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Forging pathways: insights for the green steel transformation

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1. Executive Summary

The steel industry is the backbone of the construction, manufacturing, energy and infrastructure sectors. It is also extremely carbon intensive, and one of the largest contributors to global carbon emissions, accounting for approximately 11% of global greenhouse gas emissions.[1]

As part of the worldwide effort to reduce carbon emissions and reach net zero targets, a shift towards green steel is underway, with progress in technology, innovation and policy settings suggesting the steel sector no longer deserves the reputation of 'hard-to-abate'.

However, a critical time window exists: decisions made over the next six years by investors, companies and policy makers will determine whether emissions from steel drop significantly, or stay stubbornly high.

Between now and 2030, 71% of the world's steelmaking assets will reach the end of their operating lives, necessitating significant investment in the relining of coal-dependent blast furnaces.[2] The reallocation of capital to genuine green steel processes is urgently required to prevent the lock-in of coal based methods for another 20 years – the typical lifespan of a blast furnace.

Companies and investors wanting to harness the opportunities of the green steel transition, and avoid the risks of falling behind, must act now, or miss a critical window to pivot away from carbon-intensive practices.

This report offers insights for investors and companies at the forefront of the green steel transformation who are seeking both decarbonisation and long-term shareholder value. It provides:

- a summary of iron and steelmaking technologies and their decarbonisation potential, allowing investors to distinguish genuine 'green' investments from those with less potential
- an overview of major global trends, opportunities and challenges across the steel value chain
- analysis of how 20 major companies, including 16 steelmakers collectively responsible for 27% of global steel production and four iron ore companies responsible for 41% of global iron ore production, are positioning the green steel transformation
- a set of concrete, actionable recommendations to support investors to drive emissions reductions and value-accretive capital allocation, and advocate for policy and regulatory settings that support investment.

[1] International Energy Agency, 2022, Iron and Steel.

[2] Agora industry, Wuppertal Institute, & Lund University, November 2021, "Global Steel at a Crossroads: Why the global steel sector needs to invest in climate-neutral technologies in the 2020s".

Key Findings

- Investors and companies need to reallocate capital towards genuine green steel processes in the next six years to prevent the lock-in of carbon intensive steelmaking methods.
- Steel does not have a 'climate problem', it has a coal problem. Around 90% of emissions from steel production are due to the use of metallurgical coal in conventional blast furnaces to produce iron, the primary component of steel. Eliminating coal-dependent processes from ironmaking is key to steel decarbonisation.
- Capital allocation towards innovative green iron technologies in regions with abundant renewable energy potential is imperative. One possible solution sees ironmaking decoupled from steelmaking, with iron production occurring in areas with significant renewable energy production, delivering a reliable supply of high-value green iron.
- Not all processes labelled as 'green' have the same decarbonisation potential. Across every stage of the value chain, companies are exploring advancements in technology and production innovation to enable less carbon intensive steelmaking However, the emissions reduction potential of each process differs significantly:
    - Green hydrogen-based processes, supported by renewable energy, are the most promising for emissions reductions.
    - Gas-based direct reduced iron and other lower-emission technologies offer some emissions reductions in the near term, yet to avoid reinforcing fossil fuel reliance, these should not be adopted as permanent solutions.
    - Carbon capture utilisation and storage or offsets appear one of the least cost-effective solutions, with significant uncertainty around viability and effectiveness.
- The shift towards green steel production is a major commercial opportunity for companies and their investors. Market size and demand for green steel is forecast to increase.
- Green steel offtake agreements, where consumers commit to purchasing material that is not yet produced, have become crucial mechanisms for locking in green steel demand, ensuring a stable supply chain and providing easier access to financing. The prevalence of green steel offtake agreements within European companies highlights the region's proactive stance on decarbonisation, which is supported by robust financial structures and policy settings.
- While Europe is at the forefront of technological and product innovation, a significant portion of steelmaking capacity development occurs in Asia, particularly in China. Despite a noticeable shift towards Electric Arc Furnace (EAF) production in China, the overall pace of decarbonisation in Asia is inconsistent with global decarbonisation goals.
- Of the 16 steelmaking companies ACCR reviewed:

    - 50% of the projects steelmakers have invested in have significant emissions reduction potential, while 40% of the projects still focus on solutions with limited potential to reduce emissions.
    - 94% of companies have ambitious net zero by 2050 targets, alongside quantifiable medium-term reduction goals, but short-term commitments are scarce. This suggests the steel sector has a challenging path ahead to deliver the rapid and substantial emissions reductions their targets require.
    - less than 20% of companies have net zero emissions targets that explicitly encompass Scope 3 emissions, raising concerns about the industry's alignment with the Paris Agreement and global decarbonisation goals.
    - none currently verify whether their decarbonisation targets are in alignment with the Science Based Target Initiative's (SBTi) Steel Science-Based Target-Setting Guidance, and only two have planned to do so in the future.
- Of the four iron ore companies ACCR reviewed:
    - scope 3 emissions, predominantly from steelmaking, account for more than 95% of their total emissions footprint. The companies are beginning to make strategic investments and form partnerships aimed at reducing their Scope 3 emissions, but the ambition and clarity of targets vary, leading to a mixed outlook on commitment and potential impact.
    - all are directing substantial capital expenditure towards operational decarbonisation by 2030. However, all need to improve disclosure of their expenditure, which should include detailed breakdowns of capital allocations toward steel decarbonisation projects, including forward-looking allocations for the next three years.
    - all are diversifying their decarbonisation investment strategies, collectively pursuing 64 steel decarbonisation projects that span an array of technologies with varying degrees of emissions reduction potential.
    - three mine iron ore in the Australian Pilbara region, where the vast majority of iron ores are not currently suitable for commercial Direct Reduced Iron (DRI) or Hot Briquetted Iron (HBI) production. Each company is tackling this challenge, acknowledging the significant business risk and initiating efforts to address it, with outcomes still to be determined.
- Coordinated, global advocacy by investors and companies for the right policy and regulatory frameworks is critical for creating favourable investment environments. In particular:
    - policies supporting investment in renewable energy are essential for ensuring a reliable energy supply for green steel production

   - strategies to support green public procurement (GPP) by nation-states, leveraging their substantial purchasing power, will continue to play a significant role in creating market demand for green steel production
   - aligning policy frameworks with the geographical strengths of regions across the steel value chain is pivotal for efficient investments towards zero emissions.
- Financial risks associated with failing to decarbonise are already apparent and will increase. For example, The EU's Carbon Border Adjustment Mechanism (CBAM) imposes a carbon price on steel imports based on their intensity emissions.
- Wealthier nations, including those with strong economies and industrial capabilities, have a substantial role in leading global decarbonisation efforts through technology innovation and policy development. International cooperation and technology transfer are also essential for the global decarbonisation of the steel sector. Policies that encourage collaboration and support technology sharing will be important in achieving widespread adoption of green steel practices.
- Implementing robust systems for emissions monitoring and reporting is key to enhancing transparency and accountability in the steel sector.

Key Recommendations for Investors

Investors have five key levers available to them now that can help ensure a decarbonised steel sector is a reality by 2050.

1. **Reallocate capital away from coal-dependent blast furnaces and towards processes with high decarbonisation potential.**
   - Engage with companies, using escalation where necessary, to ask for disclosures of transition pathways to low-emissions iron/steelmaking, along with a detailed outline of the capital allocation for the transition.
   - Direct investments towards regions lagging in green steel production capability, specifically to accelerate decarbonisation efforts.
   - Engage with policymakers directly and indirectly to encourage positive policy settings for steel decarbonisation.

2. **Increase renewable energy capacity to enable the green electricity and green hydrogen required for low-emissions steelmaking.**

- Fund renewable energy projects, particularly in developing countries with steelmaking operations.

3. **Work towards standardised, comprehensive and robust emissions disclosure across the industry.**

    - Engage with companies to ask for transparent disclosures.
    - Integrate emissions data and trends into investment analysis, so shareholders can invest in companies that demonstrate transparency, lower carbon intensities and a strong commitment to reducing absolute emissions.
    - Update financial risk assessment models to accurately incorporate the physical impacts of climate change, ensuring investment strategies adequately address climate risk.

4. **Catalyse immediate action towards decarbonisation with short-term climate commitments that are ambitious and science-based.**

    - Engage with companies, using escalation where necessary, to ask for the disclosure of short-term climate targets and alignment with the Science-Based Targets initiative (SBTi).

5. **Ensure that the transition of iron and steelmaking to green processes is just and equitable, supporting communities and workers.**

    - Hold companies to account on providing a just transition timeline, clear framework and outcomes for impacted workers.
    - Incorporate just transition metrics and information into investment analysis and decision-making.
    - Advocate for policies promoting a just transition.

2. State of Play

The critical investment window

The decarbonisation of the steel value chain is underway and accelerating,[3] driven by global recognition that massive, near-term cuts to CO_2 emissions are required across all sectors of the economy. However, decisions made by investors and companies over the next six years will determine whether the full potential for significant emissions reductions in the steel making process is realised.

Between now and 2030, 71% of the world's steelmaking assets will reach the end of their operating lives, necessitating significant investment in relining coal-dependent blast furnaces.[4] Reallocation of capital to genuine green steel processes is urgently required to prevent locking-in coal-based methods for the next 20 years – the typical lifespan of a blast furnace.

Investors wanting to harness the opportunities of the green steel transition, and avoid the risks of falling behind, must act now or miss a critical window to pivot away from carbon-intensive practices.

Evidence of an appetite to move away from conventional, coal-based production includes:

- a surge in market demand for green-produced steel
- significant investments and advancements in green steel technology
- industry-wide commitments to reduce Scope 1, 2, and 3 emissions across the value chain
- rapid growth in green steel partnerships
- new supportive initiatives and a rise in green steel procurement policies boosting industry-wide transformation.

Long viewed as a "hard-to-abate" sector, recent insights suggest that with the right investment and political will, the steel sector can transition into a "fast-to-abate" entity. One recent study suggested a net-zero steel sector and a coal phase-out in steelmaking is technically feasible by the early 2040s.[5]

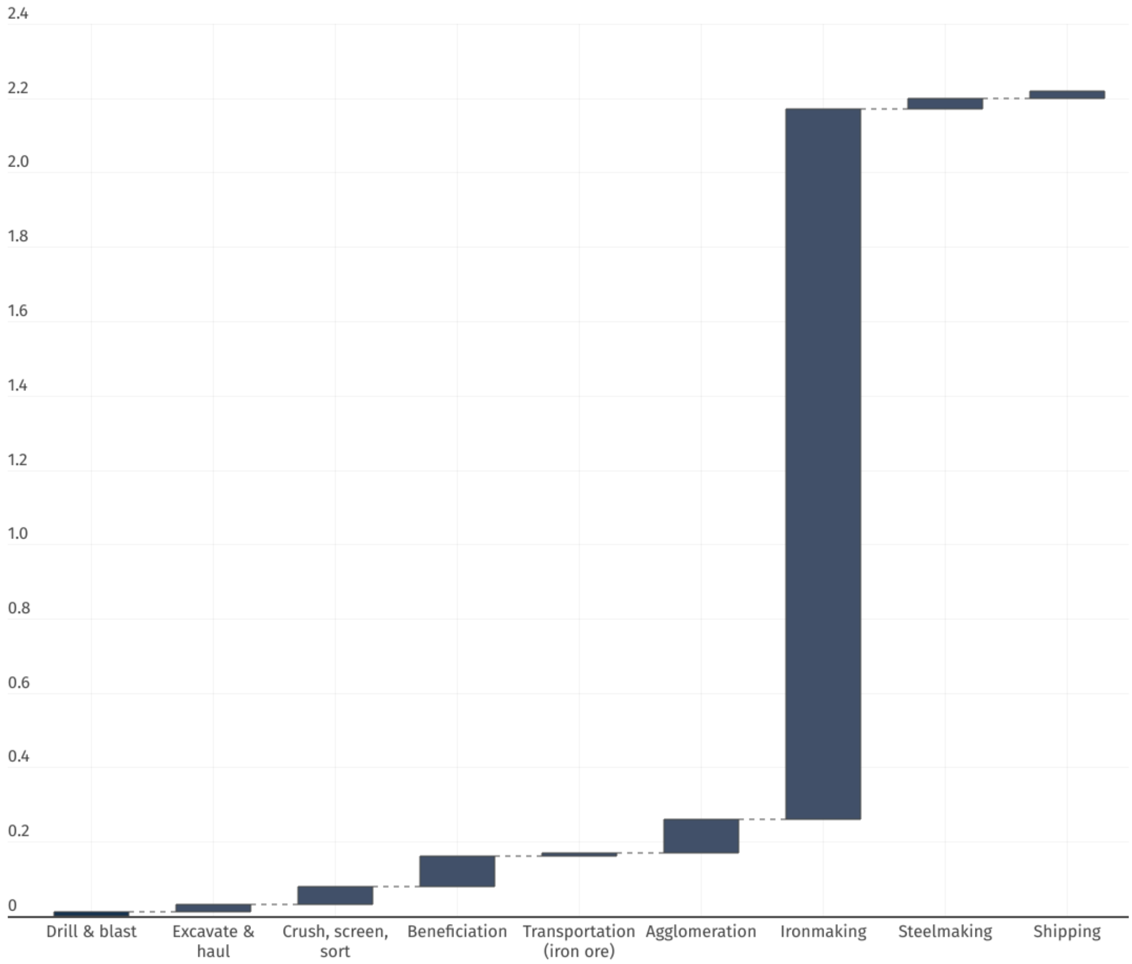
Iron's coal problem

The steel industry is extremely carbon intensive, accounting for approximately 11% of global greenhouse gas emissions.[6] The main reason for this is the industry's extensive use of metallurgical

[3] Echoing this sentiment, the Executive Director of the International Energy Agency (IEA), Fatih Birol, highlighted the broader trend, noting, 'The transition to clean energy is also accelerating in other sectors, including those where emissions are most challenging to reduce, such as steel.' Birol, F. 14 April 2023, "Clean energy is moving faster than you think," Financial Times.
[4] Agora industry, Wuppertal Institute, & Lund University, November 2021,"Global Steel at a Crossroads: Why the global steel sector needs to invest in climate-neutral technologies in the 2020s".
[5] Witecka, W.K., Somers, J. & Reimann, K., June 2023, "15 Insights on the Global Steel Transformation", Agora Industry and Wuppertal Institute,
[6] International Energy Agency, 2022, Iron and Steel.

