, without severely interrupting steel production in the existing plant.

II) Government Support and Incentives

Unlike the transportation industry, the steel industry does not receive significant decarbonisation incentives for hydrogen initiatives. Until recently, it was prohibited to provide state aid to steelmakers in locations including the EU[8]. However, as energy-intensive industries pursue decarbonisation initiatives, there is a greater movement towards funds and subsidies for steel companies. The Innovation Fund under the EU Emissions Trading Systems is providing $21 billion over 2021-2030 for low-carbon initiatives in energy-intensive industries, such as steel[9]. In coming years, steel manufacturers may expect increased support for decarbonisation.

III) Client partnerships with steel consumers

Large steel consumers are also expressing interest in purchasing sustainable metals. The automotive industry makes up 16% of global steel consumption, as the metal is used for the frame, hoods, doors, bumpers, mufflers, fuel tanks and lithium-ion battery casing. Volvo is the first automotive company to commit to consuming green steel. In June 2021 it announced a partnership with the Swedish steel maker SSAB to jointly develop green steel through the HYBRIT initiative, a joint venture between Swedish mining and energy companies to decarbonise the steel industry.

IV) Segmentation of steel product

Different steel production methodologies produce steel of varying quality. If green steel proves to be equally high or higher quality than regular steel, it may create a niche market for high-quality sustainable steel, which will be able to justify elevated prices. Baowu Steel Group has partnered with Honeywell to create hydrogen-reduced non-oriented silicon steel, which is used as a component for battery electric vehicles (BEVs).

8 FEATURE: Green steel: who's paying? | S&P Global Platts (spglobal.com)
9 swd-competitive-clean-european-steel_en.pdf (europa.eu)

RISKS, STEEL

I) Increasing Costs

According to early assessments, green steel is estimated to cost 20-30% more than traditional steel, due to an increase in renewables capacity, hydrogen production, and technology costs[10]. ArcelorMittal, the second largest global steel manufacturer, estimates that costs related to carbon-neutralising will total $35-47 billion for hydrogen integration and $236 billion for renewables infrastructure in Europe by 2050[11]. Thus, elevated price risk must be reduced by securing partnerships with consumers and funding from public markets.

II) Limited Resources

Out of the two primary steelmaking practices, EAF is more popular as the furnaces are smaller, flexible, and use electricity and recycled steel for smelting. However, steel scraps are limited and may create quality problems due to sorting and contamination problems. Thus, green steel producers must explore alternative input production, such as DRI.

III) Loss of clients

The 20-30% steel price increase may result in consumers switching to alternative steel suppliers or to seek alternative materials for their operations. Thus, steel manufacturers must conduct a thorough assessment of anticipated green steel demand and should secure necessary partnerships.

CONCLUSION & RECOMMENDATION, STEEL

On a research and experimental scale, with electrolyser capacity at ~5MW as with the Swedish HYBRIT project, hydrogen-induced steel production is feasible and straightforward. However, for the entire industry to decarbonise, green steel producers will need to reconsider steel mill location and infrastructure.

Manufacturers should seek to be well-connected to industrial hubs and ports, which will be key hydrogen suppliers. ThyssenKrupp is constructing a hydrogen pipeline parallel to natural gas infrastructure to supply hydrogen from an electrolyser site in Lingen to a steel mill in Duisberg, Germany[12]. Similar initiatives are being conducted around the Port of Rotterdam in the Netherlands[13], and in Hamburg, Germany[14]. These large European ports are already securing partnerships for hydrogen import with players including Portugal, Morocco, Oman, Australia, Chile, Brazil, and Canada[15].

10 Microsoft PowerPoint - Electricity_Generation_2020_en_b.pptx (fraunhofer.de)
Steel, Hydrogen And Renewables: Strange Bedfellows? Maybe Not... (forbes.com)

11 FEATURE: Green steel: who's paying? | S&P Global Platts (spglobal.com)
12 Green hydrogen for steel production: RWE and thyssenkrupp plan partnership
13 Hydrogen in Rotterdam | Port of Rotterdam
14 https://www.energy.gov/sites/prod/files/2019/10/f68/fcto-h2-at-ports-workshop-2019-iii2-pistol.pdf
15 Port of Rotterdam Authority and RRP to Study Feasibility of Hydrogen Delta Corridor Pipelines Between The Netherlands and Germany - Hydrogen Central (hydrogen-central.com)

CEMENT INDUSTRY, SCIENTIFIC OVERVIEW

Cement is the second-most consumed material after water, with three tonnes used per year per capita globally. Like steel, cement requires a high temperature at ~1500°C, which can only be achieved by using carbon-emitting kiln fuels, such as coal, coke, fuel oil and natural gas which are the largest sources of CO_2 emissions. These fuels are difficult to replace, as they are easily combustible, cheap, and readily available.

Minerals including limestone, clay, chalk and silica are ground and baked in a kiln at this high temperature, producing clinker. This powder substance is combined with gypsum, a mineral found in sedimentary rocks, to create powdered cement.

HYDROGEN OVERVIEW

Unlike the steel industry, the cement industry does not plan on using hydrogen exclusively as a kiln fuel, as it is too expensive and unabundant. Additionally, the safety of hydrogen in a kiln has not yet been tested. Further, cement production is generally centred around abundant raw materials and mines, making it very expensive to connect to hydrogen infrastructure. Instead, cement producers are looking more towards biofuels for decarbonisation methods.

EXISTING INFRASTRUCTURE

Although the use of hydrogen in the cement industry is still being explored and developed, with the first consortiums submitting funding applications in July 2021, electrolysers are being installed to include hydrogen in the fuel mix. Hanson, a subsidiary of the sixth largest global cement producer HeidelbergCement, has been producing green hydrogen to replace some of the natural gas used to power the plant.[16]

OPPORTUNITIES

Alternatively, cement companies are examining hydrogen to expand their product value chain. Instead of using hydrogen to decarbonise the combustion process, an international consortium is planning to capture CO_2 and use green hydrogen to produce hydrocarbons. Hydrocarbons can then be converted into synthetic fuels and various renewable chemicals. “Concrete Chemicals” is a project announced in July 2021 and is run by an international consortium including Cemex, renewable energy company ENERTRAG, and electrolysis company Sunfire.

RISKS

Hydrogen has not been extensively researched in the cement industry, which creates high barriers to usage. Considering hydrogen will mostly be used for hydrocarbon processing, the greatest risks will be related to carbon capture technology and costs.

CONCLUSION, CEMENT

As the cement industry has not been actively investing in hydrogen-fuelled kilns, it is unlikely that green sustainable cement will be produced with the help of hydrogen in the next decade. Instead, it is likely that the industry will focus on the implementation of CCUS to reduce carbon emissions. Once carbon capture becomes economically feasible and efficient, cement companies will be able to extend their product offering to include synthetic gas produced from captured CO_2 and hydrogen.

16 Collaboration on green hydrogen research | Hanson UK

FOR FURTHER INFORMATION

This paper provides insights into allocating capital into the hydrogen value chain.

The firm provides a comprehensive range of services which includes M&A transaction services and raising both debt and equity to finance hydrogen projects globally.

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