Decarbonising Steel: Market Primer

January 2025

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Executive Summary

Given that direct CO_2 emissions from steel production represent a substantial portion of all GHG emissions, there has been considerable attention from both steel market participants and policymakers on strategies for decarbonising the entire steel value chain. This report provides an in-depth analysis of the current state and future prospects of the low-carbon steel market.

In particular, the report highlights the concept of green premiums, which are the additional costs companies pay for low-carbon steel. These premiums are expected to increase as we approach global emissions targets for 2030 and 2050.

The report also discusses various low carbon-steel technologies and regulatory drivers that are shaping the market, as well as the development of low carbon steel standards and the role of clean hydrogen in steel production. In particular, the report looks at the role of the European Union's Green Deal and the Carbon Border Adjustment Mechanism (CBAM) in decarbonising steel as well as similar initiatives in the United Kingdom, the United States, and Australia, highlighting the global effort to transition to low-carbon steel production.

While the low-carbon steel market has a long way to go, it is developing rapidly creating both challenges and opportunities across the entire steel supply chain. The transition to greener steel production methods will require substantial investment and collaboration between various stakeholders, including steel producers, upstream mining companies, investors, and governments.

Ultimately, the evolution toward green steel underscores the commitment to a more sustainable future, but it is only through targeted government incentives and policies that the economic barriers to green steel can be overcome, aligning economic viability with environmental responsibility.

Introduction

As direct CO2 emissions from steel production represent a substantial portion of all CO2 emissions, it is not surprising that there has been considerable attention from both steel market participants and policymakers on strategies for decarbonising the entire steel value chain.

This global challenge requires substantial investment with steel producers, upstream mining companies, investors and governments playing crucial roles. Although the low carbon steel market has a long way to go, it is developing rapidly. This report provides a snapshot of where the market currently is and how it may develop further, including a primer on green premiums, an overview of key technologies and regulatory and other drivers.

What Creates a Premium?

The concept of a premium in commodities and metals arises from various factors, including scarcity, quality differentiation, and market demand. In essence, a premium is an additional cost that consumers are willing to pay over the base price for perceived added value. This added value can be driven by various elements such as improved environmental attributes, higher performance standards, or compliance with regulatory frameworks.

Green Premiums

The green premium is the additional cost companies pay for low-carbon steel, expected to increase as we approach global emissions targets for 2030 and 2050. As steelmaking shifts to electric arc furnace (EAF) technology and uses hot briquetted iron (HBI), a greener approach, premiums are estimated to rise significantly.

The cost of green premiums varies based on the carbon output of products and the cost differential between production methods. One example could be that hydrogen-based steel may incur different premiums compared to natural gas-based steel due to the greater carbon reduction of hydrogen-based methods. Regardless, both receive a green premium over conventional carbon steel.

Hydrogen-based steel further distinguishes between grey, blue and green hydrogen. Green hydrogen, produced exclusively from renewable sources like wind or solar through electrolysis, represents the cleanest option. Grey hydrogen results from natural gas steam reforming, while blue hydrogen involves carbon capture and storage during this process.

Among HBI, prime scrap and scrap, HBI offers the highest product quality, followed by prime scrap and then scrap. Prime scrap refers to clean, unused steel scrap typically sourced from post-consumer or post-industrial processes, and is of high quality with minimal impurities. In contrast, scrap generally includes a broader range of steel scrap, often including older, used materials with more contaminants and impurities. While scrap has very low carbon emissions, using it alone leads to poor-quality output that significantly limits its uses. Companies are thus willing to pay more for high-quality products from HBI, reducing carbon emissions compared to other methods and driving demand growth for HBI.

The cost of green premiums also reflects the cost differential between steel production methods such as EAF using HBI or scrap, compared to blast furnace (BF) - basic oxygen furnace (BOFs) using coke and iron ore. Despite their lower emissions, EAFs are known to require substantially more electricity for steel production than BOFs. Therefore, fluctuations in raw materials and energy prices have a direct impact on the production costs of EAF-based steel.

These considerations of emissions and production costs underscore the complex financial decisions faced by steel manufacturers aiming to reduce their carbon footprint while managing operational expenses. Therefore, to incentivise the production of these cleaner products, green premiums must come into play.

Green Steel

As elaborated later in this report, there is no universally applicable standard for green or low-carbon steel. For the purposes of this report, AME is defining 'Green Steel' as comparatively low carbon steel production, considered as production with a carbon intensity <0.5 tonnes of CO_2 per tonne of HRC in Scope 1 and 2 emissions. This narrows Green Steel to renewable powered EAF's processing approximately 100% scrap. Other potential process routes include direct reduced iron (DRI) to EAF — if DRI production is not fossil fuel-powered — and a substituted metallurgical coal blast furnace (e.g. use of hydrogen).

Through the energy transition, AME expects an increasing proportion of new EAF capacity to be 'green' or, at least, lower-carbon steel.

- Not all EAF steel will qualify as 'green'. EAF production can only be 'green' through the use of renewable power and processing of almost 100% scrap.
- Increasing prevalence of EAF developments for enabling the use of DRI to produce a comparatively low-carbon steel. Use of fossil fuels in DRI process still prevents achieving Green Steel under AME's <0.5tCO_2/t condition.
- Some producers are feeding EAFs with hot metal from blast furnaces—allowing improved product flexibility—this is not 'Green Steel' as metallurgical coal remains the reducing agent.
- Scrap availability is the primary limitation to increased availability of Green Steel.