coal in blast furnaces to produce iron, the primary component of steel. Around 90% of the emissions from steel production arise from this process.[7]

Figure 1: Waterfall chart of emissions in steel life cycle



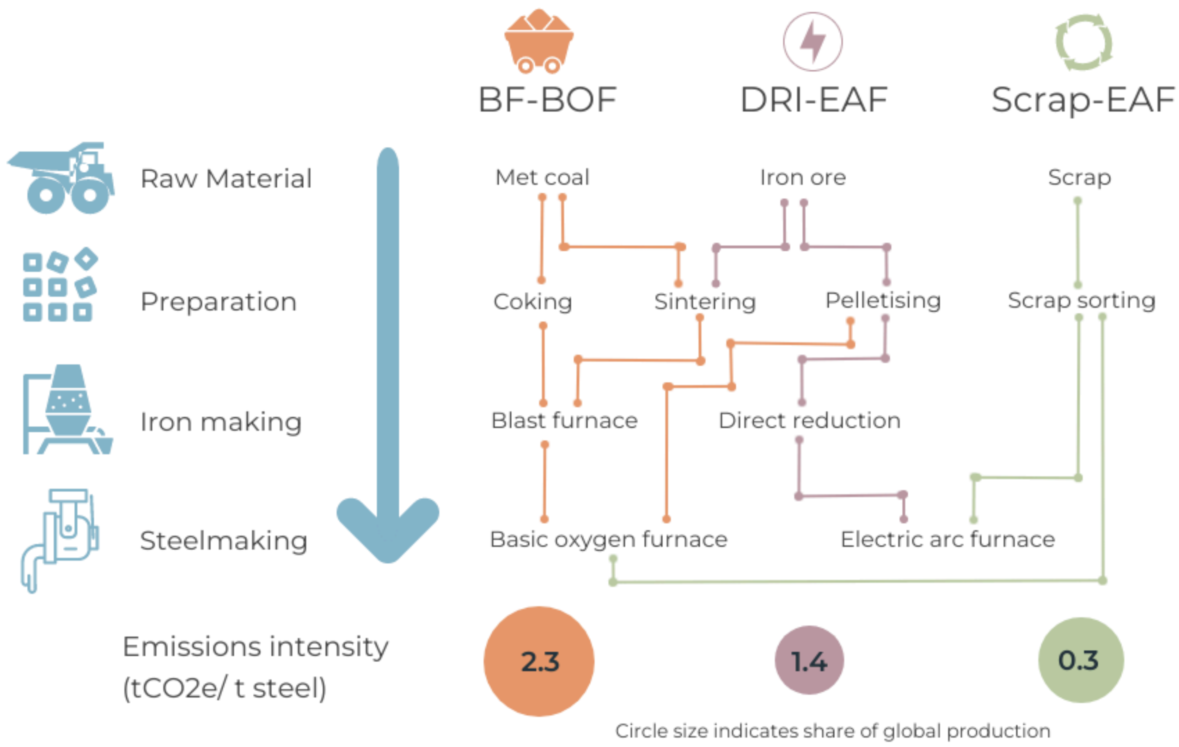
Source: Minerals Research Institute of Western Australia, ACCR

Steelmaking does not have a 'climate problem'. More accurately, conventional ironmaking currently has a 'coal problem'.

However, new steelmaking processes that do not rely on metallurgical coal are emerging as viable alternatives, and with the right investment, steel of the future does not need to leave a significant emissions footprint.

[7]Minerals Research Institute of Western Australia, 2023, "Western Australia's Grene Steel Opportunity," MRIWA Project.

Figure 2. Three main steelmaking routes and associated carbon intensities



Sources: IEEFA, ACCR

Strategic localisation of green iron production with renewables

To achieve zero emissions steel production, the most energy intensive part of the steel value chain - ironmaking - is best undertaken near plentiful renewable energy resources to produce high-value green iron.

This strategy would involve a shift where the ironmaking and steelmaking process is decoupled, with green iron production occurring where there is significant renewable energy potential, either close to iron ore mines or within a reasonable distance for transport. The resulting green iron, preferably transported as hot briquetted iron (HBI)[8], can then be moved to locations where green steel is manufactured in EAFs powered by renewable energy or basic oxygen furnaces (BOFs).

Using renewable energy to produce green iron, either closer to iron ore mines or within a reasonable distance, would:

- capitalise on the availability of renewable resources in or accessible to iron-rich regions

[8] DRI and HBI are both forms of iron produced through direct reduction, bypassing the carbon-intensive blast furnace process. DRI is produced at temperatures below iron's melting point and is prone to re-oxidation; it requires careful handling to prevent spontaneous combustion, especially when moist. HBI, formed by compressing DRI at high temperatures into briquettes, is denser and more resistant to oxidation, making it safer and a more economic option for long-distance transportation.

- create logistical and economic efficiencies to facilitate the establishment of offtake agreements for green iron
- situate green hydrogen production at the point of iron reduction, circumventing the complexities associated with shipping hydrogen. Transporting hydrogen poses challenges including the need for high-pressure tanks or cryogenic temperatures for liquefaction, alongside risks of hydrogen embrittlement in metal containers.[9]

Capital allocation toward innovative, green iron technologies in regions with abundant renewable energy resources is imperative to realising this shift.

Differing decarbonisation potential

Advancements in technology and production innovation are enabling steelmaking to become less carbon intensive during every stage of the steelmaking process. Yet the emissions reduction potential of each process differs significantly.

- Green hydrogen-based processes, supported by renewable energy, are the most promising for emissions reductions.
- Gas-based direct reduced iron and other lower-emission technologies offer some emissions reductions in the near term, yet to avoid reinforcing fossil fuel reliance, these should not be adopted as permanent solutions.
- Carbon capture utilisation and storage or offsets are looking less cost-effective, with significant uncertainty around viability and effectiveness.

Terminology including ‘net zero’, ‘carbon-free', ‘green’ and ‘low-emissions’ are all used interchangeably, which can lead to confusion and misinterpretation. Without clear definitions, it becomes challenging to measure and compare the environmental impact of different steel production methods accurately. As there is currently no universal standard for 'green steel',[10] this report places technologies into three categories based on an assessment of technology solutions by their emissions reduction potential: 'green potential', 'low-carbon potential', 'limited potential'. In this context, 'green' refers to steel production methods that eliminate the use of fossil fuels entirely, 'low-carbon' encompasses processes that significantly reduce emissions but may still utilise fossil fuels or emit carbon to some extent, and 'limited' describes technology solutions that offer minimal decarbonisation capabilities on their own.

[9] Li, H. et al, November 2022, “Safety of hydrogen storage and transportation: an overview on mechanisms, techniques, and challenges,” Energy Reports, vol. 8, pp. 6258-6269, https://doi.org/10.1016/j.egyr.2022.04.067.
[10] There is a need for a more universally applied industry standard for green steel terminology, so that investors, companies and policymakers have clarity on the emissions reduction potential of various technologies.

Table 1: Decarbonisation potentials of various steel production pathways

Green potential	
Renewable-powered Electric Arc Furnace (EAF)	Runs on 100% renewable energy sources and converts green iron, or scrap steel, into green steel.
Green hydrogen produced with renewable energy	The hydrogen, as a reducing agent, converts iron ore into Direct Reduced Iron (DRI) or Hot Briquetted Iron (HBI). This green iron can then be refined in an EAF or Basic Oxygen Furnace (BOF). Electric smelter technologies can help to alleviate iron grade issues.
Electrolysis, e.g., Molten Oxide Electrolysis (MOE)	Directly reduces iron ore into iron using renewable electricity in a molten salt environment. This green iron can then be refined in an EAF.
Low-carbon potential	
Gas-based direct reduced iron	Uses fossil fuel gas, and in some gases, gas from coal gasification, instead of coal in a shaft furnace, leading to some emissions cuts.
Biomass	Used as a reducing agent to convert iron ore into DRI or HBI to reduce greenhouse gas emissions. The extent of emissions reductions depends on the biomass source, process efficiency, and broader environmental impacts, including sustainability, potential competition with food production, and effects on biodiversity.
Hydrogen injection in blast furnaces	Still significantly reliant on metallurgical coal, with an unclear hydrogen-to-coal ratio. Emissions reductions are uncertain, especially with fossil, gas-based hydrogen. While aiming to cut blast furnace emissions, it overlooks wider steelmaking emissions from metallurgical coal mining and use. Additionally, meaningful reductions require carbon capture and storage (CCS), a technology with questionable effectiveness.
Limited potential	
Carbon Capture, Utilisation, and Storage (CCUS)	Could be coupled with current blast furnaces or limited potential steel processes. Huge uncertainties exist around costs, effectiveness and the long-term viability of storage and transport options.
Offsetting	Offsets are environmental credits purchased to compensate for emissions produced elsewhere. Due to concerns about their integrity—arising from the temporary nature of carbon storage, the inadequacy of merely storing carbon versus reducing emissions, and challenges in ensuring that integrity criteria are met—they should serve only as an additive component in decarbonisation strategies.
Mass balance approach	The mass balance approach allows companies to claim a portion of their production as 'green' by allocating actual emissions reductions across their output. For example, if emissions are reduced by 12%, a company may label 12% of its production as entirely green. This accounting method, while reflecting some level of environmental improvement, can exaggerate the sustainability of these 'green' steel products. This practice risks misleading consumers and investors about the extent of genuine emissions reductions, potentially leading to perceptions the company is greenwashing, plus legal and reputational risks.

Sources: E3G, Renewable Energy Institute, Agora Industry, ACCR

Market opportunity

The global iron and steel market is valued (by revenue) at approximately US$1.67 trillion, and is expected to reach a market size of US$2.25 trillion by 2030, with a compound annual growth rate (CAGR) of 3.7%.[11] Fairfield Market Research expects the market size for green steel to increase, projecting a CAGR of over 122% from 2023-2030.[12] In this context, the shift towards green steel production and the potential for higher prices in green steel sales presents a major opportunity for companies and their investors.

As electric arc furnace (EAF) technology becomes more prevalent, the demand for high-quality steel, particularly advanced high-strength steel used in automotive applications, is expected to triple by 2030.[13] In the USA, 71% of steel is now produced using EAFs, utilising scrap steel as the primary input.[14] China anticipates it will grow its scrap-based EAF production share from 12% in 2022 to 34% by 2030.[15] The growing use of EAFs has potential far beyond its role in processing scrap steel, as EAF producers can use green direct reduced iron (DRI) as their main raw material to produce green steel.

Customers are currently demonstrating a willingness to bear higher prices to ensure low-emissions steel:

- Swedish steelmaker H2 Green Steel has a 25% premium on its steel.[16]
- SSAB, also a Swedish steelmaker, estimates the gross premium on steels with almost zero CO_2 emissions will be around EUR 300/tonne (US$325) by 2026, in line with the full implementation of the EU's Carbon Border Adjustment Mechanism (CBAM).[17]
- Japan's JFE Steel Corporation currently charges a 40% premium on its mass balance approach, which allocates emissions reductions to its specific steel product, "JGreeX".[18] Given the limitations of mass balance's material impact on emissions reduction however, it would be optimum that any revenue made should be reinvested into authentic green steel production.

[11] Zion Market Research, Iron and Steel Industry Prospective, Jan 2024
[12] Fairfield Market Research, Green Steel Market, August 2023
[13] Nakamizu, M., "Latest developments in steelmaking capacity 2023", July 2023, OECD
[14] Nicolas, S. & Basirat, S. December 2021, "New from old: The global potential for more scrap steel recycling," Institute for Energy Economics and Financial Analysis
[15] Kolisnichenko, V. 13 March 2023, "China plans to reduce coking coal consumption by 20-25% by 2030," GMK Center
[16] Attwood, J. 26 June 2023, "Green steel demand is rising faster than production can ramp up," *Bloomberg New Energy Finance*
[17] SSAB, 28 March 2023, "SSAB presents plan to strengthen its position towards 2030."
[18] JFE Holdings, "Climate change."

> "Our customers are demanding fossil-free products from SSAB. We can solve the technical challenges and we have a strong financial position. If we can resolve the question of power supply and environmental permits together with society, then we can make the transition 15 years earlier than the plan communicated previously. We can finance the plan through our own cash flow resulting in a broader product program and improved cost position".[19]
>
> "The green transition is possible and brings results … for example, the mechanical properties and performance of our fossil-free steels are the same as our existing grades. Their forming into parts is the same. The only difference is one steelmaking method is sustainable and the other is not."[20]
>
> Martin Lindqvist, President and CEO of SSAB.

Government policies are also shifting to drive green steel demand, with many nation states, including almost all OECD countries, enacting green public procurement (GPP) programmes and other policies.

Cost decreases on the horizon

While the initial adoption of new technologies in the steel industry incurs higher costs due to the additional capex, opex, and development expenses, these costs are forecast to decrease over time.

Recent research by Bloomberg New Energy Finance found that while on average green steel costs 40% more than unabated production today, these costs could fall so that by 2050, green steel costs 5% less than fossil-based processes.[21]

Cost decreases will come from:

- opex lowering though cheaper renewable power costs
- capex benefiting from economies of scale
- development costs reducing due to increased expertise.

In particular, green hydrogen costs are projected to decrease from around US$7/kg today to less than US$1/kg by 2050.[22]

[19] SSAB, 28 January 2022, "SSAB plans a new Nordic production system and to bring forward the green transition."
[20] SSAB, 29 March 2022, "The first vehicle made with fossil-free steel already exists."
[21] Attwood, J. 26 June 2023, "Green steel demand is rising faster than production can ramp up," *Bloomberg New Energy Finance*
[22] Ibid.

Green steel offtake agreements

Offtake agreements, where consumers commit to purchasing material that isn't yet produced, have become crucial mechanisms for locking in green steel demand and ensuring a stable supply chain.

Various sectors, including transportation, automakers, and construction, have shown significant interest in procuring green steel using these agreements, demonstrating the depth and breadth of consumer demand (see Table 2).

