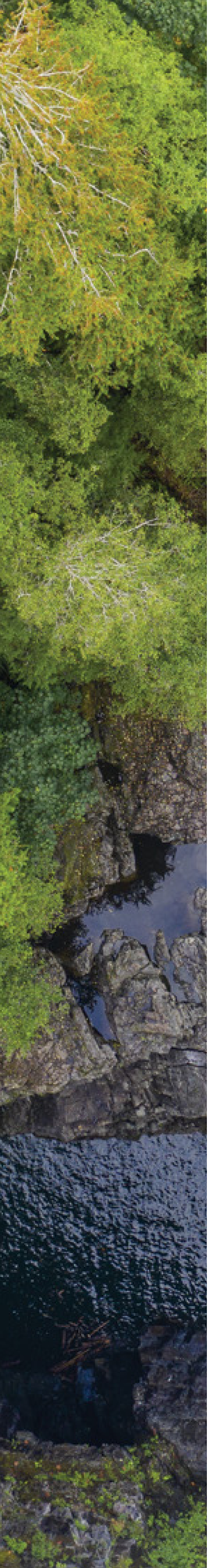
WHITE PAPER

What does the journey to fossil-free steel look like?

How to achieve a sustainable future



Foreword

Steelmaking is undergoing a historic transformation – and one that requires collaboration at all levels in the global steel supply chain to be successful. This report provides an in-depth analysis of why steel production needs to change, the pathways to fossil-free steel, and important contributions from steel producers and industry bodies about the technological innovation that is happening around the world.

While the journey to net zero won't turn green overnight, there is much inspiration to be taken from progress being made. It is our belief, as a key supplier and partner to the metals industry, that through collaboration, a sustainable steel future is achievable.

To support the industry of tomorrow, we are partnering with the world's foremost industrial players to innovate new solutions that will reduce emissions, reduce energy use, and optimize operations to achieve efficiencies, cost savings and productivity gains along the way.

I'd like to thank our partners for their ongoing collaboration, and for their contributions in this report. Together we can forge a fossil-free future with steel.

Sincerely,

Frederik Esterhuizen, Global Business Line Manager for Metals, ABB

This report is produced with special thanks to our industry-leading partners:

American Association for Iron and Steel Technology – AIST

Aperam

SSAB

Tata Steel

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Modern infrastructure requires modern solutions supported by sustainable steel.

Introduction

Steel is among the world's most valuable, in-demand and recycled materials. With its high strength to weight ratio, malleability, and cost-efficient production, steel is considered essential for public infrastructure such as buildings, bridges and railways as well as for the manufacture of vehicles and appliances.

Due to its long-lasting qualities, steel is seen as fundamental to a sustainable future. However, steelmaking itself must undergo a radical change to achieve a net zero carbon footprint and remain eligible as an environmentally-sound resource. The steel of the future must be green.

This report examines the industrial pathway to fossil-free steel, how green steel is defined, and what this means for the world. It provides an overview of the challenges steelmaking currently presents and an analysis of global trends around the production of green steel in key steel producing markets, including Sweden, the United States, India, Brazil, and China.

Importantly, this report includes specialist interviews with leading steel manufacturers SSAB, Tata Steel and Aperam, as well as experts from the American Association for Iron and Steel Technology and technology provider ABB.

Why does steel production have to change?

Current steel production is highly carbon and energy intensive. Globally, the steel industry is responsible for an estimated 8% of the world's energy demand and generates between 7% to 9% of CO_2 emissions – most of which are from burning coal[1,2].

To meet the criteria set out in the Paris Agreement on climate change and limit the global temperature increase to below 1.5 °C compared with pre-industrial levels, the steel industry must achieve a target of net zero emissions by 2050[3,4]. This will require radical transformation, especially in context of global steel demand which is projected to rise 30% by 2050[5].

The decarbonization challenge for steel is significant because carbon is such an integral part of its production. The problem is not a lack in available technological solutions, but the cost and complexity involved in transitioning to lower-carbon technologies. The steel sector is classified as one of the six 'hard to abate' sectors for this reason[6].

How steel is made

Understanding the steel decarbonization challenge requires an understanding of the methods in which steel is made. Steel can either be made from iron ore or recycled steel scrap, and these inputs determine whether it is categorized as primary steel (comprising mostly of iron ore) or secondary steel (comprising of scrap).

These categories also relate to the steelmaking method – the dominant method for primary steelmaking is via an integrated blast furnace-basic oxygen furnace (BF-BOF), whilst secondary steel production is carried out using an electric arc furnace (EAF).

According to the World Steel Association (WSA), 71% of steel is currently made using the BF-BOF process, with 29% produced by the EAF method[7].

The main difference between these methods is the raw materials expended in the process. The conventional BF-BOF method uses coal as a reductant, an energy source and a source of carbon to be used in the final product. Due to its consumption of coal, BF-BOF technology is the biggest contributor to emissions in steelmaking. In comparison, EAF production uses recycled steel and electricity and is one-eighth as energy-intensive as the BF-BOF method[8].

Key drivers of steel decarbonization

Besides adhering to the Paris Agreement, the impetus to decarbonize steel can be grouped into three key drivers: regulatory, commercial, and social.

1. Regulatory
Governments around the world are tightening regulation on greenhouse gas (GHG) emissions. In Europe, the European Climate Law has formalized the targets mapped out in the European Green Deal by writing them into the law – namely the transitional target of reducing GHG emissions by 55% in 2030[9]. Moreover, governmental trade arrangements will impact how standards are applied to the steel industry. An example is the agreement being negotiated between the EU and US on steel and aluminum where mutual tariffs will be applied to high-carbon "dirty steel" [10,11].

2. Commercial
As companies around the world decarbonize their operations to meet regulatory emissions requirements, the demand for fossil-free steel is increasing. For example, this trend has been documented among the world's major car makers as they seek to radically reduce their Scope 3 emissions[12].