AME's key assumptions related to BF relines and steel production through the energy transition are as follows:

- Typical BF campaign life of 20 years.
- Where furnace capacity is less than 2.5Mt it is expected to be switched to a DRI/EAF configuration.
- For furnaces with a capacity of 3.0 to 4.0 Mt, there is a 50% chance of conversion to DRI/EAF.
- For 4.0Mt furnaces or a furnace capacity greater than 4,500m3 assume a reline (+20 years plant life) and use of carbon capture.
- Very large BFs will survive. China will continue to consolidate, closing inefficient small BFs and replacing with large capacity furnaces.
- 2.5–3.0Mt is essentially the switching point, i.e. conversion to DRI/EAF. Any larger and the complexity is increased as one BF is being replaced with multiple units (ArcelorMittal's current strategy).
- The industry will replace small sites with DRI; big sites have the little BFs replaced but keep the very large BFs; BOFs will be replaced with hybrid EAFs that can take combinations of hot metal, DRI or scrap allowing maximum flexibility to market conditions.
- Use of EAFs in place of BOFs will allow steelmakers to tailor the melt to the quality of the end products — higher scrap proportions used for lower quality products and higher hot metal/DRI for premium products.

Technology

Steelmaking is the second step after iron making and involves the refining of the products from the iron making stage into liquid steel. This process can be accomplished in a BOF or an EAF.

The BOF process injects gaseous oxygen into the furnace as the primary agent for auto-thermic generation of heat. This results in the oxidation of dissolved elements like carbon, silicon, manganese and phosphorus — and to a limited extent, the oxidation of the iron. To produce steel through BOF, the proportion of pig iron as part of the feed is typically over 70%, with scrap accounting for the remainder of the feed.

EAF, on the other hand, is generally included in the basic design of a typical mini-mill plant for melting scrap or for taking sponge iron from a DRI plant. The main advantage of the arc furnace lies in its flexibility in accepting charge materials in any proportion, namely scrap, molten iron, pre-reduced material and pellets. It is possible to have precise control of the refining reactions because the electric power can be carefully controlled to impart heat to the bath at different desired rates. The EAF produces molten steel, which is used for high-grade alloy steel-cutting tools, die steels, and stainless steel, where the metal must be refined and melted under rigidly controlled conditions to minimise the introduction of impurities.

In order to counteract some stricter pollutant emissions and energy uses, several steelmaking technologies have been developed around the world. Some of the most advanced technologies include MIDREX, FINEX, COREX, Hybrid, and hydrogen-injection blast furnace production.

Hydrogen-based steelmaking technology has been attracting a lot of investment and government support in an attempt to achieve 'zero-emission' steel production. However, most of this technology is still in the early stages of development with no planned date for commercial production. A major issue with this technology is that it is focused on reducing emissions and does not consider economics. Thus, AME anticipates that economics and scalability will be the major issues when it comes to commercialising the plant, and it will be difficult to replace reliable and cost-effective metallurgical coal in the short to medium term. Like hydrogen, all these technologies are in relatively early stages of development with no large-scale or commercial plants operating at this stage to compete with blast furnaces.

MIDREX

MIDREX has recently become the favoured alternative innovative ironmaking process. It specifically reduces iron from iron ore using natural gas (or hydrogen) to produce DRI. The MIDREX NG Process uses natural gas in a MIDREX reformer to produce reducing gases which are in turn used for iron ore reductions in the shaft furnace. This reducing gas reduces the raw material, such as iron pellets or lumps, to iron metal (the DRI). Cooling gas then cools the DRI to roughly 50ºC.

Hydrogen–Hybrid

In 2016, SSAB, LKAB and Vattenfall joined forces to create HYBRIT, a steel-making technology that aims to use hydrogen to replace coking coal, traditionally needed for ore-based steelmaking. HYBRIT aims to become the world's first fossil-free steel-making technology, with virtually no carbon footprint. Based on the feasibility study conducted in 2017, operational costs are expected to be 20% to 30% higher than conventional blast furnaces. The programme commenced in 2016, with the demo plant commissioned in 2022 and planned to run until 2024, although there is no planned date for commercial production.

FINEX

The closest competitor to blast furnace technology, which has the potential to revolutionise the industry in the short term, is likely to be FINEX. FINEX is a combination of two technologies, the Finmet multiple fluidised bed process and the COREX melter-gasifier. The FINEX process has been in development by POSCO and Siemens VAI since 1992, the technology has progressed from a 1.5tpd lab-scale research unit to a 2Mtpa commercial-scale plant which has been in operation at the Pohang Steelworks in South Korea since January 2014.

Hydrogen-Injection

Thyssenkrupp has recently successfully achieved the injection of hydrogen into an operating blast furnace through the pulverised coal injection (PCI) system, with hydrogen replacing some of the PCI required. However, the current high cost of hydrogen does not make this process economical, and as such, coke is still required for use in blast furnaces.

COREX

With COREX, all metallurgical work is carried out in two separate process reactors — the reduction shaft and the melter gasifier. Iron ore (lump ore, pellets or a mixture thereof) is charged into the reduction shaft, where it is reduced to DRI by the reduction gas in counterflow. Discharge screws convey the DRI into the melter gasifier, where final reduction and melting take place in addition to all other metallurgical reactions. Hot metal and slag are tapped as in conventional blast furnace practice.

HyREX

HyREX technology, developed by POSCO, is a hydrogen reduction process for steelmaking that significantly reduces carbon emissions compared to traditional fossil fuel methods. In a pilot plant at POSCO's Pohang facility, the process produces 24t of molten iron per day, emitting only 400kg of carbon per ton. The company aims for the facility to become fully carbon-free by transitioning to renewable energy. POSCO plans to scale up this technology with a full-scale plant expected to produce 36t of iron per hour by 2027, ultimately targeting 2.5Mt of steel per year using hydrogen-based production by 2040.

Regulatory and Other Drivers

EU

As part of the EU Green Deal, the EU made a firm commitment to support clean steel technologies leading to a zero-carbon steel making process by 2050. The REPowerEU plan highlights that around 30% of the primary steel production in the EU is expected to be decarbonised by 2030 using renewable hydrogen. These objectives have been translated into a number of specific policy instruments.

