EMISSIONS REDUCTIONS IN THE STEEL INDUSTRY

A GUIDELINE ON GREEN STEEL

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CONTENT

INTRODUCTION

The global steel industry is the most significant industrial contributor to carbon-dioxide emissions [1]. Higher customer demand, new regulatory requirements and growth in sustainable investing drives the interest for green steel.

Clarity and transparency provides benefits to all stakeholders.

WHAT IS GREEN STEEL?

Steel production accounts for 7% of global CO2 emissions [1]. To reach net-zero emissions by 2050, the agreed-upon goal of The Paris Agreement, steel production must reduce emissions even as the demand for steel increases.

Encouragingly, demand for ”green steel” has grown stronger, which has led to several initiatives to bring down or even eliminate emissions.

Procurement and production processes within the global steel industry involve multiple stakeholders across the world. It is therefore not surprising that, at the moment, there different understanding of the meaning of green steel.

To understand what makes steel green can only be done by evaluating current technologies, ongoing research and developments, emissions-reducing initiatives, and taking into account the A-Z production processes.

”A REVOLUTION IN STEEL PRODUCTION IS NOW WITHIN REACH”

”Emissions in the production processes themselves and the need for very high temperatures make the path to decarbonization more difficult than in the power sector. The good news is that a revolution in steel production is now within reach. Major steel-producing countries, including China, Japan, the EU and now the USA, have set ambitious targets to reach net-zero economies.”

United Nations Framework Convention on Climate Change (UNFCCC)

DEVELOPMENT INITIATIVES

The European steel industry defines two pathways for low CO2 steel-making; Smart Carbon use (SCU) and Carbon Direct Avoidance (CDA).

Smart Carbon Usage means making further use of existing steel-making routes, including process integration and optimization, conversion from fossil gases to hydrogen, but also carbon dioxide capture methods like Carbon Capture and Usage (CCU) and Carbon Capture and Storage (CCS).

Carbon Direct Avoidance develops new processes that are gradually maximizing the use of carbon-lean or fossil-free electricity and/or hydrogen. The intention is the large-scale replacement of existing metallurgy based on fossil fuels and fossil raw material. This pathway includes hydrogen-based and electricity-based metallurgy [2].

This guideline describes development initiatives on high technology readiness levels.

In addition, there are promising initiatives in on lower technology readiness levels, such as:

- Fines-based Hydrogen Direct Reduction combined with Electric Arc Furnace (e.g. HyREX, Circored) [3, 4].
- Fines-based Hydrogen Direct Reduction combined with Smelting Reduction (e.g. SuSteel) [5].
- Direct electrolysis of iron ore at low temperature (e.g. Ulcowin, Siderwin) [6, 7, 8,].
- Direct electrolysis of iron ore at high temperature (e.g. Ulcolysis, Boston Metal) [6, 9].

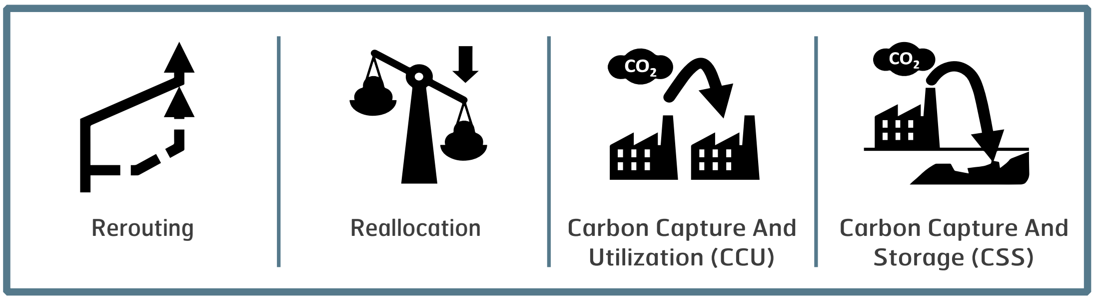
THE PARIS AGREEMENT

A legally binding international treaty on climate change adopted on 12 December 2015 which outlines the vision of fully realizing technology development and transfer for both improving resilience to climate change and reducing greenhouse-gas emissions.