3. Social
Public concern about the environment and climate change has risen around the globe[13]. Public sentiment around environmental responsibility is also impacting investor decisions and there is an increasing trend for sustainable investment. An example of this can be seen in the Institutional Investors Group on Climate Change (IIGCC), a cohort of 350 members representing over USD $55 trillion in assets[14]. IIGCC members are dedicated to sustainable financing and have several initiatives to support responsible investment, including a strategy and decarbonization action plan developed specifically for the steel industry[15].

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Steelmaking is undergoing a radical transformation to reduce global warming to 1.5 degrees. Credit: Aperam

Technology pathways to low carbon steel

To achieve the drastic emissions targets required, the steel industry must change its technological approach to steelmaking. It's important to note that there is no single solution, and a wide range of technological options are in development. The choice of technology will also largely depend on the producer's location and resources available.

Simplistically, there are three pathways in which **primary steel production** can decarbonize: through carbon capture, hydrogen, or electrochemistry.

Carbon capture and storage
Carbon capture and storage (CCS) encompasses technologies that capture carbon dioxide waste, and deposit it in a storage area where it cannot enter the atmosphere. This is considered an initial step towards decarbonization that can be used in conjunction with conventional BF-BOF steelmaking.

Direct reduction with hydrogen
This is where hydrogen substitutes carbon as a reductant, and the only waste is water instead of CO_2. The development of this technology route for steelmaking goes hand in hand with the ability to produce "green" hydrogen. Green hydrogen is made using electrolysis, powered by fossil-free electricity. If the hydrogen is produced via steam reforming of natural gas, the CCS process must be used to capture CO_2 emissions. This is referred to as "blue" hydrogen.

A route that many steelmakers are adopting is DRI-EAF. In this process, direct reduced iron, or DRI, can be melted in an electric arc furnace (EAF), and combined with available scrap to produce steel.

Electrochemistry
This is an electrolysis-based process that uses electric energy instead of conventional smelting to reduce iron ore.

What is green steel?

The term green steel has become widespread and is commonly used to describe steel that is manufactured with a smaller carbon footprint. However, there are differing opinions as to how green steel should be defined. Does it refer to zero-carbon or zero-emissions steel? Should the ‘green’ incorporate more factors than emissions alone? Is it explicitly fossil-free from the initial use of raw materials to how it is recycled from scrap?

It’s important to note that organizations such as the International Energy Agency (IEA) and World Steel Association (WSA) neither define nor refer to the term green steel in their formal documentation. Instead, the WSA defines low carbon steel in its climate change policy paper as “steel that is manufactured using technologies and practices that result in the emission of significantly lower CO_2 emissions than conventional production.”[19]

Steel that is manufactured using technologies and practices that result in the emission of significantly lower CO_2 emissions than conventional production.

– World Steel Association

Experts asked:
‘How do you define green steel?’

Ron Ashburn, Executive Director of the United States Association for Iron and Steel Technology:
“If asking, ‘How does the industry define green steel?’, a consensus on that has been elusive. Ultimately, whatever the definition becomes, it must be feasible, not aspirational, enforceable, and remain true to the spirit of the term: green steel is steel produced via processes that do not worsen the environment. The definition should set high standards – we should not adopt a definition that accommodates the lowest common denominator.”

Shiva Sander Tavallaey, Senior Principal Scientist, ABB Corporate Research Center:
“The ultimate goal is to produce steel that has a net zero carbon footprint from the mining of iron ore to steelmaking to consumption to recycling – that would be green steel. But first we must work on producing steel with a net zero carbon footprint.”

Thomas Hörnfeldt, Vice President, Sustainable Business, SSAB:
“We prefer to talk about fossil-free steel, that is steel made without fossil CO_2 emissions.”

Frederico Ayres Lima, CEO, Aperam South America:
“Although the term ‘green steel’ suggests above all the environmental impact of production, Aperam prefers to promote a responsibly-made steel and defines this by environmental, social and governance (ESG) responsibilities – these pillars must drive each step of the production process.”

Amit Kumar, Head of Corporate Sustainability, Tata Steel:
“Since steel has various roots of production and there are many intermediary steps to becoming carbon-neutral, how you define green steel is difficult. For Tata Steel, it’s about meeting the standard set by the ResponsibleSteel™ initiative and following steps to reach our target of carbon neutrality by 2045.”

Hurdles to overcome

The path to net zero will not turn green overnight, particularly in a hard-to-abate sector such as steel. The core challenges faced by the industry include:

Cost
Whether it's mitigating current emissions through retrofitting existing assets, replacing them, or the expense of using low-carbon resources, the cost implications of transitioning to green steelmaking will be significant. McKinsey projects that the upfront capital costs for decarbonizing steel production will be US $4.4 trillion, and that by 2030 the production costs for steel will be 30% more than what they are today[20].

Hydrogen not yet viable at scale
According to the IEA, green hydrogen will not be available at an industrial scale until after 2030 – currently less than 0.1% of global dedicated hydrogen production comes from water electrolysis[21]. In the interim, blue hydrogen options are being explored – blue hydrogen is produced from fossil fuels in a facility equipped with CCS – however, the main challenge will still be in producing hydrogen at scale to meet projected demands. Under IEA's Sustainable Development Scenario, global demand for hydrogen will increase to 287Mt by 2050, which represents an increase of over 400% from 2020[22].

Lack of clean electricity
Low-carbon electricity generation will need to escalate considerably to support electrolysis-based steelmaking at scale or support the increase in secondary steel making (the scrap-EAF route). While the IEA determined that power generation (such as wind or solar) needs to expand by over 12% every year until 2030 to get on track with its Net Zero Scenario in 2021, it did report significant growth in solar photovoltaic (PV) manufacturing capacity in 2023[23,24].