First and foremost, the Carbon Border Adjustment Mechanism (CBAM) was designed by the European Commissions as part of the EU's Green Deal. As from 2026, the CBAM will impose a carbon price on the import of certain goods, including steel, produced outside the EU based on the GHG emissions associated with their production, ultimately aiming to avoid so-called carbon leakage, reduce global emissions and help reach the targets of the Paris Climate Agreement.

The CBAM was designed to complement the EU's Emissions Trading System (EU ETS), which is the EU's flagship climate policy instrument to reduce domestic GHG emissions. Under the EU ETS, Member States allocate a certain quantity of emission allowances to covered industries, including steelmaking. These allowances are distributed partly via auctions and partly for free. Over the years, the free allocation of EU ETS certificates to companies in energy-intensive sectors, including steelmaking, has been gradually — albeit slowly — reduced, and one of the objectives of the Fit for 55 was to accelerate the phaseout of any free allocation of emissions. This plan, however, created an increased risk of "carbon leakage", i.e. EU companies in certain sectors relocating their production to other countries with lower costs, jeopardising the effectiveness of the EU's measures to reduce emissions and damaging the EU economy. The CBAM was designed to enable the EU to increase the carbon pricing effect of the EU ETS while reducing or preventing this risk.

In practical terms, the CBAM will require importers to report the embedded emissions in certain carbon-intensive products — including steel — and to buy certificates to account for these emissions. The CBAM has already started with a transitional phase that runs from 1 October 2023 until 31 December 2025, during which only reporting obligations — but not carbon pricing — apply. As mentioned above, carbon pricing (i.e. the obligation to buy the aforementioned certificates) will start applying from 1 January 2026. Once the carbon pricing phase starts, for covered products in the steel sector only direct emissions (i.e. not those linked to electricity use, or to transport of the steel, etc.) will be priced.

Despite being an EU regulation, CBAM will have a global impact as the rules will apply to any entity exporting steel to the EU.

Interestingly, CBAM does not operate based on a binary system whereby low-carbon steel would be exempted from carbon pricing if it meets specific standards. Instead, the European Commission will establish a detailed GHG emissions measurement methodology for CBAM, similar to the one applicable under the EU ETS, and it is the GHG emissions amount calculated pursuant to this methodology that will be carbon priced. Regardless of which low-carbon steel standard a producer applies, only a reduction of GHG emissions as calculated pursuant to the methodology adopted by the European Commission will be recognised by a reduction in the carbon pricing of the importer. Therefore, the CBAM will create demand for low-carbon steel in direct proportion to how much GHG emissions is abated under the European Commission's methodology.

CBAM is not the only regulatory driver for the development of the green steel market in the EU.

Second, the reform of the EU's Renewable Energy Directive has introduced national targets for consuming renewable energy in industry, together with support for labelling schemes for industrial goods — including steel — produced using renewable energy. Under this new reform, Member States must do the following:

- *'endeavour to increase the share of renewable sources (...) used (...) in the industry sector* [including steelmaking] *by an indicative increase of at least 1.6%'* per year until 2030.

- *'promote voluntary labelling schemes for industrial products that are claimed to be produced with renewable energy (...)'*; such voluntary labelling schemes must indicate the percentage of renewable energy used calculated based on the methodologies laid down either in Commission Recommendation (EU) 2021/2279 or in ISO 14067:2018.

While these EU-level obligations must still be translated into actual policies at the level of Member States, they are aimed to incentivize, among others, the production and consumption of low-carbon steel made with renewable energy sources, notably by encouraging Member States to provide direct support schemes for steel producers and to make the identification of such renewable-based low-carbon steel products easier.

These EU-level targets (among other EU-level decarbonisation targets) have already incentivized Member States to provide substantial subsidy packages for the production of low-carbon steel. The EU Commission has granted state aid approval for German federal and state government funding of Thyssenkrupp's 'tkH2Steel' decarbonisation project in a total amount of around EUR 2 billion. The European Commission has also approved a EUR 1.3 billion German measure, made available in part through the Recovery and Resilience Facility, to support ArcelorMittal Bremen and ArcelorMittal Eisenhüttenstadt in decarbonising part of their steel production processes. The European Investment Bank (EIB) is taking part (among other lenders) in the project finance deal to support H2 Green Steel's large-scale production facility in Sweden. A substantial part of the EIB's contribution is expected to be backed by a guarantee from the European Commission under the InvestEU programme. These are just a few notable examples of direct EU support and we expect this trend to continue.

Lastly, the EU corporate sustainability governance requirements will have a significant impact on operations and governance of most EU companies and of many multinational (non-EU) companies active in the EU — including steel market players across the entire value chain. The most noteworthy recent regulatory developments include the following:

- *Corporate Sustainability Reporting Directive (CSRD)*

The CSRD is currently the most demanding ESG reporting framework in the world. It requires companies to make very detailed and complex disclosures on environmental and social risks, as well as their impact on people and the environment. Disclosures will have to comply with mandatory, sector-specific and detailed EU sustainability reporting standards. The CSRD applies to a very broad set of large companies and listed SMEs, with phased implementation from 2024 to 2028.

The consumption/planned consumption of green steel will be disclosable under CSRD in many cases, triggering reputational incentives for potential low-carbon steel users.

- *Corporate Sustainability Due Diligence Directive (CSDDD)*

The CSDDD introduces obligations of due diligence regarding human rights and environmental impacts along supply chains as well as, more importantly for low-carbon steel demand, an obligation on covered companies to adopt and put into effect — on a best effort basis — a climate transition plan aligned on the Paris Agreement's 1.5°C target. The CSDDD applies to a number of very large companies (with turnover above EUR 450 million) active in the EU. The obligation to adopt and put into effect such a climate transition plan is enforceable by (among others) fines of up to 5% of the company's worldwide turnover.