- Mercedes-Benz has partnered with H2 Green Steel (H2GS) to secure around 50,000 tonnes of green steel per year for its manufacturing plants in Europe and North America.[23]
- Automakers like Volvo and BMW have entered agreements with H2GS[24], SSAB[25] and HBIS[26] to obtain green steel and low-emissions steel.
- Cargill has signed a multi-year offtake agreement with H2GS.[27] This agreement not only secures a supply for Cargill but expands the availability of green steel to markets beyond the European Union.
- IKEA's agreement with H2GS for the delivery of green steel to be used in warehouse racking from 2026 onwards highlights the demand from the retail and logistics sectors.[28]

The prevalence of green steel offtake agreements within European companies highlights the region's proactive stance on decarbonisation, supported by robust financial structures and policy settings. It also highlights the need for wealthier nations, especially those with historic contributions to carbon emissions, to take the lead and invest in technologies with green potential.

[23]H2 Green Steel,7 June 2023, Mercedes-Benz and H2 Green Steel announce agreements in both Europe and North America
[24] Hill, J. 19 September 2023, "Volvo signs deal to buy 'near zero emissions' steel that is not made from coal"; H2 Green Steel, 19 August 2022, "H2 Green Steel and BMW Group sign final agreement on delivery of CO2-reduced steel"
[25] Volvo, 24 May 2022, "Volvo Trucks: First in the world to use fossil-free steel in its trucks"
[26] BMW, 4 August 2022, "BMW Group partners with HBIS to establish 'Green Steel' supply chain first to announce the use of 'Green Steel'"
[27] Cargill, 19 June 2023, "Cargill and H2 Green Steel sign multi-year offtake contract to supply near zero-emission steel"
[28] H2 Green Steel, 13 September 2023, "Ingka Group (IKEA) and H2 Green Steel sign agreement for the supply of green steel across its warehouse operations"

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Table 2: Cross section of public green steel offtake agreements, as of October 2023.

Company	Company headquarters	Sector	Steelmaker	Announcement date	Time supply commences	Destination of green steel
Bilstein Group	Hagen, Germany	Manufacturing	H2GS	Apr 2023	2026	Not disclosed
BMW	Munich, Germany	Automaker	H2GS	Aug 2022	2025	Not disclosed
BMW	Munich, Germany	Automaker	HBIS	Aug 2022	2026	Shenyang-made cars
Cargill	Minnesota, US	Multi-industry	H2GS	June 2023	Not disclosed	Not disclosed
Ford	Michigan, US	Automaker	TATA Steel Netherlands	Oct 2022	After 2030	Europe
General Motors	Michigan, US	Automaker	Nucor	Oct 2021	Q1 of 2022	Not disclosed
IKEA	Leiden, Netherlands	Retail	H2GS	Sep 2023	2026	Not disclosed
Mercedes-Benz	Stuttgart, Germany	Automaker	H2GS	June 2023	Not disclosed	Europe, North America
Mercedes-Benz	Stuttgart, Germany	Automaker	ThyssenKrupp	Apr 2023	2026	Not disclosed
Scania	Södertälje, Sweden	Automaker	H2GS	Jun 2023	2027	Not disclosed
Steel Processing Midlands (SPM)	Burntwood, UK	Steel processing	H2GS	Apr 2023	Not disclosed	UK
Volvo	Gothenburg, Sweden	Automaker	H2GS	Sep 2023	2026	Not disclosed
Volvo	Gothenburg, Sweden	Automaker	SSAB	May 2022	Q3 of 2022	Not disclosed
Zahnradfabrik Friedrichshafen (ZF)	Baden-Württemberg, Germany	Auto technology	H2GS	July 2023	2026	Not disclosed

Sources: Company announcements, ACCR

Challenges to the transition

The transition to global green steel production encompasses several significant challenges. In the sections that follow, we highlight the key areas that require attention and propose actionable steps for investors to facilitate, support and accelerate decarbonisation.

Renewable energy capacity and availability

The transition towards green steel production is intricately linked to the availability and capacity of renewable energy sources. Securing a stable, affordable, and sufficiently large supply of renewable energy is critical in decarbonising the sector, particularly for the production of green hydrogen and green iron, and powering EAFs. Electrification is also necessary for various other processes within the steelmaking value chain.

According to AFRY Management Consulting and the International Renewable Energy Agency (IRENA), meeting global steel production in 2021 with green steel would require 97.6 Mt of hydrogen and 1,371 GW of renewable energy.[29] To put this into perspective, the renewable energy capacity required is nearly half of the total global renewable energy generation capacity, underscoring the significant scale of resources needed for this transition. However, the world added 50% more

[29] AFRY & International Renewable Energy Agency, 28 September 2022, "Green Steel: decarbonising with hydrogen fueled production"

renewable capacity in 2023 compared to the previous year, with record growth from China, the USA, Europe and Brazil.[30] With well over 100 countries signing up to a pledge at COP28 to triple the world's installed renewable energy generation capacity by 2030, further acceleration is certain. Yet, financing gaps for developing countries remain a key challenge, risking uneven clean energy distribution globally.

Actions for investors:

- Fund renewable energy projects, particularly in developing countries, to increase the availability of green electricity and hydrogen for the steel industry.
- Advocate for supportive policies that facilitate the steel industry's transition to renewable energy and green production methods.

First Nations engagement for renewable energy

The huge growth in renewable energy projects necessary for green iron and green steel production requires companies to ensure that local First Nations people are engaged early in the planning of renewable projects and that the practice of gaining Free, Prior and Informed Consent (FPIC)[31] is followed to avoid delays and challenges to projects.

In Australia, a member of the First Nations Clean Energy Network has noted investing meaningfully in First Nations-led clean energy projects makes the transition more likely to succeed, can mean fewer legal delays, and a much-needed social licence to operate for resource companies.[32]

This opportunity is playing out in Western Australia, with a ground-breaking new partnership between renewable energy company ACEN and the Yindjibarndi people to create Yindjibarndi Energy. The CEO of the Yindjibarndi Nation states that the expansion of energy transition projects offers a pathway to forge a new model of engagement. Indigenous co-ownership of resource projects can mitigate community exclusion from project benefits, and ensure Indigenous peoples have agency over their land and economic development.[33]

[30] Wood, J. 8 February 2024, "The world added 50% more renewable capacity last year than in 2022" World Economic Forum,
[31] Free, Prior, and Informed Consent (FPIC) is a principle that requires obtaining the consent of indigenous peoples and local communities before undertaking activities that affect their lands, territories, or resources. FPIC ensures that these groups are adequately informed about projects in a timely manner, have the freedom to agree or disagree without coercion, and are involved in decision-making processes that respect Cultural Heritage.
[32] Fish, A. & Norman, H. 8 February 2024, "First Nations people must be at the forefront of Australia's renewable energy revolution," The Conversation.
[33] Woodley, M. & Donovan, B. 19 January 2024, "Unlocking Indigenous potential in mining regions: From stakeholders to shareholders," OECD.

Actions for investors:

- Emphasise the importance of Free, Prior and Informed Consent (FPIC) for new renewable energy projects.
- Seek to understand and promote locally appropriate opportunities for Indigenous engagement and co-ownership of the required renewable energy projects.

Geographic imbalances

While Europe is currently at the forefront of technological and product innovation, the majority of steelmaking capacity development occurs in Asia, particularly in China. Despite a noticeable shift towards EAF production in China,[34] the overall pace of decarbonisation in Asia is inconsistent with global decarbonisation goals. For example, India's expansion of coal-based blast furnace capacity[35] would potentially quadruple the country's steel emissions between 2021 and 2050[36] - jeopardising its 2070 carbon neutrality target.

Japan and South Korea, with limited natural resources, rely heavily on imports for raw materials, complicating their green steel transition. Their challenges are exacerbated by ageing infrastructure, high energy costs, and reliance on thermal power, hindering renewable energy integration for steel production.

On the other hand, the EU and USA, leveraging their industrial legacies, lead in steel innovation and sustainability. The EU's stringent regulations and renewable resources drive its green practices, while the USA's abundant scrap supply and the Inflation Reduction Act are catalysing a shift towards technologies with low-carbon potential.

A further critical aspect of this transition is the need for a steady supply of high-grade iron ores (>67% iron content) with minimal impurities, essential for the production of high-quality primary steel through DRI processes in EAFs. However, the global prevalence of lower-grade hematite ores (55-65% Fe) presents a significant challenge.

To address this, a number of companies are exploring innovative methods to incorporate these lower grade iron ores into the green steelmaking process. Among these companies, as illustrated in Figure

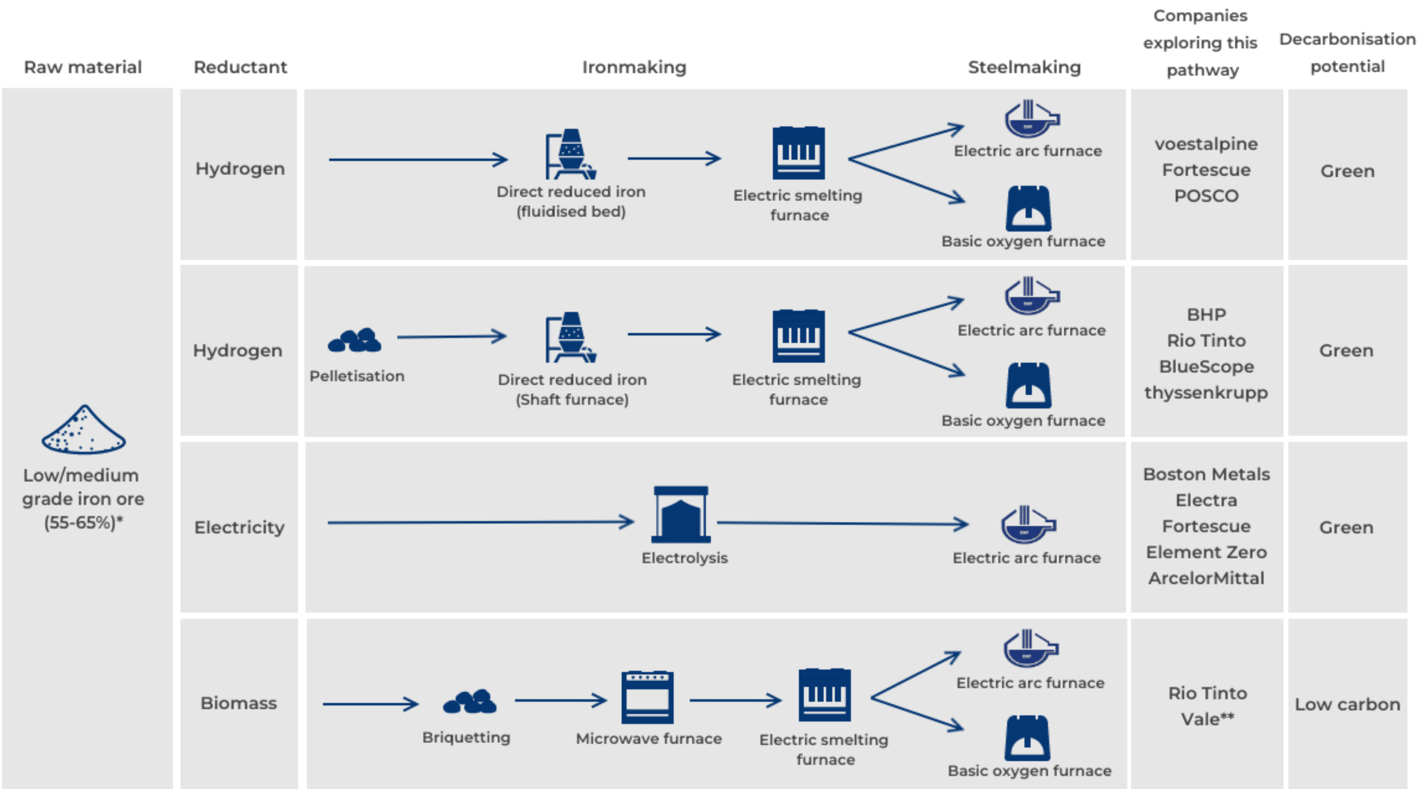
[34] S&P Global, "29 April 2022, "China's EAF capacity growth gathers pace in 2022 as steel sector tracks decarbonization goals"
[35] Basirat, S. & Nicholas, S. 14 February 2022, "IEEFA: India's technology path key to global steel decarbonisation," IEEFA
[36] Swalec, C. & Grigsby-Schulte, A. July 2023, Pedal to the Metal: it's time to shift steel decarbonisation into high gear," Global Energy Monitor

3, are industry giants such as Rio Tinto, BlueScope, BHP, POSCO,[37] ArcelorMittal,[38] voestalpine,[39] ThyssenKrupp, and Fortescue.[40] These initiatives may involve additional processing steps, such as the integration of an electric smelting furnace (ESF)[41] to remove impurities not eliminated in earlier stages. Underlining the importance of these efforts, competitors Rio Tinto and BHP have notably collaborated with Australian steelmaker BlueScope to develop this technology, a partnership that underscores the significant potential they see in this approach.[42] Additionally, ThyssenKrupp has already begun construction on their DRI plus electric smelter plant, which is set to be operational by 2026 and aims to run on 100% green hydrogen from 2029.[43] Beyond these methods, these companies are also investigating other decarbonisation routes for low-grade ores, such as electrolysis and biomass use.

Ultimately, the successful integration of these methods to process the world's dominant ore types will significantly enhance the feasibility of producing green steel at scale.

[37] POSCO, "Breakthrough hydrogen reduction ironmaking technology with near-zero emission"
[38] ArcelorMittal, 14 June 2023, "ArcelorMittal and John Corckerill announce plans to develop world's first industrial scale low temperature, iron electrolysis plant"
[39] Fortescue, 20 December 2022, "Fortescue, Primetals Technologies, and voestalpine to jointly evaluate groundbreaking green ironmaking plant"
[40] Ibid.
[41] Also referred to as an electric melter or reducing electric furnace.
[42] See recent announcement from BHP, BlueScope and Rio Tinto, 9 February 2024, "Australia's leading iron ore producers partner with BlueScope on steel decarbonisation"
[43] ThyssenKrupp, 1 March 2023, "ThyssenKrupp Steel awards a contract worth billions of euros to SMS group for a direct reduction plant: one of the world's largest industrial decarbonisation projects gets underway"; ThyssenKrup Newsroom, "Green light for the transformation"

Figure 3: Low- to medium-grade iron ore processing solutions being explored by steelmakers and iron ore miners



Source: Company data, ACCR

Actions for investors:
• Diversify green investments towards regions lagging in green steel production capability, particularly in Asia, to elevate their renewable energy capacity and technological capabilities.
• Promote cross-regional partnerships between leading and emerging steel-producing regions, facilitating technology and best practice sharing to harmonise global decarbonisation efforts.