Limited high-grade iron ore
While direct reduced iron-electric arc furnace (DRI-EAF) technology is proven and in use today, it requires high-quality iron ore (DR-grade) which has an iron content of 67% and above. Currently, DR-grade iron comprises just 4% of the global iron ore supply[25]. Moreover, McKinsey data suggests that despite a momentous expansion of DRI production in the next decade, supply will fall considerably short of demand due to a raw materials crisis[26].

Scarcity of scrap
Current estimates suggest that around 85% of available scrap steel is recycled[27]. Even if this figure reaches 100% it already reveals that there is a limited amount of scrap in the short term. There is simply not enough scrap to meet demand today and it is unlikely to change by 2050.

Access to fossil-free carbon and lime
Carbon and lime are key ingredients in the recipe for steel. Carbon is an essential element in the composition of all steel, while quicklime is used as a flux for clearing out impurities such as slag in the melting process. Current lime production is carbon intensive, with CO_2 released during the production process from raw materials. There are no global estimates of CO_2 emissions due to lime but the estimates for Europe are 0.2-0.45 tons of CO_2 per ton of quicklime[28]. Having access to sustainable sources of both carbon and quicklime will require attention.

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Steelmakers are tasked with maintaining production of materials critical to modern life while simultaneously reducing their carbon footprint.

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Dr. Stefan Thorburn
Development Engineer,
ABB Corporate Research Center,
Sweden

Finding the path forward

Dr. Stefan Thorburn of ABB Corporate Research Center responds to the challenges above:

"While the transformation costs are significant it's encouraging to note that first suppliers have seen both a market demand and acceptance to pay higher prices for fossil-free steel. For example, steel manufacturing company H2 Green Steel has pre-sold over 1.5 million tons of its green steel product at premium price rates[29].

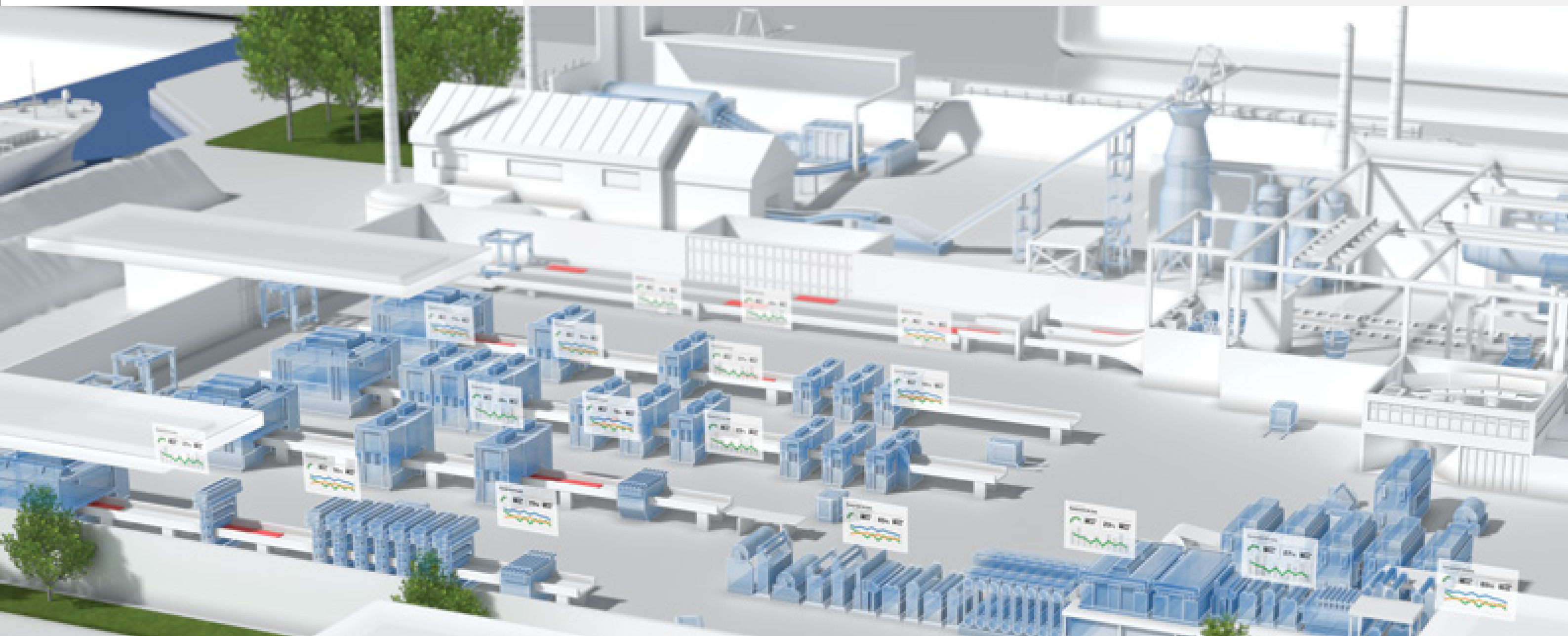
Hydrogen production must scale but there has been substantial technological advancement in this area – please see the next section in this report where we have highlighted what's happening in Sweden, the U.S., India, China and Brazil.

Likewise, we've seen record growth in the generation of CO_2 free electricity. As reported in the 2023 Global Electricity Review, wind and solar energy now comprise 12% of the world's electricity generation[30]. We just need to keep up the momentum.

In terms of the challenge regarding a lack of high grade iron ore – this is true for the present technology platform. However, the Institute for Energy Economics and Financial Analysis (IEEFA) reports that various steel stakeholders are exploring pathways with lower grade iron[31].

And regarding scrap, it is understood that more mining is required for the energy transition, and that the availability of scrap will increase in tandem with that growth.

We've also seen encouraging collaboration in the development of fossil-free carbon and lime, for example the zero carbon quicklime partnership, ZEQL[32]."