In many industrial sectors that are dependent on steel as inputs, the obligation on the covered company to adopt and put into effect a climate transition plan will indirectly require such company to seek to produce low-carbon steel, thereby creating demand for low-carbon steel.

UK

Similar to the EU, the UK government has shown a commitment to implement a UK version of CBAM to complement the UK Emissions Trading Scheme by 2027. Recently, the UK government has confirmed that a UK CBAM will be introduced on 1 January 2027, and it will apply to steel (among others).

The UK government is currently working on the design and delivery of the UK CBAM. It is expected that (i) the liability applied by the CBAM will depend on the GHG emissions intensity of the imported goods and the gap between the carbon price applied in the country of origin (if any) and the carbon price that would have been applied had the good been produced in the UK and that (ii) the UK CBAM liability will lie directly with the importer of imported products within scope of the UK CBAM on the basis of emissions embodied in imported goods. This system is not expected to involve the purchase or trading of emissions certificates.

The UK government has also started to provide direct support to the low(er) carbon steel industry. The government has confirmed that it will provide a grant of up to GBP 500 million (one of the largest government support packages in history) to Tata Steel for a new EAF replacing the existing coal-powered blast furnaces for greener steel production at Port Talbot.

US

The US also has a range of policies that support the development of the low carbon steel market, although the US policy approach has been different to what we have seen in Europe.

The Inflation Reduction Act introduced new and expanded tax incentives, bonus credits and more flexible options for monetising tax credits for the clean energy sector (including renewables and hydrogen) at an unprecedented scale, which in turn created a cost competitiveness for the steel manufacturers utilising clean energy sources for the production of low-carbon steel.

Through Federal Buy Clean Initiative, the federal government is prioritising the use of US-made, lower-carbon construction materials (including steel) in federal procurement and federally-funded projects. Furthermore, through the Federal-State Buy Clean Partnership, a number of states have made a commitment to prioritise efforts that support the procurement of lower-carbon infrastructure materials in state-funded projects, and to collaborate with the federal government and one another to send a harmonised demand signal to the marketplace.

The Buy Clean California Act requires the Department of General Services, in consultation with the California Air Resources Board, to establish the maximum acceptable global warming potential limit for certain materials, including structural steel and concrete reinforcing steel.

In addition, the US government is looking to provide direct support of up to USD 1 billion via the Department of Energy's Office of Clean Energy Demonstrations scheme to two projects: SSAB's 'Hydrogen-Fuelled Zero Emissions Steel Making' project in Mississippi and Iowa, and Cleveland-Cliffs Steel's 'Hydrogen-Ready Direct Reduced Iron Plant and Electric Melting Furnace Installation' in Ohio.

Although there are indications that the new Trump administration will prioritize support for the US steel industry, its position on the decarbonisation of steel remains unclear at this time.

Australia

The approach of the Australian government in relation to low-carbon steel contains elements of the European and US approaches and could be described as "the best of both worlds".

The 2024 National Hydrogen Strategy states that "Australia, the world's largest iron ore producer and exporter, should play a leading role in decarbonising the iron and steel industry". The strategy identifies green metals (including green iron) as one of the key hydrogen demand sectors and introduces a wide range of state support to the hydrogen industry. In line with the US approach, the strategy includes a hydrogen production tax incentive of AUD 2 per kg of eligible renewable hydrogen produced provided as a refundable tax offset for a maximum of 10 years. This incentive will be complemented by revenue support for large-scale early movers under the AUD 4 billion Hydrogen Headstart programme akin to the UK approach. In addition, and similar to the EU and the UK approach, the Australian government is also undertaking a review of policy options to address carbon leakage, including considering the feasibility of an Australian CBAM which would apply to steel.

Australian steel producers are also expected to continue benefitting from direct state support. For example, the Australian government awarded AUD 63.2 million towards the purchase and commissioning of a low-carbon electronic arc furnace to support green steel manufacturing.

In the 2024-25 federal budget, a significant AUD 19.7 billion of the AUD 22.7 billion Future Made in Australia package designed to supercharge Australia's clean energy transition will be dedicated to accelerating investment in 'priority' industries, including green hydrogen and green metals (which includes green steel). Notably, green metals is one of the five industries aligned with Australia's National Interest Framework, which imposes rigour on government's decision-making on significant public investments, particularly those used to incentivise private investment at scale. Key items include the following:

- The AUD 1.7 billion Future Made in Australia Innovation Fund will focus on innovation, commercialisation, pilot and demonstration projects and early-stage development in priority sectors, including green hydrogen and green metals.
- AUD 18.1 million has been allocated over six years for the Green Metals Foundational Initiatives to expedite the emergence of Australia's green metals industry. This forms part of a clear budget focus on the growth of the green metals industry at every stage of the supply chain. Funding will support industry and research collaboration, exploration of opportunities to improve the use of Australian scrap metal and undertaking of further consultation on incentives to support the production of green iron, steel, alumina and aluminium.
- Funding to fast track the Guarantee of Origin scheme to bolster Australia's green metals and green hydrogen industries.

In June 2024, the South Australian government released its Green Iron and Steel Strategy to establish a world-leading green iron industry and supply chain in South Australia, commencing with a global express of interest process to engage with companies to define ways to support industry investment.

Rise in ESG and Greenwashing Claims Globally

There has been a marked shift from aspirational statements by corporates on ESG issues towards specific goals associated with international treaties and metrics. That shift is driven not only by legislative initiatives and regulatory scrutiny but also by investor and consumer demands. As a result, corporates may now expect litigation where their ESG commitments are misleading or inaccurate, as well as where their commitments are perceived to be inadequately ambitious or not pursued at sufficient pace. We expect to see that volume of litigation activity increase, and an expansion of the risk of litigation beyond claims targeted at their own operations, to claims challenging the management of supply chain and risk of misuse.