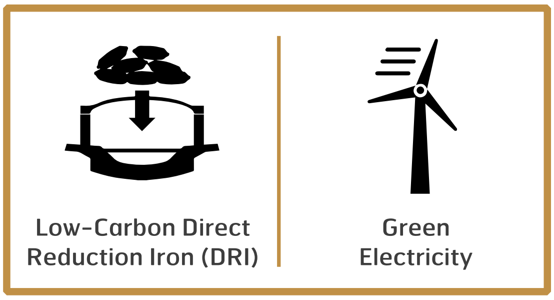
United Nations Framework Convention on Climate Change (UNFCCC)

In an attempt to categorize the current developments and initiatives by existing manufacturing processes, four areas emerge:

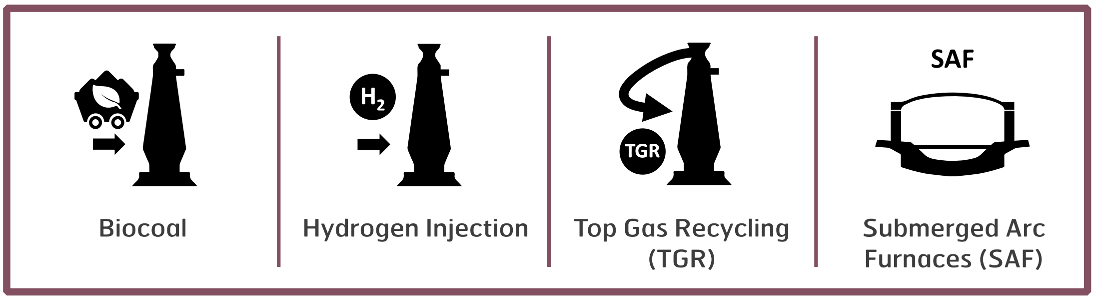
1 NO CHANGE TO THE MANUFACTURING PROCESS



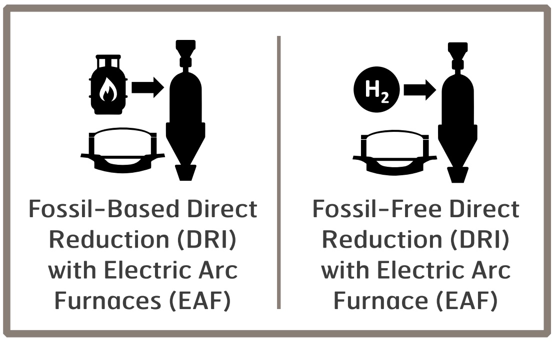
2 UPGRADING SCRAP-BASED STEELMAKING



3 UPGRADING IRON ORE-BASED STEELMAKING



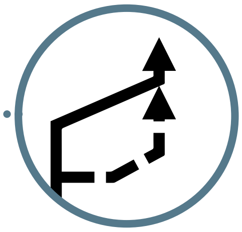
4 THE SHIFT IN TECHNOLOGY



NO CHANGE TO THE MANUFACTURING PROCESS

1

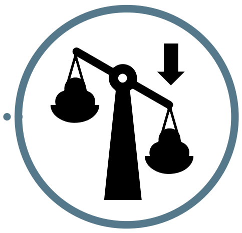
Rerouting



When there are production routes within a production system with significant differences in carbon-emission levels, a product can be moved to a less emitting route. On paper, that makes the rerouted product greener, but rerouting is zero-sum game because the direct emissions within the overall steel production system will remain the same.

In essence, the solution cannot truly be called a solution. Rerouting does not make the world cleaner nor does it promote initiatives to reduce carbon-dioxide emissions.

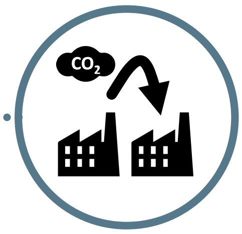
Reallocation



While there are several sound reasons to start off small with initiatives to reduce carbon emissions – such as giving enough time to R&D, production process engineers and operators to collaborate during test-and-trial phases – the long-term intention must be to apply solutions to production in its entirety.

Allocating all the emission savings in a mill to a part of the output, means that the promise of ”green steel” is quite deceptive. As long as the remaining part of production output stays as dirty as ever, there’s little substantive gain.