Strategies and actions around the world

The transformational change required of the global steel industry can be intimidating. Yet initiatives from around the world show that the industry is committed to a green and sustainable future, with several promising developments in the works. This report focuses on five steel producing markets in the following sections – Sweden, United States, India, China and Brazil – with a spotlight on fossil-free steel innovation.

Market Focus: Sweden

Sweden - a frontrunner in the fossil-free steel journey

Sweden's steel production comprises a modest portion of the global market: only 0.03%, as estimated by the Swedish steel association, Jernkontoret[33]. Yet the country is recognized as a frontrunner on the journey to green steel – a position that will become increasingly advantageous in the decades to come.

In August 2021, Swedish company SSAB delivered the first shipment of fossil-free steel to the transportation, mobility and construction equipment provider Volvo Group, demonstrating to the world that making fossil-free steel is indeed achievable[34]. This steel was the product of a collaboration between the steelmaker (SSAB), state-owned iron ore miner LKAB, and state-owned energy company Vattenfall, under the HYBRIT initiative.

Fossil-free steel under HYBRIT project

HYBRIT stands for Hydrogen Breakthrough Ironmaking Technology and in 2016 the trio started a pilot project to make steel using green hydrogen and fossil-free electricity instead of coking coal derived from high grade iron ore supplied by LKAB mines. This initial objective was realized in 2021 – in fact, fossil-free steel ingots were passed around at the COP26 conference to showcase the project's success[35] – and SSAB will begin industrial scale production of fossil-free steel in 2026.

Additionally, the company has set an aggressive decarbonization target for its own operations – one that is several years earlier than the Swedish requirement of 2045.

"SSAB plans to be a largely fossil-free steel company around 2030 through an extensive investment program of about 50 billion SEK (US $4.65 billion)," explains Thomas Hörnfeldt, Vice President, Sustainable Business, SSAB. "And we see two drivers for this change. Firstly, this is a business decision – customers are asking for fossil-free steel, and we need to meet that increasing demand. Secondly, we have to get rid of our CO_2 emissions."

SSAB's vision

The company's vision for a stronger, lighter, and more sustainable world has involved a strategy that divests any technology that emits carbon dioxide in favor of greener methods.

"This means investing in new, green technology and plants, and letting existing blast furnaces become stranded assets," says Hörnfeldt. "The other prerequisite is access to sufficient amounts of fossil-free electricity and efficient permit processes. We are working closely with local and national authorities to address these issues."

Another green steel Swedish venture is that of H2 Green Steel, which is on track to start large scale production of green steel in 2025. Essential to its strategy is having a fully integrated, digitalized and automated greenfield fossil-free plant and sustainable hydrogen facility[36].

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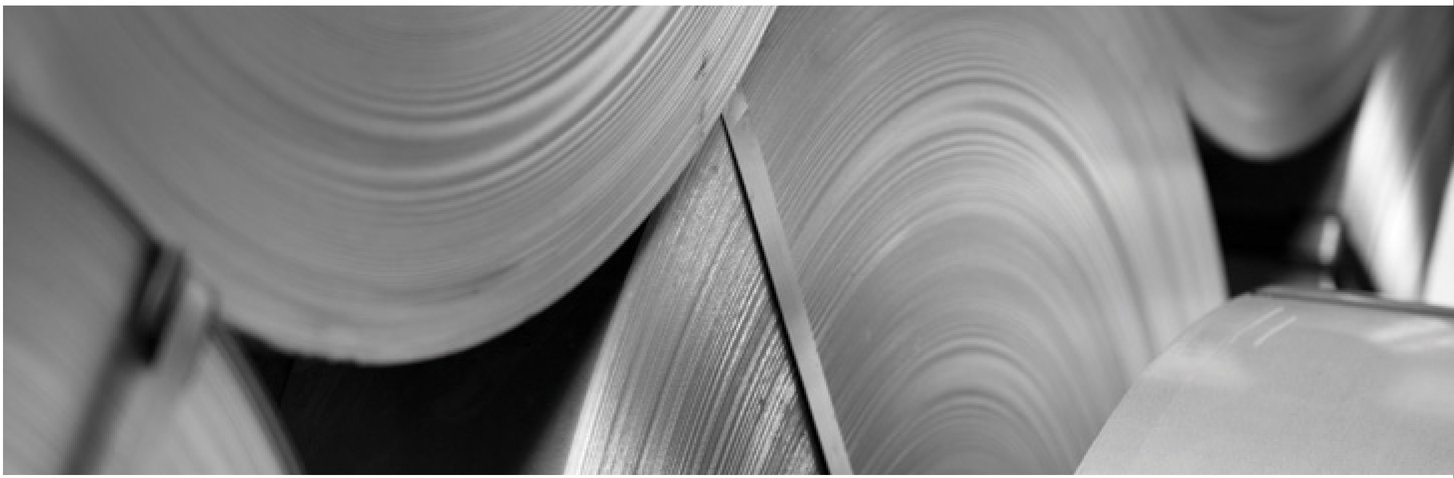
SSAB's commitment: Pioneering the transition to fossil-free steel. Credit: SSAB

Market Focus: U.S.

Clean energy progressing green steel in U.S.



The United States ranks as the fourth largest steel producer in the world, comprising 5% of the global market[37]. From a domestic perspective, the value of the steel industry is substantial, accounting for $US 520 billion in economic output[38].

According to the American Iron and Steel Institute (AIST), U.S. steel is "the most energy efficient of the leading steel industries" in the world, with over 70% of steel produced in the U.S. made from recycled scrap in EAFs. Almost all U.S. steel is made from domestic iron pellets and natural gas has increasingly replaced coal as an energy source, reducing the total energy use by 34% between 1998 and 2018[39].

Inflation Reduction Act to drive energy transition and decarbonization
Importantly, the Inflation Reduction Act of 2022 – which came into effect in early 2023 – is seen as the most significant climate legislation in U.S. history[40]. Provisions in the Act comprise of a series of incentives, programs and funding to U.S. iron and steelmakers that will accelerate the transition to a clean energy economy and drive decarbonization in the hard-to-abate sector. It is reported that U.S. industry will soon have access to the cheapest green hydrogen in the world[41].