Trends in ESG compliance and regulation create a base for stakeholder challenges and litigation relating to what corporates say to the market, how businesses operate day-to-day and the standards that they commit to deliver and who corporates choose to deal with from a third-party supplier and customer perspective.

Having a clearly defined, robust low-carbon steel standard and certainty about the true environmental performance of steel products is essential for preempting any greenwashing claims across the entire steel supply chain. As companies will devote increasing attention and resources to their ESG performance, reporting and disclosure processes, more will be focused on (and will drive) the development of the low-carbon steel market.

Sustainable Finance/ Transition Finance

The concept of 'transition finance' has become well-known among financial market participants, though there are still varying opinions on its exact definition. Some believe it includes climate transition efforts across all economic sectors, while others see it as specifically targeting funding for high-emission industries like energy production, steelmaking, transportation, mining and cement, to help them move towards decarbonisation.

A number of leading financial institutions expressed concerns about using labels such as 'green' or 'sustainable' to support transition activities (particularly when investing in high emitting sectors such as steel making) due to the potential reputational damage from greenwashing claims that such investment might attract. Nevertheless, there is a strong drive in the market to raise capital, invest and obtain financial services to facilitate a transition to a net zero future.

One example is the bank-led, UN-convened Net-Zero Banking Alliance (NZBA) which brings together banks worldwide that are committed to aligning their lending and investment portfolios with scientific pathways to achieve net-zero emissions by 2050. NZBA (i) provides support to banks that are looking to set targets for the iron and steel sector, to monitor and measure progress towards those targets and take action towards the transition of the iron and steel sector in line with a 1.5°C pathway, (ii) outlines the critical components that banks need to consider to inform their key design choices with regard to the decarbonisation of their iron and steel portfolios, and (iii) provides a high-level overview of the carbon measurement standards banks can apply in relation to their iron and steel portfolios.

Another example is the EU Taxonomy Regulation, which was adopted in the context of the EU's Sustainable Finance Initiative and has been in force since 12 July 2020. It created an EU-wide classification system for sustainable activities and the associated reporting obligation for companies operating in the EU. One of the key goals of this regulatory framework was to promote investment into certain economic activities that qualify as 'sustainable'. Manufacture of iron and steel subject to a certain technical screening criteria (which focuses on substantial contribution to climate change mitigation) is a taxonomy-aligned activity. It should be noted that activities that are not taxonomy-aligned can count as 'sustainable' if there is a plan to align them over the next 5-10 years.

We expect that the concept of transition finance will evolve and adapt to market needs and provide a framework for the development and application of innovative solutions in line with advancements in technology and policies. With further development and alignment of low-carbon steel standards, transition finance could become a key enabler of the low-carbon steel market.

Standards

Establishing a clear, robust and working low-carbon standard (or standards) is crucial for the following, among others:

- The development of the global low-carbon steel market at the pace and the scale required to meet the leading economies' net-zero goals
- Governments developing measures aimed directly at incentivising production of low-carbon steel
- Steel makers benefitting from these incentives, being able to price and justify a low-carbon premium and remaining competitive in the global market
- Buyers of low-carbon steel and products down the value chain seeing a clear benchmark for sustainable steel production, being able to meet and demonstrate achieving their sustainability goals and avoiding greenwashing claims
- Rolling out technologies enabling the sector's long-term success and driving innovation
- Building support and confidence in the market for low-carbon steel and promoting international trade
- Making finance flows consistent with net-zero goals

Based on a large number of low-carbon steel standards and other related initiatives developed over the past few years, there appears to be a consensus in the market that a standard is required. However, there is no consensus as to the following:

- *Who the standard should be aimed at*

  There are a number of standards that are aimed at steel producers, including the following:

  - The ResponsibleSteel International Production Standard (RSIPS) by the Responsible Steel
  - The Low Emission Steel Standard (LESS) by the German Steel Association backed by the German Federal Ministry for Economic Affairs and Climate Action
  - The Steel Climate Standard (SCS) by the Global Steel Climate Council (GSCC)

  There are also a number of initiatives aimed at the demand side (e.g. Industrial Deep Decarbonisation Initiative, the SteelZero Initiative and First Movers Coalition) and the finance side (e.g. the Sustainable STEEL Principles and Climate Bonds Initiative's Criteria for Climate Bonds for the Steel Industry) of the steel industry.

- *How the standard should be designed (methodology)*

  Steel is made from iron ore and/or scrap. Significant GHG emissions from steel are generated while producing steel from iron ore, as (i) coal and natural gas are generally used as energy and (ii) coke is used in the BF-BOFs. Therefore, even if the whole energy system is changed and the steelmaking industry is using clean energy sources, it will still be an emitter if the process for making steel is not changed.

  Producing steel from scrap with clean electricity in an EAF results in a very low-carbon product. Steel decarbonisation approaches taking account of the variable amounts of scrap used in production are often referred to as the 'sliding scale'.

  The sliding scale methodology is adopted in standards such as RSIPS and LESS. However, the GSCC believes that any standard that features a ferrous scrap sliding scale runs counter to net zero objectives because *'this approach sets two disparate standards for emissions from steel producers; one standard for steel made from iron ore extractive production processes, and another for steel made from circular electric arc furnace (EAF) processes'*. The GSCC warns that *'we must avoid a standard that enables greenwashing'*.

- *What the standard should be in numerical terms*

  In numerical terms, most standards are defined as the ratio of GHG (in tons of CO_2e) per ton of steel (depending on the ratio of scrap used). The issue is that there is no commonly agreed emissions measurement methodology. Due to different methodologies used by different standards, it is very difficult for the demand and finance side of the market to compare GHG emissions from steel and related products in numerical terms (and, therefore, define a 'low-carbon premium').