Challenges in aligning financial practices with climate science and methane emission tracking

Companies, investors and financial institutions are increasingly playing catch up with the pace of climate science. Recent publications have highlighted that many financial models considerably underestimate the costs linked to the physical impacts of climate change. As Baer and colleagues (2023) noted, the current climate risk scenarios are sometimes misused, potentially leading to a systematic underestimation of the risks tied to climate change. Similarly, a 2023 report by the

Institute and Faculty of Actuaries[44] demonstrated a misalignment between climate science and the economic models guiding financial services' climate-scenario modelling. Such models lead to skewed risk evaluations that overlook devastating impacts, including sea level rise, heat stress, and possible tipping points.

It is therefore crucial for investors and financial institutions to update financial risk assessment methods to accurately reflect the latest climate science. This ensures well-informed decision-making and investment strategies that facilitate a prompt transition while effectively addressing climate and financial risks, including the repercussions of stranded assets and carbon pricing penalties.

Additionally, steel producers face challenges in tracking methane emissions, which have a global warming potential (GWP) 82 times greater than that of CO_2 over a 20-year period[45], and contribute significantly to their Scope 3 emissions.

Research has identified the underreporting of methane emissions as a serious climate issue.[46] Obtaining accurate methane measurements, especially in open-cut metallurgical coal mines, can be complex, due to the widespread and irregular release of methane across the mining area, making consistent monitoring challenging, yet not impossible.[47]

For steel companies reliant on coal, this means methane emissions in mining are an intractable concern, underscoring the need for a transition to alternative production methods.

Actions for investors:

- Update financial risk assessment models to accurately incorporate the physical impacts of climate change, ensuring investment strategies effectively address climate risks.
- Advocate for a just transition and phase-out of metallurgical coal in steel production, focusing on sustainable and low-emission alternatives.

Transition planning with workers and local communities

Enhanced disclosures around forward plans and timelines for technology changes will allow for just transition outcomes for workers and local communities. These signals can help ensure workforces

[44] Trust, S. et al., "The Emperor's New Climate Scenarios - Limitations and assumptions of commonly used climate-change scenarios in financial services", 4 July 2023, Institute and Faculty of Actuaries, United Kingdom Government,
[45] Denis-Ryan, A. 5 July 2023, "Gross under-reporting of fugitive methane emissions has big implications for industry," IEEFA
[46] Assan, S.& Whittle, E. 28 November 2023, "In The Dark: underreporting of coal mine methane is a major climate risk", EMBER
[47] Assan, S., "Tackling Australia's Coal Mine Methane Problem," 8 June 2022, EMBER

are well prepared for any changes, with additional training requirements and new career opportunities factored in as the steel value chain shifts towards more sustainable practices.

There can be strong support for green industries when workers are engaged respectfully on the changes. In Australia, for example, the Australian Manufacturing Workers Union (AMWU) has noted:

> The development of our green steel and green aluminium sectors will be instrumental in creating a green manufacturing sector that is sustainable and that creates thousands of long-term, high-quality and secure jobs for our members.[48]

There is an immediate role for investors to play in engaging companies to provide clarity on forward changes and to help ensure decent work in clean energy projects.

Actions for investors:

- Encourage companies to provide clear, detailed plans about upcoming technological shifts and their impact on the workforce.
- Advocate for programs that offer targeted green iron and steel processing training pathways for workers likely to be affected by the transition. This could also include advocating for internal job-matching policies able to efficiently transition affected workers within companies with diversified asset portfolios.

[48] Australian Manufacturing Workers' Union, 17 August 2023, "AMWU celebrates Labor's commitment to the most significant industrial transformation in generations."

3. Company analysis - Steel companies

ACCR reviewed 16 steelmaking companies, collectively representing 27% of global steel production (521 Mt) and 23% of global steel sector emissions. (See Appendix 1 for method). We selected these companies for analysis because they represent a cross-section of the industry's key players worldwide, and each are among the largest in their respective geographies. Data is accurate as of 22 December 2023.

Table 3. Steelmaking companies under examination: Location and production (2022).

Company	Headquartered location	Production (Mtpa)
Ansteel	China	56
ArcelorMittal	Luxembourg	59
BlueScope Steel	Australia	6
China Baowu	China	132
HBIS Group	China	42
JFE Steel	Japan	27
JSW	India	24
Kobe Steel	Japan	7
Nippon Steel	Japan	39
Nucor Steel	United States	20
POSCO	South Korea	39
SSAB	Sweden	7
TATA	India	30
ThyssenKrupp	Germany	11
US Steel	United States	16
Voestalpine Group	Austria	7

Sources: Company data; numbers are rounded.

Emissions profile

The absolute total emissions recorded for steelmakers in this study account for well over 2% of global carbon emissions in 2022. The majority of steel companies that disclosed carbon intensities had intensities above the global steel industry average (1.91 tCO_2e/t steel[49])[50], with many emitting substantially more carbon than the global average.

[49] World Steel Association, Sustainability Indicators 2023 Report: Sustainability performance of the steel industry 2004-2022, Nov 2023

[50] Carbon intensities also factors in some Scope 3 emissions where disclosed, according to the WSA website.

While a majority of steelmaking companies are transparent about their emissions, disclosure gaps and discrepancies in reporting remain. This lack of comprehensive and accurate disclosure makes it challenging to accurately assess and compare their performance against each other, as well as against global averages and targets.

Scope 1, 2 and 3 emissions

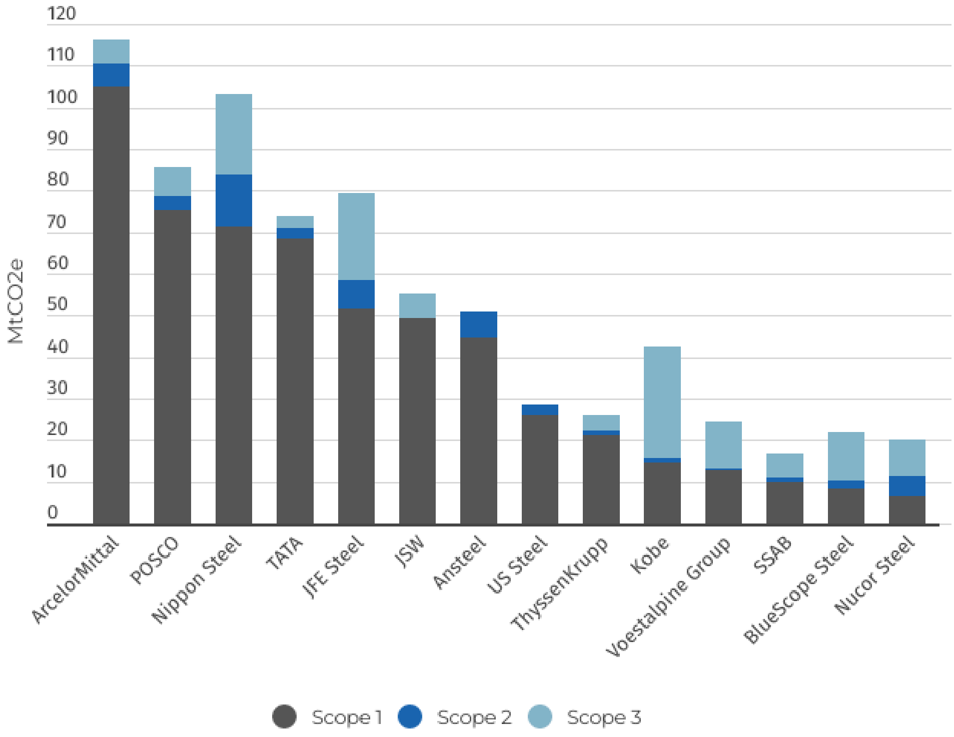
The absolute total emissions (Scope 1, 2, and 3) recorded for the steelmakers in this study amount to 0.74 Gt of CO_2 for the latest reporting year. The actual figure is likely much larger, due to gaps and discrepancies in company reporting:

- 14 of the 16 companies (88%) disclosed absolute Scope 1 and 2 emissions.
- 12 of the 16 companies (75%) disclosed their absolute Scope 1, 2 and 3 emissions.
- China Baowu and HBIS Group - which produced 131Mt and 42Mt of steel respectively in 2022 – did not provide any information on their Scope 1, 2 and 3 absolute emissions.
- Ansteel and U.S. Steel did not disclose their absolute Scope 3 emissions.

Additionally, ACCR believes methane emissions are significantly underestimated in these disclosures, often due to insufficient measurement and reporting efforts, as well as lenient reporting requirements that do not fully address the complexities of capturing methane's emissions footprint.[51]

[51] Methane emissions should be reported as carbon dioxide equivalents (CO_2e) to reflect their relative impact on global warming compared to CO_2, based on their global warming potential (GWP).

Figure 4: Absolute emissions for steelmaking companies by Scope ($MtCO_2e$). Latest reported emissions were used. HBIS and Baowu are excluded as absolute emissions were not disclosed



Sources: Company data

Carbon intensity

12 of the 16 steel companies analysed disclosed their steelmaking carbon intensities. Based on these disclosures:

- 57% had carbon intensities above the global average (1.91 tCO_2e/t steel[52]), including JSW Steel, TATA Steel, Kobe, JFE Steel, POSCO, ArcelorMittal, U.S. Steel, and Ansteel.

Of the four that did not disclose this information:

- China Baowu and HBIS Group did not disclose carbon intensity data
- ThyssenKrupp and voestalpine did not report their carbon intensity, however they did disclose their absolute emission and production volumes, allowing their carbon intensity to be calculated using the below equation.

$$Carbon\ emissions\ intensity\ =\ \frac{tonnes\ CO2\ (Scope\ 1 + Scope\ 2)}{tonnes\ crude\ steel}$$

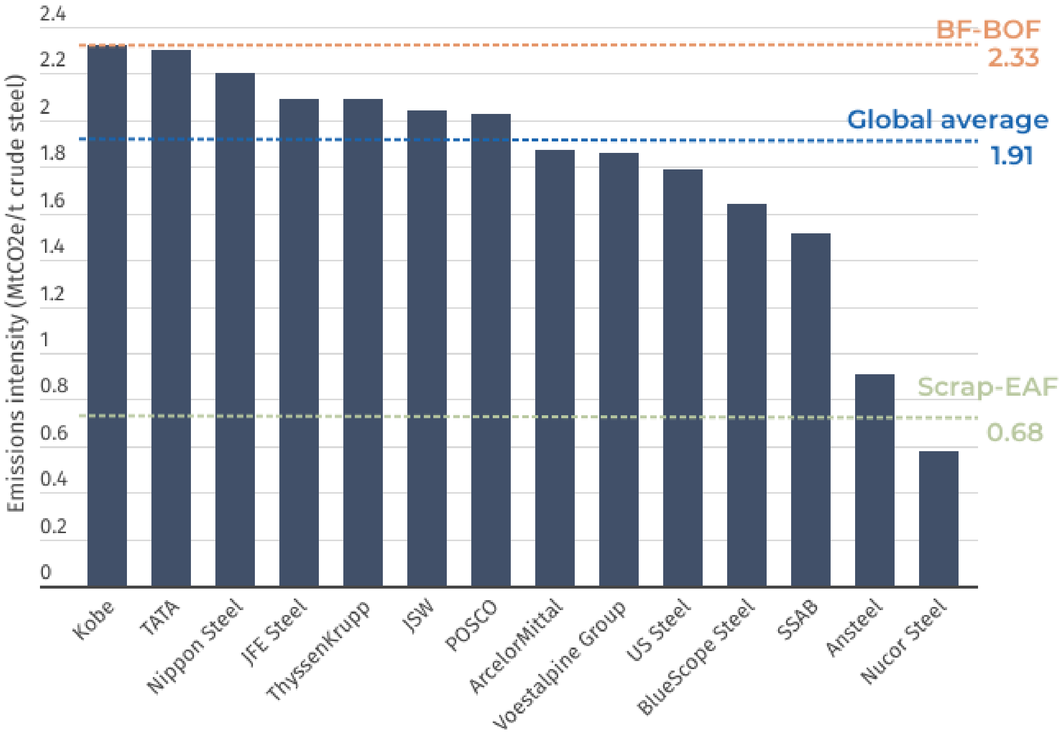
[52] World Steel Association, November 2023, Sustainability Indicators 2023 Report: Sustainability performance of the steel industry 2004-2022.

ACCR also applied this method to companies that disclosed both production volumes and absolute operational emissions, finding discrepancies between the reported carbon intensities of seven companies and the numbers sourced from its calculations.

These could be attributed to variations in the scopes or accounting boundaries used in their calculations, but for consistency, ACCR has chosen to use our calculated carbon intensities in the graph below.

The graph shows 44% of companies had carbon intensities above the global average: Kobe, TATA Steel, Nippon Steel, JFE Steel, ThyssenKrupp, JSW Steel and POSCO.

Figure 5: Carbon intensities for steelmaking companies (MtCO_2e/t crude steel). Horizontal lines indicate 2021 global average emissions intensities (WSA, 2022) for scrap steelmaking (green) and BF-BOF steelmaking (orange), and overall (blue)[53]



Sources: Company data, World Steel Association, ACCR

When analysing the carbon intensities of companies that use BF-BOF (blast furnace-based production) against the global average BF-BOF intensity (2.33 tCO_2e/t) ACCR found:

[53] According to the World Steel Association: in 2022, the global average steelmaking carbon intensity is 1.91 tonnes CO_2 per tonne of steel (tCO_2e/t steel) - factoring in Scope 3 emissions, where disclosed. The carbon intensity for blast furnace-based production was 2.33 tCO_2e/t steel and the carbon intensity of steel produced via the scrap-EAF route had an average global carbon intensity of 0.68 tCO_2e/t steel.

- using company disclosures, JSW Steel, with a carbon intensity of 2.36 tCO_2e/t, was the only steelmaking company with an emission intensity above the global average
- using ACCR's equation, Kobe Steel, with two carbon intensive blast furnaces in Japan and a calculated emissions intensity of 2.32 tCO_2e/t, and TATA Steel with a calculated emissions intensity of 2.3tCO_2e/t, were the only steelmakers whose emissions intensities aligned closely to the BF-BOF global average carbon intensity.