While there are a number of decarbonization strategies in progress, one currently being deployed by the country's largest flat-rolled steelmaker, Cleveland-Cliffs, involves using DRI and hot briquetted iron (HBI) in integrated and EAF steelmaking[42].

Boston Metals and Molten Oxide Electrolysis technology
Meanwhile, Boston Metal has developed an electrolysis process – Molten Oxide Electrolysis (MOE) technology – which removes carbon from the steelmaking equation. Instead, MOE uses renewable electricity and iron ore to produce liquid steel, eliminating CO_2 emissions altogether. The company states that MOE is the most direct, scalable solution to making green steel[43].

Executive Director of the AIST, Ron Ashburn, says that while the biggest challenge to making green steel is the availability of clean energy, he's optimistic about the future in the context of progress being made.

"The technology exists to make fossil-free steel, but we're missing the baseload green energy in terms of availability and affordability. That situation is improving, certainly, but the pace of the transition has been slower than it needs to be. Governments around the world are now working to catalyze manufacturing's adoption of green energy," he says. "There are numerous examples of public and private collaborations where steel producers are partnering with renewable energy suppliers on projects to support their production. There is significant innovation underway… which bodes well for the future of steel."

Market Focus: India

India's green steel vision

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Tata Steel is committed to achieving carbon neutrality by 2045. Credit: Tata Steel

As the second largest steel producer in the world – India produced 118.1 million tons of crude steel in 2021 – the role that the industry plays in India's economy is significant, accounting for 2% of its total GDP[44].

Due to its heavy reliance on coal-based direct reduction (DR), and the presence of both dated and relatively inefficient blast furnace units, the Indian steel sector is rather energy intensive compared to international benchmarks. Currently, the emissions from this sector account for 10% of the country's total. Yet as India's economy and population grows so will its domestic consumption of steel – emissions from the steel sector are projected to increase threefold by 2050[45].

India's roadmap to steel decarbonization
In 2022, India's The Energy and Research Institute (TERI) and Energy Transitions Commission (ETC) published a roadmap for achieving green steel in the country, outlining the steps required to reach net zero by 2070 (the Government's economy-wide target), as well as a more ambitious scenario of achieving 'Atmanirbhar Bharat' (self-reliance) by 2047, putting India on track for net zero by 2050[46].

In both roadmap scenarios, it is acknowledged that the primary route to replace the blast furnace will be hydrogen direct reduction, which can be scaled from the 2030s. Likewise, the roadmap predicts MOE plants will be deployed but not until the 2040s. While the document notes scrap-based EAFs will play an "ever-increasing role" it argues that growth is limited by the availability of scrap. In the interim, it says the following actions are required: a fast phase out of all coal-based DR facilities, an energy transition to natural gas, and the use of carbon capture, utilization, and storage (CCUS).

A technology developed by Tata Steel, called the HIsarna process, is a promising transition route that can reduce emissions by up to 20% compared with the traditional BF-BOF method. Instead of using processed ores such as coke, sinter or pellets to make liquid pig iron, the HIsarna installation uses a powdered form of the raw ore material to convert to liquid pig iron, and then make steel. If combined with CCUS, this route can reduce emissions by 80%. Tata Steel have been trialling the technology at a test plant in The Netherlands since 2011, with a plan to build a second facility in India and bring HIsarna to industrial scale production by 2030[47].

Tata Steel committed to sustainability
Amit Kumar, Head of Corporate Sustainability at Tata Steel says that while the company is committed to developing new technologies that replace carbon in the steelmaking process, there are other challenges to contend with – namely, the cost of converting the assets, and the availability of space in India for CCUS.

"We are talking about converting highly capital-intensive assets that have a lifespan of about 30 to 40 years. Retiring these blast furnaces, funding new facilities and retrofitting assets will be a big challenge for us as we wait for green hydrogen to become readily available," he says. "In terms of carbon capture, though the technology exists, where to sequester or store the captured carbon is a challenge – in India we don't have much in the way of oil fields or dry oil wells where we can put carbon. Similarly, there is currently a limited market for utilizing the captured carbon."

Despite the challenges, Kumar is optimistic about Tata Steel's trajectory to meet carbon neutrality by 2045. The company is a member of ResponsibleSteel™ and has committed to investing in several initiatives to reach its net zero target. One mentionable project is a recent hydrogen injection trial that has shown encouraging results[48].

"This is where we are injecting hydrogen gas at the blast furnace of our flagship plant in Jamshedpur to reduce coal usage," he says. "It is the first time in the world that such a large quantity of hydrogen gas is being continuously injected in a blast furnace, and it has the potential to see a reduction of 10% CO_2 emissions per ton of crude steel produced."

Positive developments in Chinese green steelmaking

As both the world's largest steel producer and carbon emitter – accounting for one-third of global CO_2 emissions – China's pledge to achieving carbon neutrality is arguably the most significant in terms of curtailing global warming[49]. In 2021, President Xi Jinping announced its net zero targets and highlighted the need to accelerate the transition to a green and low-carbon economy.

"China will strive to peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060," he told the UN General Assembly, adding that China would not build any new coal-fired power projects abroad[50].

Outlook is positive

According to Chen Ran, General Manager and Chief Analyst of the gongkong (www.gongkong.com) Market Research and Consulting Business, the outlook for green steel production in China is positive.

"The future of green steel plants in China is bright," he says. "At present, the domestic construction of green steel plants primarily focuses on tackling pollutant discharge mitigation and solid waste treatment; however, in terms of the optimization of energy utilization, production management, assets management and other areas there is still room for improvement."

Chen points out that as there are numerous metallurgical enterprises in China, there is diverse range in the enterprise scale and management methods.