- *Whether any low-carbon steel standard should focus only on reducing GHG emissions or should it also address the 'S' in ESG*

  While standards such as LESS and SCS focus primarily on decarbonisation of the steel industry, other standards such as the RSIPS consists of a wide range of principles (underpinned by detailed requirements) aimed at the responsible sourcing and production of steel. Decarbonisation is just one of many principles — the standard goes beyond climate change mitigation and sets out requirements on labour, human rights, water, biodiversity and more.

- *How the standard should be verified*

  Most of the existing standards involve some form of independent verification/audit. However, the process of verification varies across the standards.

- *Whether a standard should be voluntary or mandatory*

  At present, the low-carbon steel standards applicable to steel producers are voluntary. There have been calls across a number of jurisdictions (including the UK and the US) to go further and implement mandatory product standards that would apply directly to steel producers. Such a mandatory standard would only be possible with government intervention. If standards become mandatory, international cooperation and alignment would become critical for the global market.

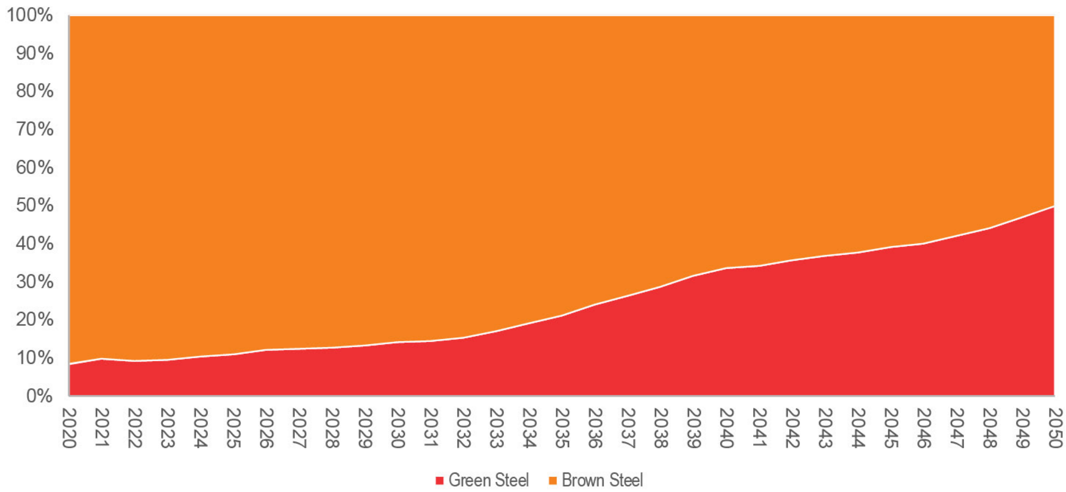
- *Whether a single globally applicable standard should be developed*

  Most of the existing standards are opened to market players globally. However, there is no single standard that has been universally adopted by market players. Lack of alignment in the market on a standard is also evident from a wide array of jargon used to refer to low carbon steel — 'green', 'responsible', 'sustainable', 'low emissions/carbon', 'zero/near zero emissions/carbon ', 'clean' just to name a few, with standards and related initiatives being promulgated by industry bodies, governments, financiers and individual steel producers. Policymakers have an important role in streamlining these standards. However, despite a number of international cooperation initiatives in this space (including at the government level), it is unlikely that a single globally applicable standard could ever be developed and adopted by a very diverse global market.

Market Appetite

Low-Carbon/Green Steel is forecast to comprise up to 50% of global steel production by 2050. As the world decarbonises and in light of the regulatory and other drivers outlined above, steel producers are looking at reducing the carbon emissions associated with their production processes. Steel production, due largely to its scale, has been estimated to account for approximately 8% of global CO2 emissions. In particular, the use of metallurgical coal in conventional blast furnaces is the major source of emissions in the industry.

Estimated Proportional Increase of Green Steel Production to 2050, %



Source: AME

The transition of steel production to a greener future will have a significant effect on demand for metallurgical coal and a range of iron ore products. Metallurgical coal demand will decline as the conventional blast furnaces are phased out and demand for value-added iron ore products will see them increase as a proportion of the iron ore market. The shift will be initially less pronounced in China and India but will be forced to maintain competitive access to major markets.

Increased use of scrap will also be a significant driver in the gap between metallurgical coal demand and growing crude steel production. The availability of scrap is currently a limitation to the wider production of Green Steel. Significant volumes will become available as products from China's economic ramp-up reach end-of-life and reenter the supply chain.

Constraints to this transition include the availability of scrap for use in EAF secondary production as well as suitable iron ore deposits for producing DRI.

- While scrap is easy to recycle and lends itself to the greener EAF process route, scrap steel availability is insufficient to fulfil steel demand. This ensures continued demand for steel produced from iron ore whose process routes are more difficult to decarbonise.
- Production of DRI requires a feed of DR feed pellets from the iron ore source. Deposits appropriate for producing this feed material are currently more limited than the Direct Shipping Ore sources which currently dominate iron ore supply.
- Further, the DRI-EAF process route, while reducing the carbon emissions associated with primary steel production, will generally still exceed AME's definition of <0.5 tCO2/tsteel.

Implementation of the regulatory frameworks discussed above will be a significant driver in forcing and/or incentivising the steel industry to adapt and decarbonise. While all of the policies will have a role to play in the development of the green/low carbon steel market, it is those policies that imposea price cost on associated carbon emissions that are likely to incentivise producers the most to reduce emissions to remain competitive.

It is important to note that for 'Green Steel' to be zero-carbon steel, all power must be sourced from renewables or green hydrogen and the graphite anodes used in EAFs need to be replaced/substituted/eliminated from the process.