Carbon Capturing And Utilization (CCU)



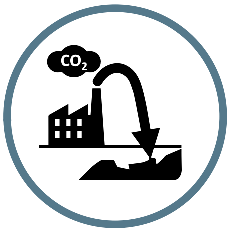
Capturing carbon dioxide is most cost-effective at point sources [10]. The main sources at a steel mill are the power plant, the sinter strand, the pellet plant, the coke plant and the blast furnaces [11]. A carbon dioxide scrubber absorbs carbon dioxide in the exhaust gases. Impurities in CO2 streams, such as sulfurs and water, can have a significant effect on the hydrate stability zone in the exhaust gas [12].

There are still no large-scale commercial CCU processes in the steel industry, but several research studies have indicated great potential. It is possible to capture approximately 65% of the emissions-embedded CO2 and sequester it in a solid form [13].

The carbon dioxide can be compressed or processed further with the help of other process gases to make products such as carbon monoxide, methane, methanol, polycarbonates or other organic products including acetic acid and urea [14]. The captured carbon dioxide can thus replace carbon-based raw materials needed by the chemical industry.

However, seen from a system perspective, including the chemical industry, the same amount of fossil fuels are still used.

Carbon Capturing And Storage (CCS)



CCS shares the same capturing process and challenges seen with CCU. Instead of processing in order to reuse the carbon dioxide, it is compressed, transported and stored in underground geological formations [15].

Appropriately selected and managed geological reservoirs are 'very likely' to retain over 99% of the sequestered carbon dioxide for longer than 100 years , according to IPCC calculations, and 'likely' to retain 99% of it for longer than 1,000 years [16].

There are still no large-scale commercial CCS processes in the steel industry. Similarly to CCU, challenges include the cost of scrubbing, covering a significant proportion of the many point sources of a steel mill, the utilization rate, and also the total cost and efficiency.

According to the International Energy Agency (IEA), carbon capture is unlikely to be significant by 2030. The IEA estimates that 1% of the annual CO2 emissions from the steel industry will be captured (16 MtCO2/year) [1]. From a system perspective, the same amount of fossil fuels will still be used.

Some experts state that CCS should be prioritized for other industries than the steel industry, such as plastics or cement, that face large costs in developing fossil-free technologies. In these sectors, the carbon dioxide could be reduced by up to 60-70% [17].

UPGRADING SCRAP-BASED STEELMAKING

2

Low-Carbon DRI

Blast furnaces (BF) using iron ore account for some 72% of the total global output of crude steel. The remaining 28% comes from electric arc furnaces (EAF) using scrap metal and direct reduced iron (DRI) or hot-briquetted iron (HBI) [18].

A greener alternative to fossil-based DRI would be to replace them with low-carbon DRI. Using low-carbon DRI could reduce the carbon dioxide footprint with 10-20% depending on the amount and type of DRI and on the electricity mix.

Green Electricity

In 2019, almost two-thirds (63.3%) of electricity produced globally came from fossil fuels, predominantly coal [19]. Even switching partially to renewable energy sources could make a significant impact. Depending on the electricity mix and the availability of fossil-free electricity, the carbon dioxide footprint could be reduced with 0-50% [19, 20]. A complete swap from fossil-fueled to fossil-free electricity could, in other words, cut down current emissions by half.

UPGRADING IRON ORE-BASED STEELMAKING

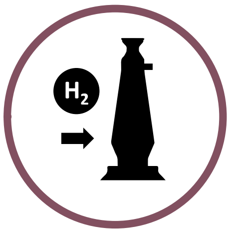
3

Biocoal

Part of the blast furnace (BF) ironmaking process involves pulverized coal injection (PCI) into the furnace. Some steel producers are running tests to replace the fossil coal with biocoal which is produced with biogreen pyrolysis and carbonization of raw biomass [21, 22]. When made with fossil-free energy and without binders, biocoal is a carbon-neutral fuel.

While biocoal can replace PCI, it's still necessary to use coal to make the blast furnace coke. In addition, biocoal normally contains higher share of Potassium (K) and Phosphorus (P), challenging the steel quality [23]. Regardless, the method could reduce the carbon emissions with up to 40% [24].

Hydrogen Injection

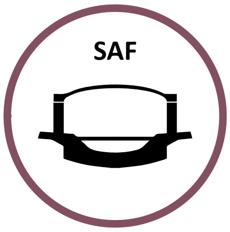


Alternatively, the pulverized coal injection (PCI) into the blast furnace can be partly replaced with hydrogen [25, 26, 27]. The resulting carbon-dioxide decrease is limited, approximately 10%-40% depending on the technology [28].