"Therefore, the construction of green steel plants should be catered to local conditions, time scales, long-term planning, and begin by resolving basic issues before advancing gradually step-by-step."

Moreover, Chen says digitalization plays a crucial role in the green steel developmental pathway.

"On top of meeting environmental standards, it is even more important to swiftly set up the digitization of each link and utilize digital tools to accumulate internal enterprise data, before finally targeting the issues and gradually resolving them," he advises. "Putting environmental protection first, following up with good management practices, and achieving energy optimization and increased efficiency could be one of the primary developmental paths for future green steel plants."

Baowu Steel Group to complete its first zero carbon electric arc furnace by 2024

Meanwhile, there has been some notable investment and development on the green hydrogen-based EAF technology front amongst China's larger steel players. An example of this can be seen with the construction of a hydrogen-fueled EAF in Guangdong province by the world's largest steelmaker, Baowu Steel Group. It is scheduled for completion by the end of 2023 and will be Baowu's first zero-carbon EAF[51].

Likewise, China's HBIS Xuansteel started its world-first 'Hydrogen Energy Development and Application Pilot Project', which will use wind and solar power to produce hydrogen. The project will employ new hydrogen reduction technologies, including Tenova Energiron-ZR technology, to replace traditional blast furnace hot metal methods[52].

Market Focus: Brazil

Brazil in 'advantageous position' for producing sustainable steel

Brazil is the ninth-largest steel producing country globally and the largest in Latin America, with its iron and steelmaking industry also accounting for most of the country's industrial CO_2 emissions[53].

Significantly, Brazil is the second largest exporter of iron ore, with its Government reporting that Brazilian iron ore is of a better quality than its global counterparts, with an iron content of approximately 60%[54].

Brazil's road to decarbonization

A scoping report produced by the E+ Energy Transition body (formed by Brazil's Institute of Climate and Society) says that Brazil will be looking to harness its expertise in charcoal and biomass production processes, natural gas reserves and renewable electricity production in the road to decarbonization[55].

"Regarding the technologies, replacing coal with natural gas in DRI can act as a bridge to hydrogen use. On the other hand, greenhouse gas mitigation policies have been focused on the use of charcoal in blast furnaces," it states. "In general, clean electricity generation, abundant iron ore and biomass reserves, potential for natural gas supply and low-cost green hydrogen put Brazil in an advantageous position."

One of the country's major steelmakers, Aperam, has adopted a three-pronged strategy to decarbonization. The CEO for Aperam South America, Frederico Ayres Lima, explains that this comprises a scrap-EAF component, a low-carbon energy mix and the use of charcoal instead of coal-based coke in blast furnaces.

Aperam's unique use of charcoal

"The use of charcoal is really unique in our sector, because Aperam can also be considered an agricultural company, operating over 100,000 hectares of FSC®-certified forests in Brazil. We use our forests to produce our own charcoal, which we then use as input in our steelmaking process as a natural and renewable substitute for fossil fuels (coal-based coke)," he says. "Unlike many of our global competitors, this allows us to entirely eradicate the use of extractive coke in our blast furnaces and makes our steel more sustainable."

While Lima says the company recognizes the overarching challenges to making sustainable steel, he says there is also a great business opportunity.

"That is why Aperam was the very first stainless-steel company to join the newly established ResponsibleSteel association in 2019. The backbone of our sustainability strategy is the ResponsibleSteel certification. Most of Aperam's major production sites are already certified. For us, it means improving the responsible production of steel in order to adhere to all the environmental, social and governance principles set out in the standard."

Powerful, integrated solutions are key to phasing out fossil fuels – ABB's distributed control system 800xA is a digital platform for automated control and operation of plants and processes.

Addressing the challenges to sustainable steel

In line with the multiple innovations occurring in key markets, there is an acknowledgment that collaboration is essential on the journey to green steel. To achieve carbon neutrality, there must be coordination between stakeholders at all levels in the global steel supply chain – private and public – to address the core challenges.

The pathway to sustainable steel will require a significant reduction in waste and emissions, a better utilization of resources, major improvements in energy efficiency, and the widespread adoption of cleaner iron and steel production technology.

Digitalization a key enabler
To address core challenges and phase out fossil fuels, the steel industry will need powerful, integrated solutions.

According to Shiva Sander Tavallaey, Senior Principal Scientist at ABB Corporate Research Center, the journey to green steel is not possible without digitalization.

"Digitalization is not only intrinsic to collaboration between entities but to optimizing the use of resources and energy management, and in providing the traceability required to keep organizations accountable to emissions targets," she says. "To succeed, data that flows from equipment, processes, and systems must be integrated. You cannot achieve sustainability without the connectivity and integration that digitalization provides."

Sander Tavallaey's opinion is not singular. In fact, she points to an ABB-led international survey of 765 business and technology decision-makers that reveals 96% consider digitalization "essential to sustainability". The same study highlights the role of Industrial IoT solutions to realizing sustainability aims[56].

Benefits seen with JSW Steel and ArcelorMittal Construction
On the positive side, the benefits that come with digitalization – such as increasing the uptime of equipment, improving productivity and the capacity to develop autonomous operations, can translate to considerable cost savings.

An example of the positive possibilities that can be realized through digital integration can be seen in ABB's development of a smart factory solution for Indian steelmaker, JSW Steel.

The ABB Ability™ Smart Melt Shop digital solution connects several process steps, and with real-time data from the furnace via ladle and tap systems to continuous casting, the company can better predict and optimize thermal losses at its Dolvi Works. JSW Steel expects to see a profit of approximately $2 million per year through higher casting speeds, time savings and additional production. The lower energy consumption also means fewer consumables and a lower carbon footprint[57].

Another example of where digital solutions can translate to both economic and sustainability benefits can be seen in the modernization of the ArcelorMittal Construction steel mill in Contrisson, France. ABB will install its ABB Ability™ Manufacturing Operations Management system (MOM4Metals) in addition to Roll-Gap Control (RGC) and Automatic Gauge Control (AGC) technology to improve productivity, quality and performance.