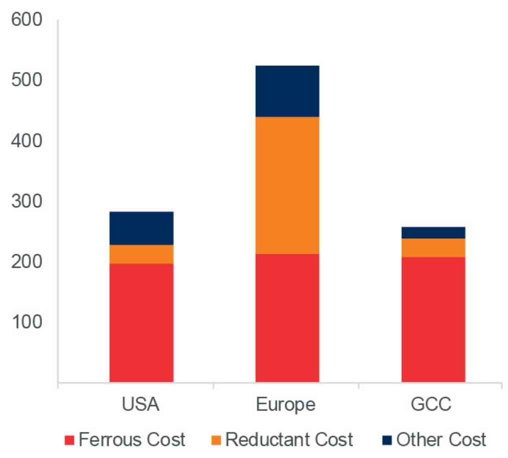
Costs and Regional Dynamics

High energy, labour and regulatory costs in Europe significantly increase the overall cost of steel production, even as ferrous costs remain lower. In contrast, the Gulf Cooperation Council region benefits from low energy costs and a supportive regulatory environment, which helps mitigate the impact of its reliance on relatively high-cost DRI and HBI. Meanwhile, India enjoys both low ferrous and conversion costs, further enhanced by vertical integration in its production processes. While CBAM is expected to provide some relief for Europe, its slow phase-in poses significant challenges. By 2030, the CBAM is projected to cover only 22.5% of emissions, even though a domestic transition is anticipated to be well underway.

Current carbon prices do not reflect the necessary levels to effectively accelerate the transition to green steel. There is an urgent need for additional government support to protect steelmaking in high-cost regions from imports, and this situation is unlikely to change as the industry shifts towards green steel. As energy costs are expected to become the dominant factor driving production expenses, addressing these challenges will be critical for maintaining competitiveness.

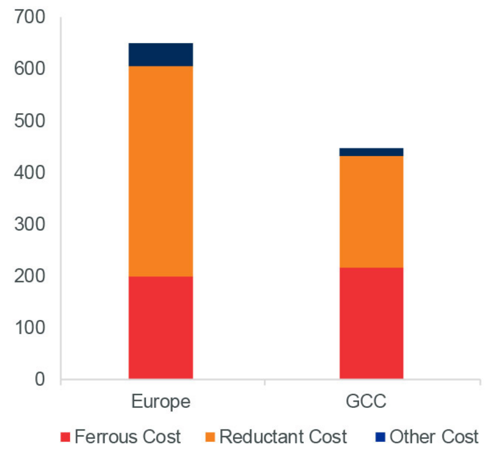
Regions with low-cost natural gas are well-positioned to produce green hydrogen at competitive prices, further enhancing their steel production capabilities. While the CBAM may offer some protection against imports of brown (produced using conventional methods that rely on high-carbon processes) HBI, additional measures will be essential to develop domestic production capacities for green HBI. It is also crucial that green hydrogen is utilised where it is produced; otherwise, the logistics of transporting it will exacerbate the support needed by the steel industry to sustain local production.

HBI Cash Costs 2024, USD/t



Source: AME

Green HBI Cash Costs 2030, USD/t

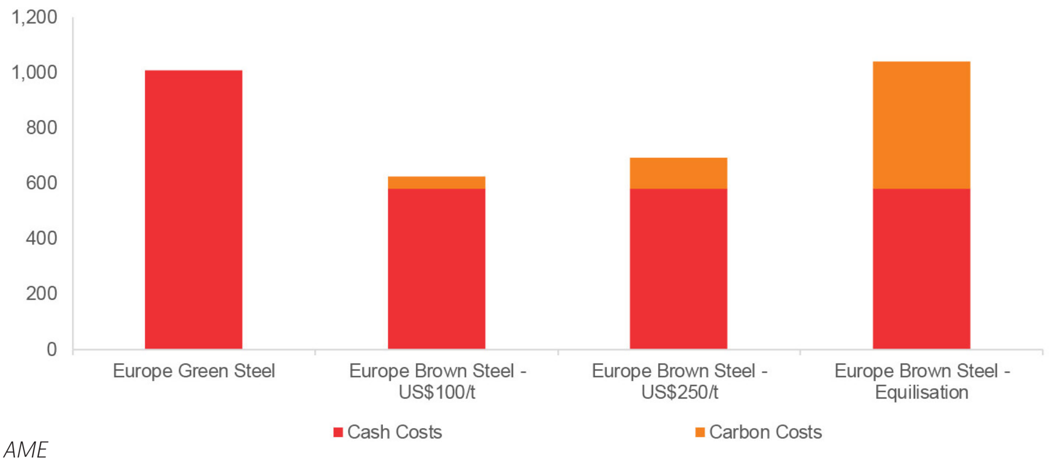


Source: AME

Cost differentials will more than offset the expenses associated with transporting HBI from the lowest cost regions. It is anticipated that the Middle East will be able to produce green HBI at a lower cost than Europe can produce brown HBI. Current carbon taxes, approximately USD100/t, are insufficient to deter low-cost brown DRI from entering European markets.

2030 is a pivotal year for Europe's green transition. Brown steel is likely to remain cheaper to produce than green steel, and the gradual phaseout of free carbon permits alongside the slow implementation of CBAM may hinder the achievement of green targets. With only 22.5% of emissions covered by 2030, and a full 100% by 2034, there is a risk of locking in low-cost supply chains elsewhere without additional support and protective measures. To ensure the competitiveness of green steel in Europe and maintain a localised metallic supply chain, carbon taxes will need to reach approximately USD 230/t by 2030. As the world aims for carbon neutrality by 2050, the steel production sector presents a formidable challenge, accounting for around 8% of global carbon emissions.