When analysing the carbon intensities of companies that use scrap-EAF against the global average (0.67 tCO_2e/t), we found:

- using company disclosures and ACCR's equation, only one company, Nucor, has steelmaking emissions below the global average carbon intensity for scrap-EAF.
  - Nucor predominantly engages in secondary steelmaking and was the seventh-largest corporate buyer of renewable energy in the USA in 2022.[54]
  - In its latest reporting, Nucor includes Scope 3 and non-steelmaking operations in its carbon intensity disclosures. This updated its carbon intensity to 1.075t CO_2/t steel and is the baseline for which the company is now measuring emissions reductions from, targeting a 9.3% reduction in intensity by 2030. Nucor's decision to include Scope 3 and non-steelmaking operations in its carbon intensity disclosures is a positive development in corporate transparency.

Using ACCR's equation, the average steelmaking intensity of the companies examined in this report was 1.8 t CO_2e/t steel (or 1.9 t CO_2e/t steel when excluding Nucor as a predominantly secondary steel producer), which is consistent with global averages.

While ACCR was able to obtain standardised results from its methodology, consistent data gaps and discrepancies in reporting remain. This is a critical barrier to understanding the industry's overall impact on global carbon emissions.

Climate commitments

The steel industry is actively committing to long-term decarbonisation, with nearly all the analysed companies (15 out of 16) setting ambitious net zero targets by 2050, alongside quantifiable medium-term reduction goals. (See Table 4 below for details of the companies' climate targets.)

However, our analysis reveals:

- short-term commitments are scarce, with a trend of backended commitments. This:

[54] Nucor, 2023,"Our greenhouse gas reduction target strategy."

  - suggests the steel industry is deferring the majority of its decarbonisation efforts to after 2030, raising concerns about its ability to meet net zero emissions targets and achieve Paris alignment.
  - highlights the need for rapid advances in company strategy and the adoption of new practices and technologies to avoid the lock-in of high-emissions processes.
- the use of peak emissions targets and the selection of baseline years during periods of high emissions further exacerbate the risk of delayed action and increased cumulative emissions.
- while companies are generally moving towards setting medium and long-term goals, the ambition of their targets varies. Upon recalibrating these targets against companies' respective 2022 emissions data (see Figure 6), this reliance on backended strategies also suggests companies will struggle to deliver the rapid and substantial emissions reductions their goals require.

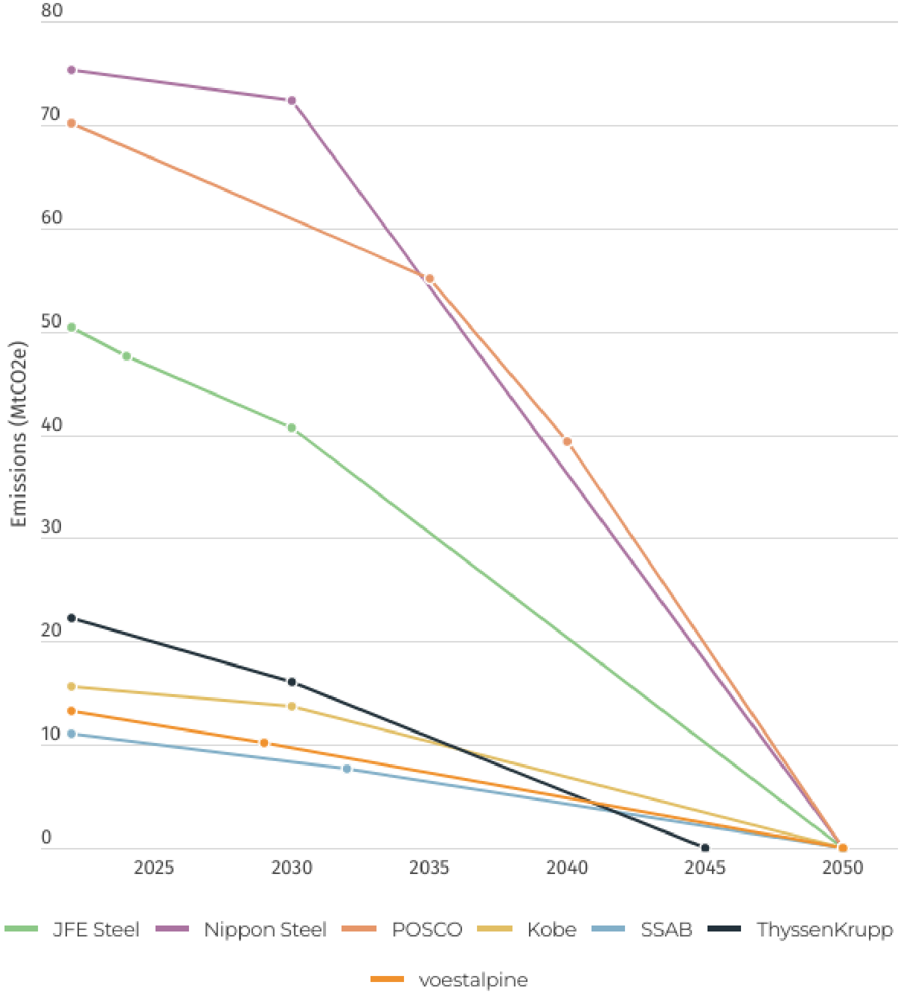
Table 4: Overview of steelmakers' climate commitments: Targets, SBTi alignment and net zero aspirations.

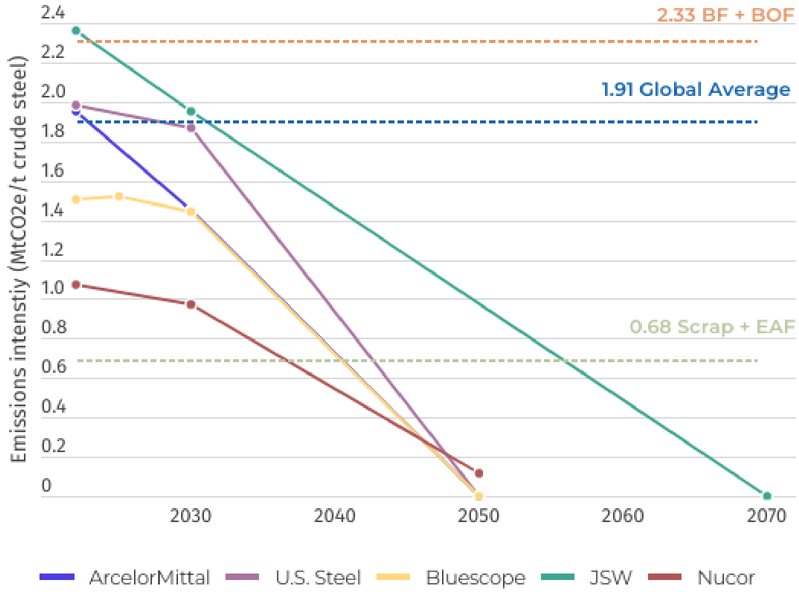
Company	Base year	Short-term target (up to 2026)	Medium-term target (2027-2035)	Long-term (2036-3050)	SBTi-aligned	Scope(s) covered by targets	Target type	Scope 3 targets	Additional details
Ansteel	2025	NA	30% in 2035	Net zero 2060	No	Not disclosed	Peak, absolute	NA	Ansteel are targetting 30% reduction from peak emissions in 2035. The company hopes to reach emissions "peak" by 2025.
ArcelorMittal	2018	NA	25% by 2030	Net zero 2050	No	1 & 2	Intensity	NA	ArcelorMittal's primary steelmaking operations are in line with SBTi's 2030 targets. However, this alignment does not account for its secondary production, which constitutes about 25% of its total output. ArcelorMittal set a group-wide reduction target of 25%, and an EU reduction target of 35% in emissions intensity by 2030. Committed to publish a science-based target with SBTi within two years (from 2021).
BlueScope Steel	2018	7% by 2025	12% by 2030	Net zero 2050	No	1 & 2	Intensity	NA	BlueScope's primary steelmaking operations are aligned with SBTi's 2030 targets, but there's ambiguity regarding the alignment of its secondary production, which accounts for approximately 40% of its total output. BlueScope aims for a 1% annual reduction in emissions from a 2018 baseline, targeting a 7% reduction by 2025 and a 12% emissions intensity reduction for its steelmaking activities by 2030. For non-steelmaking activities, it targets a 30% emissions intensity reduction by 2030.
China Baowu	2023	NA	30% by 2035	Net zero 2050	No	Not disclosed	Peak, absolute	NA	China Baowu aim to "have the process engineering capability to reduce carbon emissions by 30%" by 2025, and reduce emissions by 30% by 2035.
HBIS	2022	NA	30% by 2030	Net zero 2050	No	Not disclosed	Peak, absolute	NA	HBIS aim to reduce carbon emissions by 30% or more compared to carbon peak. The company aimed to achieve "carbon peak" in 2022.
JFE Steel	2013	18% by 2024	30% by 2030	Net zero 2050	No	1 & 2	Absolute	NA	JFE updated its target in Feb 2022 from 20% to 30% by 2030.
JSW Steel	2005	NA	42% by 2030	NA	No	1 & 2	Intensity	NA	JSW aim to reduce intensity to less than 1.95tCO_2/tcs by 2030, which is equivalent to a 42% decrease from its 2005 baseline. JSW Steel plans to have net zero operational emissions however has not committed to a timeframe to achieve this.
Kobe Steel	2013	NA	30-40% by 2030	Net zero 2050	No	1 & 2	Absolute	NA	Kobe's emissions targets are outlined in its medium-term management plan that was released May 2021.
Nippon Steel	2013	NA	30% by 2030	Net zero 2050	No	1 & 2	Absolute	NA	Nippon Steel's climate strategy outlining their emissions targets was released in March 2020.
Nucor Steel	2015	NA	0.975t CO_2/ t steel	Net zero 2050	No	1, 2 & 3	Intensity	Net zero by 2050	Nucor only operates EAF steel mills and was the 7th largest corporate buyer of renewable electricity in the U.S. through Virtual Power Purchase Agreements. Nucor's baseline carbon intensity is 1.075t CO_2/ t steel, which represents a reduction of 9.3% to 2030.
POSCO	2017-19 average	NA	30% by 2035	50% by 2040 Net zero 2050	No	1 & 2	Absolute	NA	POSCO updated its target in 2023 from 10% by 2030 to 30% by 2035.
SSAB	2018	NA	35% by 2032	Net zero 2050	Yes, Scope 3 not included	1 & 2	Absolute	NA	SSAB aim to largely eliminate operational emissions by 2030.
TATA Steel	2018	NA	UK: 30% by 2030 EU: 30-40% by 2030 Group-wide: NA	Net zero 2045	No	1, 2 & 3	Absolute	Net zero by 2045	TATA Steel's UK and European operations have measurable mid-term targets. However, TATA Steel has no group-wide mid-term target.
ThyssenKrupp Steel	2018	NA	30% by 2030	Net zero 2045	No	1, 2 & 3	Absolute	Net zero by 2045	ThyssenKrupp are looking to get SBTi verification of targets.
US Steel	2018	NA	20% by 2030	Net zero 2050	No	1 & 2	Intensity	NA	US Steel are exploring submitting a goal to the SBTi to advance its decarbonisation journey. Notably, US Steel states that it currently does not measure or disclose Scope 3 emissions, but is in the process of developing the data to make it available in the future.
Voestalpine	2019	NA	30% by 2029	Net zero 2050	Yes, medium-term target only	1& 2	Absolute	25% reduction by 2030	Voestalpine have set a 30% group-wide 2029 target, and a 50% reduction 2029 target for High Performance Metals Division. The company is also targetting a 25% reduction in Scope 3 emissions.

Green: Leader - Company target ahead of the NZE pathway/ SBTi aligned	Orange: Neutral - Company target in line with the NZE pathway	Red: Laggard - Company target behind the NZE pathway/ not SBTi aligned

Source: Company data, ACCR

Figure 6: Comparative analysis of steelmakers' climate targets from a 2022 baseline. The left side of the figure presents absolute emissions, while the right side displays carbon intensities. Companies that are not part of this analysis are listed in an accompanying table, which provides details on their lack of disclosures and the reasons for their exclusion.





	Commitments
TATA	TATA has committed to a group wide target of net zero by 2045. However, mid-term targets vary depending on location. TATA Netherlands and TATA UK are targeting emissions reductions ranging between 30-40% by 2030. TATA India has not set any measurable mid-term targets.
HBIS	HBIS aimed to reach a carbon peak in 2022, reduce emissions by 10% from this peak in 2025 and 30% by 2030. However, emissions are not disclosed.
Ansteel	Ansteel is targeting 30% emissions reduction from carbon peak in 2035. Ansteel expects to reach a carbon peak in 2025. Ansteel does report carbon emissions, however the use of a future baseline meaning reduction calculations are not possible.
Baowu	Baowu aims to reach carbon peak in 2023, reduce emissions by 30% from peak by 2035 and reach net zero by 2050. However, emissions are not disclosed.

Short-term (up to 2026) climate commitments

- JFE Steel and BlueScope were the only companies to set short-term targets. JFE Steel sets an absolute emissions target of 18% by 2024 (baseline year 2013). BlueScope aims for a 1% year-on-year reduction in carbon intensity from a 2018 baseline, equating to a 7% reduction by 2025.
- Three companies, China Baowu, Ansteel and HBIS Group, have established short-term peak emissions targets.[55] ACCR does not view peak targets as effective or appropriate climate commitments for companies because they:
    - allow companies to continue increasing emissions until the peak year, leading to higher cumulative emissions before any reduction efforts are implemented.
    - delay the immediate and significant emissions reductions required to limit warming to 1.5°C, as outlined in the Paris Agreement.
    - risk baseline manipulation. By setting an artificially high baseline for emissions reductions, it creates the illusion of more significant progress when reductions are made, as the reductions appear larger relative to the inflated baseline.

Medium-term (2027-2035) climate commitments

15 of 16 companies have set medium-term targets. These range in ambition from 12 to 42% reductions in emissions intensity or absolute emissions. Of these companies:

- JSW Steel in India is the most ambitious, targeting a 42% reduction of absolute emissions by 2030.
- SSAB also stands out with significant ambition, with a target to reduce emissions by 35% in 2032. SSAB's medium-term targets have also been approved as 1.5°C aligned by the SBTi. The company is looking to improve ambition and update its targets by 2025.
- TATA Netherlands aims to reduce emissions between 30-40% by 2030, however the TATA Group has not set company wide interim targets.