Frédéric Geoffroy, who leads the process and automation department at ArcelorMittal Construction, said the combined MOM4Metals, RGC/AGC automation solution "allows us to offer our customers innovative solutions based on decarbonized and sustainable steel" [58].

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Acciaieria Arvedi in Italy produce high-quality steel with the highest output from a single electric arc furnance using ABB and Tenova's innovative technology package. Credit: Tenova

Partnering to forge a fossil-free steel future

Frederik Esterhuizen, Global Business Line Manager for Metals at ABB, says a digital, autonomous and fossil-free steel industry is possible through partnership.

"ABB is taking an approach of partnership and collaboration to integrate innovative technology with ABB's existing portfolio for the steel industry," he says. "For example, ABB and Tata Steel has signed a Memorandum of Understanding (MoU), to co-create innovative models and technologies that will reduce the carbon footprint of steel production".

Energy optimization is at the heart of the partnership project with Tata Steel, starting with integrated electrification initiatives managed by digital systems such as ABB Ability™ solutions, and progressing to the substitution of hydrogen in upstream processes[59].

Boliden partnership demonstrates circular economy in action

Another collaboration that illustrates how organizations can work together towards a sustainable future in steel is that of ABB and Swedish mining and smelting company, Boliden. In the strategic cooperation, Boliden will supply ABB with low-carbon copper that will be used to make electromagnetic stirring (EMS) equipment and high-efficiency motors.

The partnership is a prime example of the circular economy in practice. By using Boliden's copper, ABB can reduce its environmental footprint and the scope 3 emissions of steel manufacturers using ABB's EMS products. Similarly, ABB can install more energy efficient motors at Boliden – also made with Boliden low-carbon, recycled copper – to assist in the mining operation's decarbonization[60].

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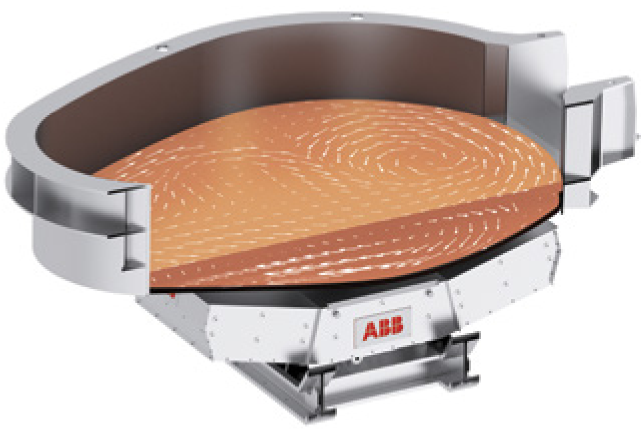
ABB and Tenova collaborate on world's most productive electric arc furnace

ABB has collaborated with metals industry supplier Tenova to deliver an innovative charging, melting and electromagnetic stirring solution for electric arc furnace (EAF) operation. Tenova's Consteel® EAF continuous scrap charging system is complemented by Consteerrer®, an electromagnetic stirring technology jointly developed by ABB and Tenova, based on ABB's proven and patented ArcSave®. Operation of the world's most productive EAF at Acciaieria Arvedi, Italy has already been optimized using this technology package resulting in 5% higher productivity, 3.6% lower energy consumption and increased scrap yield[61].



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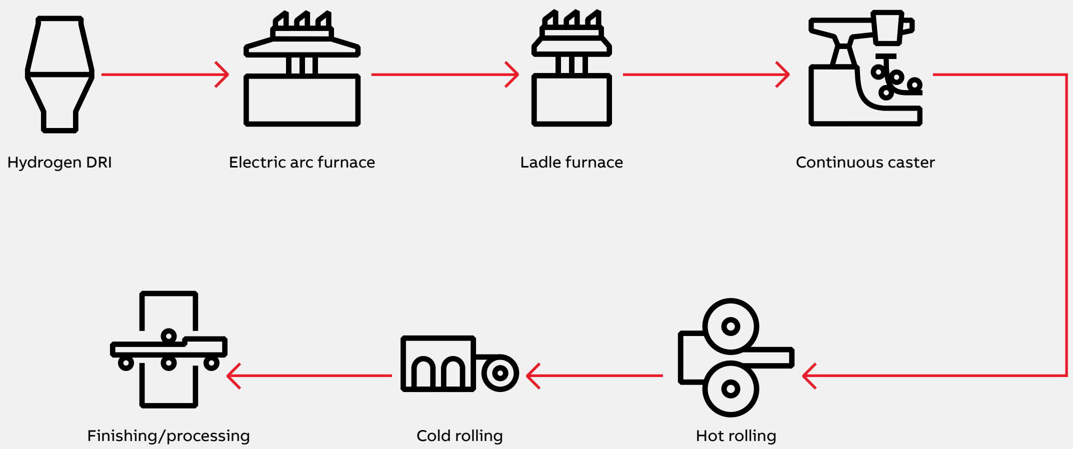
By generating a travelling magnetic field that penetrates the furnace bottom and refractory, ABB ArcSave lowers total energy consumption in electric arc furnaces.

The direct reduced iron-electric arc furnace (DRI-EAF) route in action

Reports show that by using green hydrogen in electric arc furnaces (EAF) instead of coal in traditional steelmaking with a blast furnace, CO_2 emissions can be reduced by up to 95 percent. As illustrated in some earlier examples, there have been developments in various countries around the world on this method. A recent partnership worth highlighting is that of Rio Tinto and H2 Green Steel. Rio Tinto will supply high grade direct reduction iron ore pellets to H2 Green Steel who will make steel through an EAF using green hydrogen[62].

Example of a DRI-EAF steel production process



What can steel producers do now?

This report has provided information as to why steel manufacturers, industry suppliers and partners need to work together towards a fossil-free steel future. The question is, what are some actions steel manufacturers can take now?