Top-Gas Recycling (TGR)

The top gases produced during blast-furnace energy production or heating could be recycled by feeding the carbon emissions and hydrogen back to the furnace. This requires less energy and lowers the demand for coke. Depending on flame temperatures, the injection location, and the oxygen-coal, the expected carbon savings are 21-25% [29].

Submerged-Arc Furnaces (SAF)



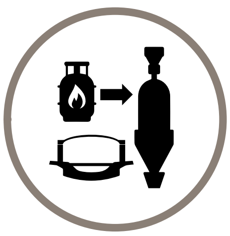
Submerged Arc Furnaces (SAF) or the similar Open Slag Bath Furnaces (OSBF) can replace blast-furnace ironmaking, which would lower the need for coke and coal. A primary advantage comes from the possibility to use iron ore of a lower quality.

This technology is still under development and there are no large-scale commercial processes in the steel industry. If the technology is brought to success on a large scale, employing an improved electricity mix, there could be a substantial reduction of carbon-dioxide emissions.

TECHNOLOGY SHIFT

4

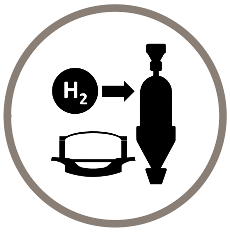
Fossil-Based Direct Reduction (DRI) with Electric Arc Furnaces (EAF)



Replacing the main carbon dioxide sources with a direct reduction process would have a significant impact, because such a shift would make the pellet plant, the coke plant and the blast furnaces redundant.

Powered by natural gas-based DRI, coal-based DRI, or syngas (a mixture of hydrogen and carbon oxide), carbon-dioxide emissions are estimated to decrease by 10-40% [24, 30].

Fossil-Free Direct Reduction (DRI) with Electric Arc Furnaces (EAF)



The largest impact would come from replacing all main carbon dioxide sources with the direct reduction process. In the traditional ironmaking process, fossil fuels and fossil raw material as coal and coke are used to remove the oxygen from the iron ore (iron oxide), resulting in the by-product carbon dioxide. Fossil-free direct reduction uses hydrogen produced with fossil-free electricity. Instead of carbon dioxide, the only by-product is water.

The process requires an EAF designed for continuous DRI feeding and for high metallization. For a traditional EAF made for steel scrap, the upper amount of DRI is limited due to the risk or DRI ice-bergs or "ferrobergs", restricting the productivity, in particular when using sponge iron rather than HBI [31]".

The technology development of using fossil-free direct reduced iron for fossil-free steelmaking started in 2016 and produced the world's first virtually fossil-free steel products in July 2021 [32].

A Note on Hydrogen

Several green steel initiatives employ hydrogen. To make iron, oxygen must be removed from the iron oxide of the ore. Traditionally, coal has been used as the reducing agent, which pairs with the oxygen to leave pure iron, creating carbon dioxide as a by-product. Using hydrogen instead produces only water [25].

However, all hydrogen does not have a low carbon footprint. Where there are limits to the accessibility to green energy, it is easier to use the existing supply of natural gas or coal [13], [35].

THE EU TAXONOMY

The EU Taxonomy Regulation is a classification tool to determine whether an economic activity is environmentally sustainable. It helps investors, companies and policy makers to make more informed decisions by identifying activities that are deemed to make substantial contributions to environmental objectives and thereby help to finance the transition to a more sustainable economy. By defining what is "green" or "sustainable", the EU Taxonomy creates a common language for sustainability that sets strict standards to prevent greenwashing. This is done by setting performance thresholds that help to identify environmentally friendly activities. Production of steel is included in the EU Taxonomy and large steel companies will report on their taxonomy alignment as of 2022. [27]

RECOMMENDATIONS

1

Do not make decisions based on the label ”green steel”

2

Make sure to investigate what is behind a statement of ”green steel”, including choice of report methods

3

Request scientific methods for CO_2 intensity reporting with clear describtion of the value-chain covered (e.g. cradle-to-gate, cradle-to-cradle, end-of-life approach and Scope numbers).

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