Long-term (2036-2050) climate commitments

14 of 16 companies have committed to achieving net zero emissions by 2050 or earlier. Two companies have not committed to net zero by 2050:

[55] A peak emissions target is a commitment to reach its highest point of emissions by a certain date, after which emissions will decline. China Baowu aims to develop the "process engineering capability" to reduce carbon emissions by 30% by 2025, and an actual reduction of 30% in emissions by 2035 based on this anticipated peak. HBIS Group reports it reached peak emissions in 2022, and is targeting a 10% reduction from peak by 2025. Ansteel anticipates peak carbon in 2025, and is targeting a 30% reduction from peak by 2035.

- Ansteel has a net zero target by 2060, in alignment with the Chinese Government's commitment.
- JSW Steel does not have a long-term commitment, despite an ambitious medium-term commitment to reduce emissions by 42% in 2030. (We have assumed JSW's net zero target aligns with India's target of net zero by 2070.)

Intensity vs absolute emissions targets

Among the 13 steelmakers without peak targets, five companies (ArcelorMittal, BlueScope Steel, JSW Steel, Nucor Steel, and U.S. Steel) have set targets for carbon intensity. However, these targets do not distinguish between primary and secondary production methods, as required by the SBTi Steel Sector Guidance.

Scope 3

Setting Scope 3 targets is distinctly rare in the steelmaking industry. Three of 16 companies have net zero emissions targets that explicitly encompass Scope 3 emissions - Nucor, Tata Steel, and ThyssenKrupp. Voestalpine has committed to a medium-term goal, aiming for a 25% reduction in Scope 3 emissions by 2030.

Targets

Science-Based Target initiative (SBTi) verified targets

The Science-Based Targets initiative (SBTi) recently published guidance for the steel sector, aiming for alignment with the 1.5°C Paris Agreement goal.[56] This guidance is crucial, as it delineates distinct decarbonisation pathways for primary and secondary steelmaking, highlighting why it is important for steelmaking companies to disclose their production proportions according to the method used.

- None of the companies analysed in this report have SBTi-verified targets aligned to its specific steel sector guidance.
- Only ThyssenKrupp[57], ArcelorMittal[58]and U.S. Steel[59] have indicated the intention to seek such verification.
- Two companies, SSAB and voestalpine, have partially aligned their emissions targets with SBTi's broader criteria.
- There is a need for rigorous, science-based target setting in the steel industry.

[56] Science Based Targets, September 2023, New guidance for the steel sector.
[57] SBTi, 1 March 2022, "Scaling up steel industry climate actions through science-based targets"
[58] ArcelorMittal, 29 July 2021, "ArcelorMittal publishes second group climate action report"
[59] US Steel, 8 April 2022, "Climate Strategy Report," p. 3

Paris-Aligned targets

ACCR examined two pathways: the IEA's Net Zero Emissions (NZE) Scenario, which focuses on reductions in absolute emissions, and the SBTi's 1.5°C carbon intensity-based reduction pathway.

While alignment with NZE is crucial, setting carbon intensity targets for the steel sector can be an effective measure of ensuring Paris alignment because:

- it emphasises the transition to less carbon-intensive processes
- the SBTi's steel guidance recognises the diverse nature of steel production by offering different carbon intensity pathways for companies producing primary steel (from raw materials) and secondary steel (from recycled materials), accounting for the varying levels of emissions inherent in different production methods
- by focusing on carbon intensity, tracking and encouraging the steel industry's adoption of technologies and processes with green and low-carbon potential is easier, which is an essential step for achieving the broader objectives of the Paris Agreement.

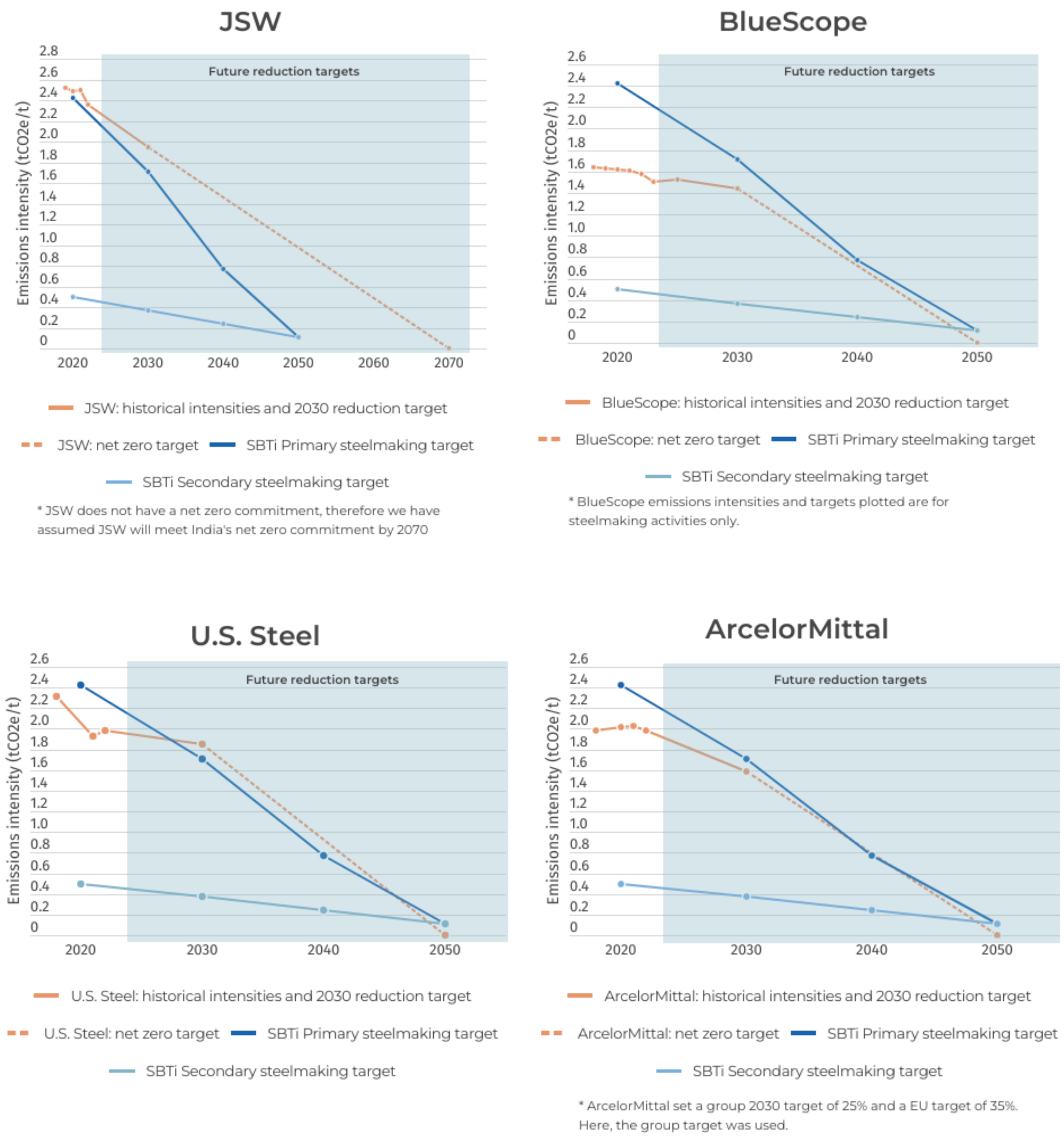
Assessing steel companies with carbon intensity targets

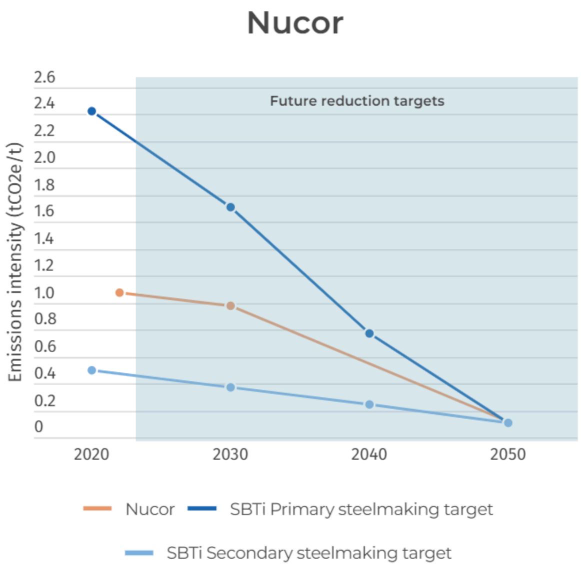
Among the 13 companies that disclosed either absolute emissions reduction targets or carbon intensity targets, five companies have set specific carbon intensity targets: US Steel, ArcelorMittal, JSW Steel, BlueScope Steel and Nucor.

The minimal disclosure from the five companies of their operational assets, and the carbon intensities of those assets, made it difficult to assess both the appropriateness of the companies' targets, and whether alignment with the SBTi's primary or secondary steelmaking carbon intensity targets is more suitable. ACCR has provided both SBTi targets in its graphs below.

Figure 7. Steelmakers with carbon intensity targets.

Figures compare company targets (orange) to the SBTi primary (dark blue) and secondary (light blue) steelmaking target guidelines. The blue highlight represents future carbon intensities targeted by the company.





Sources: Company data, SBTi Steel Guidance, ACCR

Of the five steelmakers that have carbon intensity targets:

- only BlueScope and ArcelorMittal appear to be on a SBTi-aligned primary steelmaking trajectory.
    - BlueScope's lower-than-average steelmaking carbon intensity can be attributed to its use of several electric arc furnaces in the United States, in contrast to operating just one blast furnace in Australia.
    - ArcelorMittal, with a disclosed carbon intensity of 1.98t CO_2/t steel, aims to reduce the carbon intensity of its operations by 25% in 2030. However, despite this ambition ArcelorMittal sees strong demand growth in India, with plans to build two new coal-based blast furnaces by mid-2026 in partnership with Nippon Steel.[60] This suggests the company is planning a two-speed decarbonisation plan - deploying decarbonisation measures in Europe, yet continuing to build carbon intensive assets in the global south. Investors should be concerned about how ArcelorMittal's Indian expansion plans conflict with its ambitious climate commitments.[61]
- JSW Steel is particularly misaligned to an SBTi primary steelmaking trajectory, despite setting a medium-term target of a 42% reduction in carbon intensity by 2030.[62]

[60] Obayashi, Y. "Nippon Steel says India JV with ArcelorMittal to spend $5 bln to boost capacity," *Reuters*, 28 September 2022
[61] Nicholas, S. & Basirat, S. 16 February 2023, "ArcelorMittal: Green steel for Europe, blast furnaces for India," IEEFA
[62] JSW Steel lacks a long-term climate commitment. For the purposes of our analysis, we've assumed their net zero target aligns with India's national goal of achieving net zero by 2070.

- Nucor's climate commitments fall short of what is required under a 1.5°C secondary steel pathway, according to the SBTi. Nucor recently announced science-based targets aligned with the GSCC Climate Steel Standard.[63] However, it is clear that these current carbon intensity targets are not aligned with what is required under a 1.5°C SBTi secondary steel production pathway.

For clearer accountability, companies should set distinct carbon intensity targets for primary and secondary steelmaking, reflecting the significant carbon intensity differences between these processes. The current general targets obscure alignment with SBTi's Primary or Secondary pathways, potentially favouring secondary producers with lower carbon intensities. Specific targets would correct this imbalance and enable a more precise evaluation of compliance with SBTi standards.

Assessing steel companies with absolute emissions reductions targets

Seven companies have set absolute emissions targets: JFE Steel, Nippon Steel, ThyssenKrupp, voestalpine, POSCO, SSAB, and Kobe Steel.

All exhibit a pattern of significant backloaded ambition, with planned steep declines in emissions primarily occurring post-2030. This delayed approach makes global climate goals harder to achieve and poses risks for investors, including risks of capital misallocation, exposure to stranded assets and a loss of market share as the economy shifts towards greener alternatives.

ThyssenKrupp, voestalpine, and JFE Steel appear to have strategies that are consistent with the IEA's Net Zero Emissions (NZE) trajectories, including medium-term goals. SSAB's alignment is projected to commence from 2030.

The three European steelmakers—ThyssenKrupp, voestalpine and SSAB—report significantly lower emissions compared to their Asian counterparts, with at least a threefold difference in emissions levels. This distinction is not merely a result of differences in production volume, but reflects regional variations in emissions efficiency and the potential for different regions to contribute to global decarbonisation efforts.

Asian steelmakers, namely Nippon Steel, JFE Steel, POSCO, and Kobe Steel, have all experienced periods of decline in emissions, which have corresponded with reductions in production. This trend suggests that production adjustments have been the primary driver of their downwards emissions trajectories, highlighting the complex relationship between production levels, operational efficiency, and emissions output.