1. Formulate a strategic digitalization and decarbonization roadmap ahead of the hydrogen energy transition.

2. Invest in technology solutions that reduce energy consumption, costs and waste in the present, and enable flexible use of available raw materials and scrap in the future. Recommendations include implementing automation, metallurgical and digital solutions that maximize efficiency in resource-intensive iron and steelmaking processes. Leveraging available technologies for precise process monitoring and control in rolling mills and processing lines will enable production of the desired steel grades and reduce avoidable material rejects. Plantwide electrification including upgrading to energy efficient motors and drives, and data-driven energy management, will play a key role in reducing carbon footprints in the short to medium term.

3. Ensure flexibility with energy management. Energy prices will continue to fluctuate. Steel producers that are more agile about when they are using electricity, and how they make use of any surplus renewables, will have a competitive advantage.

4. Prepare your workforce – ready your people for the impending changes to your business model and processes, start upskilling and hiring digitally-literate talent.

ABB’s sustainability strategy 2030

With its 2030 sustainability strategy supporting the achievement of the United Nation’s Sustainable Development Goals, ABB has outlined its active commitment to enabling a low carbon society, preserving resources and promoting social progress. This strategy is underpinned by a commitment to integrity and transparency, with the ABB code of conduct forming the foundation of how the company’s people work in a sustainable way[63].

CO_2

Reducing emissions for a low carbon society
- ABB has committed to achieving carbon neutrality across its own operations.
- ABB is committed to working with impactful suppliers to achieve a 50% reduction in their emissions.

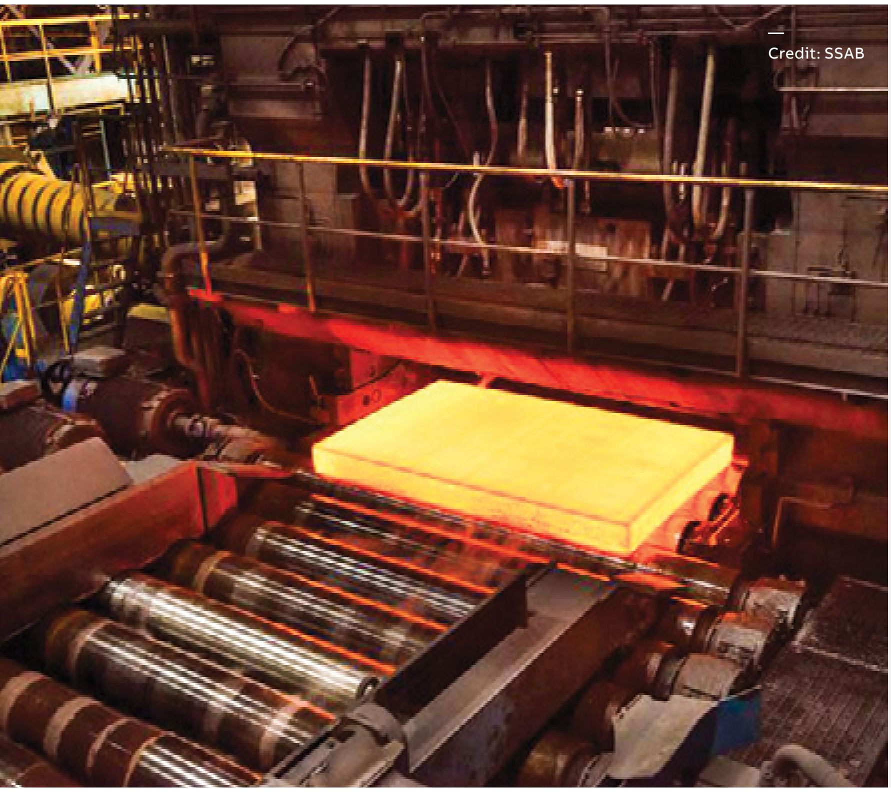
Circularity approach to preserve resources
- At least 80% of ABB products and solutions will be covered by the circularity approach.
- ABB commits to zero waste from its own operations.

Improving safety, achieving zero harm
- ABB’s goal is to achieve zero harm to its people and contractors with the aim of a year on year reduction in lost time due to incidents.

Driving social progress
- Doubling the number of women in senior management.
- Achieving top-tier employee engagement score.

Conclusion

Green steel is indispensable to a sustainable future. However, the global steel industry must contend with significant challenges to decarbonize its processes and switch to fossil-free technology. While there are several initiatives occurring around the world, the industry must collaborate at every level of the global steel supply chain in order to succeed. Yet through innovation and partnership, a green steel future is an achievable reality.



Credit: SSAB

ABB – one solid partner and enabler

ABB is a trusted partner and leading supplier for the sustainable transformation of the steel industry, delivering a broad portfolio of integrated electrification, automation, metallurgical and digital solutions. Its extensive global footprint serves the complete steel, aluminum and other metals value chain.

Drawing on over 100 years of experience, ABB collaborates with metals producers, original equipment manufacturers (OEMs) and other suppliers to develop process specific and customized solutions that optimize production, improve quality and safety – while driving the transition to autonomous plants and a more circular economy.

Contact an ABB in metals expert

Glossary

Abbreviations

BF-BOF	Blast Furnace-Basic Oxygen Furnace	**EAF**	Electric Arc Furnace
CCS	Carbon Capture and Storage	**GHG**	Greenhouse Gas
CCUS	Carbon Capture, Utilization and Storage	**HBI**	Hot Briquetted Iron
CO_2	Carbon Dioxide	**HYBRIT**	Hydrogen Breakthrough Ironmaking Technology
DR	Direct Reduction	**IEA**	International Energy Agency
DRI	Direct Reduced Iron	**MOE**	Molten Oxide Electrolysis
DRI-EAF	Direct Reduced Iron-Electric Arc Furnace	**WSA**	World Steel Association

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