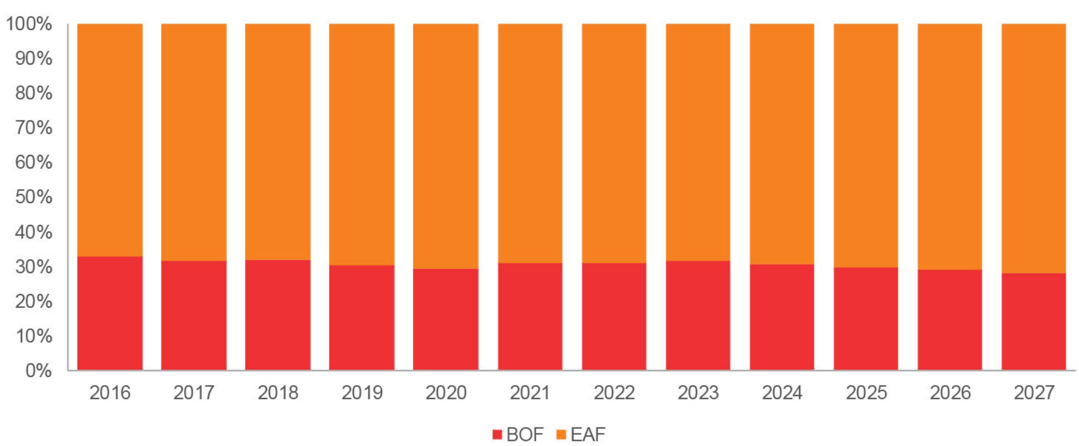
Steel Cash Costs by Route 2030, USD/t



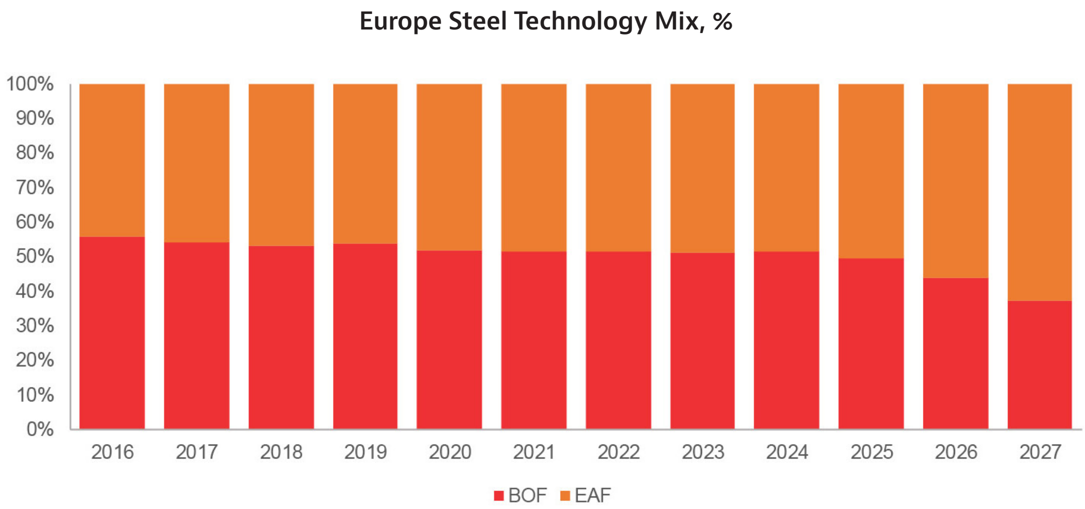
Source: AME

Currently, global production of green steel stands at approximately 200Mt, with forecasts predicting an increase to around 340Mt by 2030. Europe is positioned to lead this energy transition by replacing existing BF-BOF assets with more environmentally friendly steelmaking technologies. Meanwhile, the Gulf region and the United States are also making significant strides in green steel production. This collective effort underscores the industry's commitment to reducing its carbon footprint and advancing toward a sustainable future.

US Steel Technology Mix, %



Source: AME



Source: AME

Conclusion

The transition to green steel represents a pivotal shift in the steel industry, driven by the urgent need to reduce carbon emissions and align with global sustainability goals. Policymakers have a key role to play in developing and aligning regulatory frameworks supporting transition to green steel. As technologies such as EAF and hydrogen-based production methods gain traction, the demand for low-carbon and high-quality steel will likely rise. While green premiums reflect the added costs of these eco-friendly processes, the long-term benefits — including environmental sustainability, regulatory compliance and enhanced brand reputation — make them an attractive option for forward-thinking companies. However, challenges such as limited scrap availability and fluctuating energy prices will need to be navigated carefully. Ultimately, the evolution toward green steel underscores the commitment to a more sustainable future, but it is only through targeted government incentives and policies that the economic barriers to green steel can be overcome, aligning economic viability with environmental responsibility.

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Report Limitations and Restraints

Production and Cost Analysis

Available data varies greatly between operations and projects. Certain information is unreliable due to language difficulties, the confidential nature of the information, the inability to estimate the reliability of AME's sources and general lack of data. Consequently, much information has to be estimated, and the quality, accuracy and completeness of the resulting cost comparisons will reflect this and cannot be guaranteed. Furthermore, forecast costs embody a number of significant assumptions with respect to exchange rates and other technical variables. Because of these factors, direct comparability between individual projects may be limited and, as such, our supply and cost estimates must be treated with caution and cannot be relied upon.

Supply/Demand Analysis

In addition, AME has supplied tables of historical data and estimated future supply, demand and market trends by compiling, interpreting and analysing engineering, supply, economic, statistical and technical information from many third-party sources. Such company and country statistics usually contain inconsistencies and utilise sampling data techniques and, thus, should not be relied upon.

Data Accuracy

AME has prepared this Report using information from its in-house database as well as a wide range of public domain and industry data sources for which assessment cannot be made in regard to accuracy. This is because AME does not have access to confidential company information to verify our data quality. Therefore, reliance can only be provided where we have data of sufficient quality that is acceptable to an international commercial court.

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