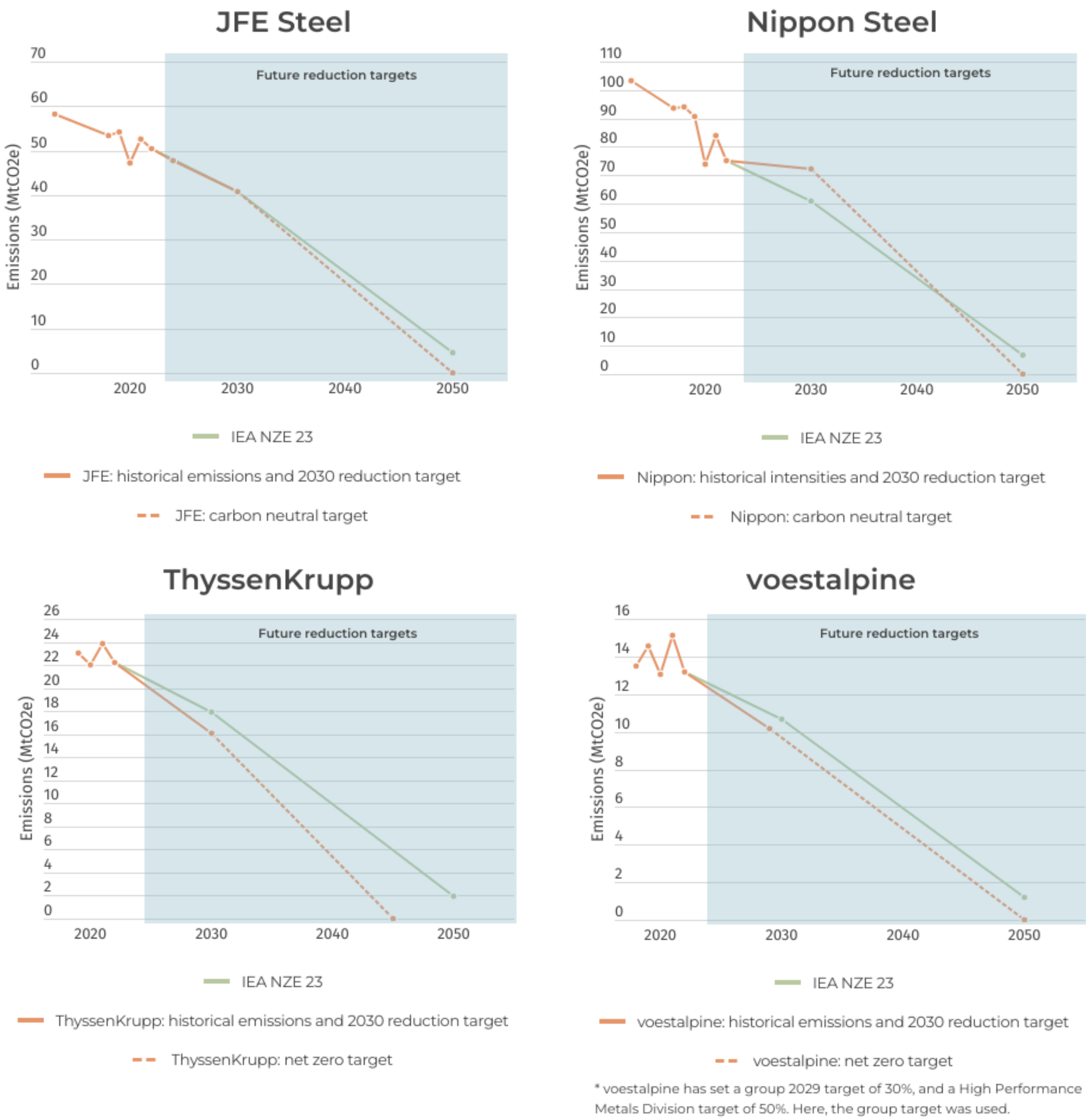
We believe that carbon intensity levels provide a more standardised metric for comparing and improving operational efficiencies across the industry. As the steel industry continues to evolve,

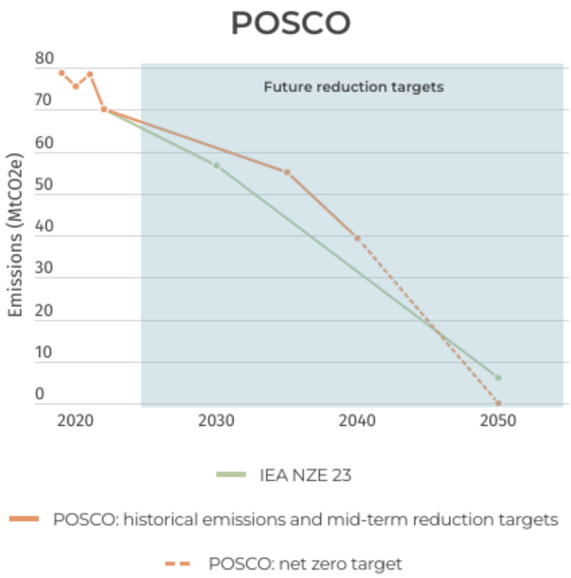
[63] Nucor, "Net Zero by 2050", November 2023

understanding and addressing these dynamics will be important for setting and achieving emissions reduction targets.

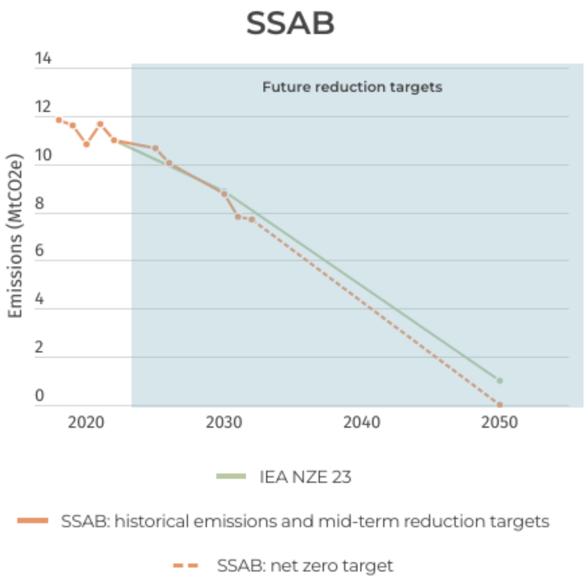
Figure 8: Steelmakers with absolute emissions reduction targets.

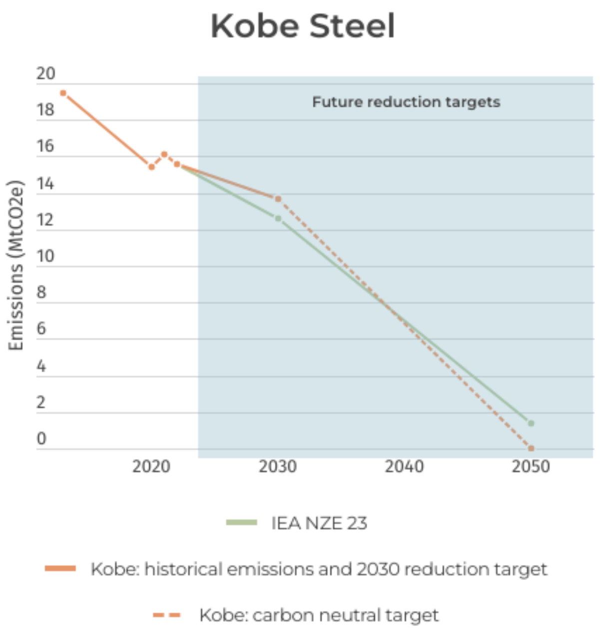
Figures compare company targets (orange) to the IEA NZE 2023 pathway (green) for each steelmaker. Company targets were calculated based on operational emissions ($MtCO_2e$) as reported for their baseline year. The IEA NZE pathway was calculated using each company's 2022 operational emissions ($MtCO_2e$) as a baseline. The blue highlight represents future absolute emissions targeted by the company.





* POSCO uses a 2017-19 average as their baseline. This baseline is plotted at 2019.





* Kobe's 2030 reduction target is 30-40%. Here, 30% was used.

Sources: Company data, IEA NZE 2023, ACCR.

Capital allocation

While a number of leading steel producers are making substantial financial commitments to the decarbonisation of their operations and supply chains, there is significant variability in their specificity of reporting, allocation of funds and timelines for investment.

Specificity in reporting

No company included in this study has disclosed the specific technology or decarbonisation pathways their capital was allocated towards. Additionally, no company has specifically aligned its disclosed investments with a projected abatement value. Most steelmakers have reported investments under the broader category of operational decarbonisation, or have only disclosed some specific amounts.

This lack of detailed reporting hinders the ability of shareholders to assess the effectiveness and direction of decarbonisation investments, and therefore complicates the ability of shareholders to assess financial and transition risks associated with these investments.

Differing timeline for investments

Some companies are focusing on immediate, short-term investments, while others have outlined longer-term financial commitments, reflecting varying strategies and timelines for decarbonisation.

Limited disclosure

A notable number of companies – including JSW, Ansteel, SSAB, ThyssenKrupp, voestalpine, Nucor Steel and U.S. Steel – have not disclosed their decarbonisation capital expenditures, making it challenging to fully assess the industry's financial readiness and commitment to reducing emissions from steel production.

Table 5. Steelmakers' disclosed capital allocations for decarbonisation

Company	Decarbonisation Expenditure
Ansteel	Not disclosed
ArcelorMittal	ArcelorMittal expect US$10 billion total investment is required to achieve 2030 Group decarbonisation target.
BlueScope Steel	BlueScope have allocated AU$150 million (US$102 million) to climate initiatives from 2022-2027 Estimated cost of AU$300-400 million (US$204-273 million) to meet 2030 targets.
China Baowu	Baowu's total investment in low-carbon development and upgrades expected to reach CNY 200 billion (US$28.25 billion) by 2035 (announced Nov 2021).
HBIS Group	HBIS spent CNY 3.1 billion (US$438 million) in "environmental protection" and CNY 128.1 million (US$18 million) in "environmental protection tech R&D" in 2022.
JFE Steel	Planned expenditure of JPY 1 trillion (US$7.2 billion) on low-carbon technology to achieve 2030 emissions target.
JSW	Not disclosed
Kobe	In FY2021, Kobe spent JPY 4.8 billion (US$34 million) on climate change.
Nippon Steel	Nippon Steel is expected to require JPY 4-5 trillion (US$28-35 billion) in capital expenditure to achieve net zero.
Nucor Steel	Not disclosed
POSCO	POSCO will invest KRW 20 trillion (US$15 billion) in technologies to cut emissions (announced Sep 22). POSCO's estimated cost of transitioning to carbon neutrality is approximately KRW 40 trillion (US$30 billion).
SSAB	Not disclosed
TATA	TATA Steel's capital expenditure on Social, Climate Change and Environment in FY2023 was INR 14.37 billion (US$172 million).
ThyssenKrupp	Not disclosed
US Steel	Not disclosed
Voestalpine Group	In March 2023, the Board of voestalpine AG approved EUR 1.5 billion (US$1.66 billion) in investment funding to build one electric arc furnace at each of the two sites, Linz and Donawitz.

Sources: Company annual reports

Investment in decarbonisation technology

The steelmaking industry is distributing its investments across technological solutions that vary in their potential to reduce emissions. This suggests a strategic yet cautious approach to decarbonisation, however with time ticking away, steelmakers need to be solidifying their pathways.

We found that while steelmakers have made significant investments in technologies with green steel potential, many continue to rely on technologies with limited emissions reduction potential, including CCUS.

1. **Steelmakers are concentrating decarbonisation efforts on ironmaking**

We identified 119[64] announced decarbonisation projects across the 16 steelmakers as of 22 December 2023.[65] Of these:

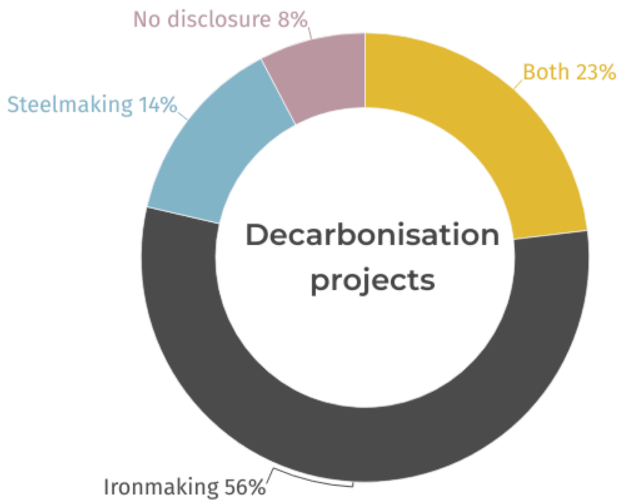
- 65 projects (56%) target the ironmaking stage of steel production

[64] This report covers 119 unique projects, with the total reaching 158 when including collaborative efforts among companies, leading to some projects being counted more than once. This includes nine projects which do not have sufficient disclosures for analysis.
[65] For the full table and further details, go to the steel sector announcement tracker webpage ACCR is keeping updated at https://www.accr.org.au/companies/steel_sector

- 16 projects (14%) focus on decarbonising steelmaking, predominantly through investments in large-scale Electric Arc Furnace (EAF) development.

Given that ironmaking accounts for more than 90% of process emissions, these decarbonisation projects are appropriately targeting the most emissions-intensive stages of steel production.

Figure 9. Steelmaker decarbonisation projects by process

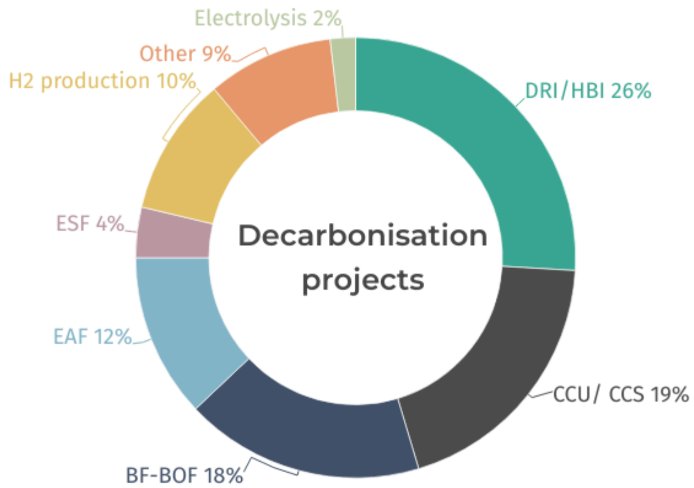


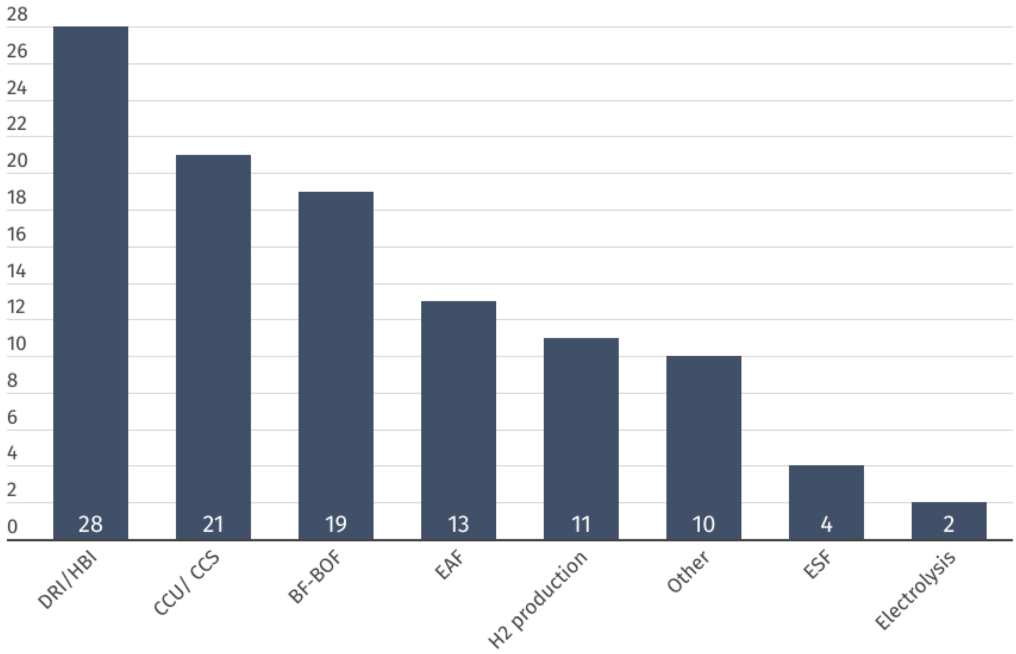
Sources: Company data, ACCR

NB: "Both" category is predominantly CCU/CCS, mass balance approaches, and any projects that seek to tackle both ironmaking and steelmaking emissions.

2. **Steelmakers have a preference for green iron production with green hydrogen, blast furnace optimisation and CCUS technology.**

Figures 10a and 10b. Steelmaker decarbonisation projects by technology





Sources: Company data, ACCR

3. **The most prevalent technology being advanced in 28 projects is green iron production (DRI/HBI).**

This trend reflects the market's increasing acknowledgment of the necessity for fossil-free production methods at the initial stage of steel production, as well as a potential industry consensus that DRI-EAF represents the future path for green steel.

The majority of companies developing green iron are channelling investments into green hydrogen production – a critical component of green iron and steel – with 11 projects in the pipeline.

A lesser number, including ArcelorMittal, Kobe, Baowu and JFE, are investing in assets for producing DRI/HBI with gas. This indicates a potential shift away from traditional integrated iron and steelmaking processes, with three projects in the Middle East and North Africa region aiming to produce low-carbon iron using regionally available gas for emissions reductions over the short to medium-term.

4. **Carbon Capture, Utilisation, and Storage (CCUS) continues to be explored, despite its challenges.**

We found 21 projects investigating the use of CCUS. Despite decades of development, CCUS remains unproven at scale,[66] often characterised by high capital expenditures and uncertain long-term

[66] Robertson, B. & Mousavian, M. 1 September 2022, "Carbon capture: a decarbonisation pipe dream," IEEFA

viability. This is further complicated by the multiple sources of CO_2 from the BF-BOF process, and the technical feasibility and storage constraints, presenting a complex challenge unlikely to yield meaningful reductions.[67]

This persistence in CCUS investment in steel decarbonisation may reflect the industry's exploration of all possible options, yet it also underscores the need for a critical evaluation of its practicality and cost-effectiveness in achieving substantial emissions reductions.

5. **Blast furnace optimisation, including hydrogen and plastic injection into the blast furnace, is a predominant strategy, particularly among Asian companies like Nippon Steel, TATA Steel and JSW Steel.**

Technologies such as COURSE 50 and Super COURSE50[68] primarily depend on CCS to reduce emissions. However, this approach has a critical limitation: it continues to rely on coal, even though the exact mix of coal to hydrogen, and in some cases, plastic, remains unclear. These factors cast doubt on the potential for these technologies to drive significant decarbonisation.[69]

6. **The mass balance approach is currently employed by major steel producers, including JFE, Kobe, Nippon, POSCO, ArcelorMittal and TATA Steel, despite presenting a significant set of limitations.**

This is an incremental and less impactful solution, whereby a company markets a portion of their production as 'green', even if produced in mixed processes. If the mass balance approach is to be used, it should be employed transitionally, with revenues generated from green premiums clearly and transparently reinvested in decarbonisation solutions that are proven to reduce emissions at the necessary scale.

7. **Electrolysis, as a newer technology, represents a smaller cohort within the industry.**

Electrolysis, a method with potential for zero-carbon steel production, uses electricity to convert low-grade iron ore into iron. This process avoids the use of traditional fossil fuels, yet requires a considerable amount of renewable energy. Companies such as ArcelorMittal, Boston Metals, and Electra are actively developing this technology. Additionally, it has attracted investments from steelmakers like Nucor Steel and iron ore miners including BHP, indicating a growing interest in electrolysis as a cleaner alternative for iron production.

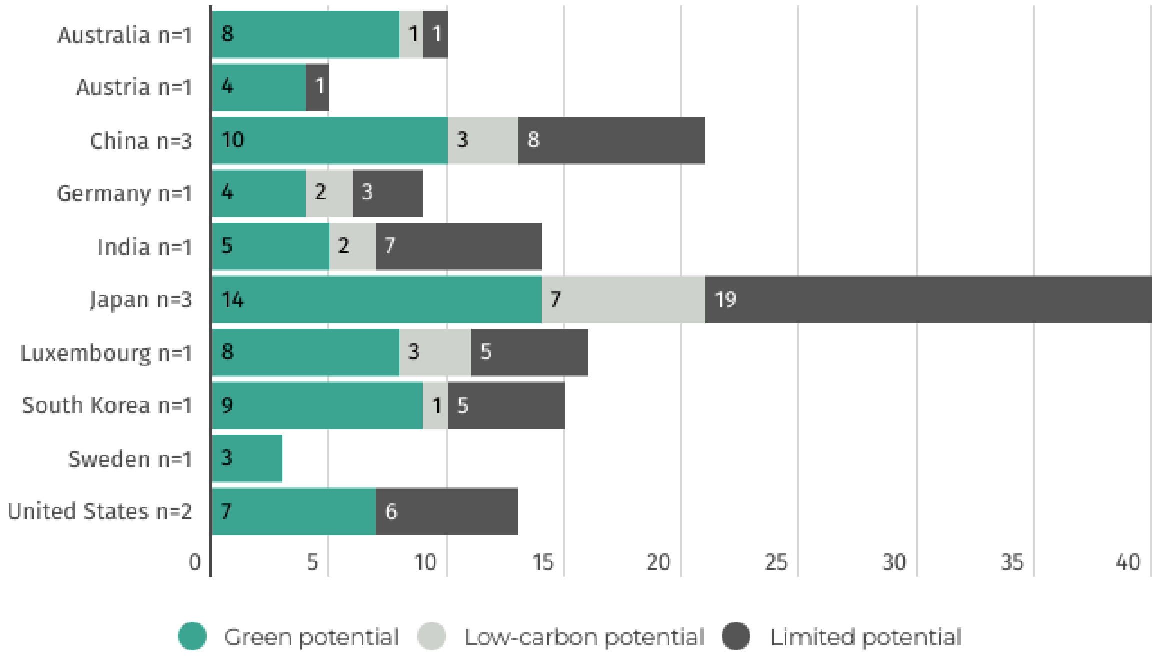
[67] Cavaliere, P. 19 July 2019, "Clean ironmaking and steelmaking processes - Chapter: Carbon capture and storage: Most efficient technologies for greenhouse emissions abatement," p. 485, DOI:10.1007/978-3-030-21209-4_9
[68]See Nippon Steel, 4 August 2023, "Development hydrogen injection technology into blast furnace (Super Course50)"
[69] Nishida, Y. et al. February 2023, "The path to green steel: pursuing zero-carbon steelmaking in Japan"

Global investment trends

With half of all projects demonstrating green potential, there is a clear momentum towards sector-wide decarbonisation.

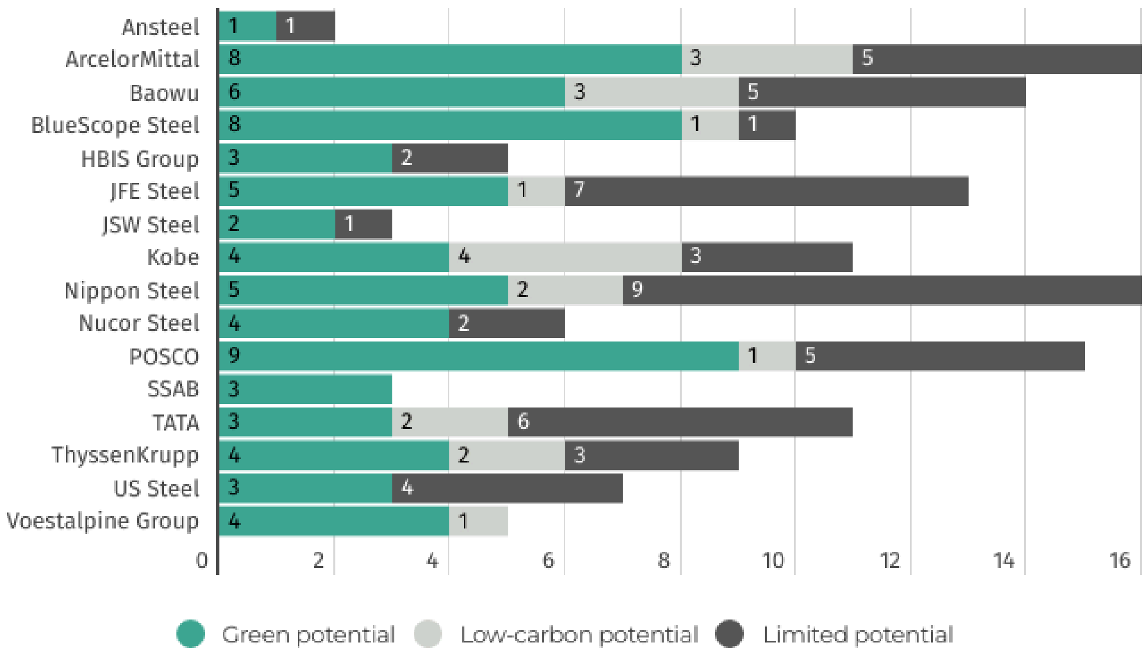
- Companies in the Austrian and Swedish steel markets, as the dominant players in their respective jurisdictions, are primarily focused on green potential initiatives. Their strategic investment in projects with a higher likelihood of meaningful emissions reduction shows how targeted efforts can lead to more sustainable steel production.
- European companies have demonstrated a pronounced inclination towards investing in green potential steel technologies, driven by competitive advantages like early industrialisation. This has provided them with greater access to scrap steel and renewable energy sources, facilitating a smoother transition to greener technologies. Additionally, the introduction of carbon pricing via the CBAM and public subsidies further support this transition.
- While Asian companies- including JFE, Nippon Steel and Tata- have also made substantial investments in green potential solutions, they have tended to favour a majority of decarbonisation projects with limited potential for emissions reduction.
- Investment trends in Asia, particularly in Japan, reflect a critical juncture. Despite not sharing Europe’s historical advantages, Asian companies have a significant opportunity to intensify their commitment to impactful green technologies, leveraging their advanced technological capabilities and market influence. By realigning investment portfolios towards more ambitious and effective decarbonisation strategies, these companies can significantly contribute to global sustainability goals and enhance their competitive stance in the evolving green steel market.
- In the USA, the approach to green steel production is notably divided, reflecting both a strong commitment to innovation and a lingering adherence to traditional methods. While this region has seven green potential projects, the simultaneous investment in six projects with limited potential suggests a cautious approach within the industry.
- The Chinese steelmakers also present a range of technology solutions, with initiatives spread across all three categories, including a notable number of limited potential projects. This reflects a transitional phase in the country's steel industry, moving from traditional methods to greener alternatives. However, the significant level of investment in limited potential solutions suggests the need for a more decisive shift towards technologies with green or low-carbon potential.
- More than a third of the projects still focus on solutions with limited potential to reduce emissions. Predominantly, companies in this category have invested in CCU/ CCS, a technology with limited applicability and proven effectiveness in the steel sector.

Figure 11: Steelmakers decarbonisation projects, by country and green potential



Sources: Company data, ACCR

Figure 12: Steelmakers decarbonisation projects, by company and green potential



Sources: Company data, ACCR

The transition to green steel production is characterised by a diverse array of strategies and commitments among key industry players. In examining company-specific data, we make the following observations:

- SSAB and voestalpine demonstrate a more focused commitment to green steel production, with almost all disclosed projects falling under the green potential category. The approach positions them as potential leaders for industry-wide transition, highlighting the importance of a clear and dedicated strategy for achieving substantial emissions reduction.
- ArcelorMittal's approach to decarbonisation is multifaceted, having spread its investments across a diverse range of technology options and levels of green steel potential, showcasing uncertainty about the company's future direction in decarbonisation. While this diversification might appear beneficial, it underscores the necessity for well-defined decarbonisation pathways, as well as strong advocacy and investment to facilitate and accelerate these pathways. Furthermore, this approach raises concerns about the efficient use of shareholder funds, as investing in limited potential decarbonisation solutions might not yield the long-term returns or emissions reduction impact necessary for sustainable progress.
- BlueScope Steel's commitment to green steel production is evident in its significant investment in projects with green potential. However, it's noteworthy that the company is also investing over 1 billion AUD in relining its blast furnace in Australia,[70] a move that underscores the complexity of transitioning to greener practices within existing infrastructural constraints.
- JFE Steel and Nippon Steel have shown a tendency towards investing in projects with limited potential for decarbonisation. This trend may reflect the current challenges and perceived barriers within Japan's steel and renewable energy industries. However, leveraging their status as major steel producers, JFE and Nippon Steel could play a pivotal role in shifting industry norms. By advocating for policies that enhance Japan's renewable energy capacity and transmission or by fostering collaborations for the import of green iron, these companies have the potential to significantly influence Japan's path towards more sustainable steel production.

[70] Fernandez, T. & James, M. 21 August 2023, "BlueScope Steel to reline coal-fired blast furnace at Port Kembla, reports $1b after tax profit," ABC.

Table 6: Analysis of the quality and transparency of steelmakers decarbonisation projects.

Company	HQ Region	Total projects with clear research areas and objectives	% projects with clear objectives and green potential	% projects with limited potential	% progressed to pilot	% projects with spend or investment disclosed
JFE Steel	Asia	11/13	15.4%	53.8%	23.1%	15.4%
Nippon Steel	Asia	8/16	6.3%	56.3%	25.0%	0.0%
POSCO	Asia	6/15	26.7%	33.3%	13.3%	46.7%
China Baowu	Asia	11/15	26.7%	40.0%	33.3%	33.3%
TATA Steel	Asia	6/15	20.0%	33.3%	26.7%	13.3%
JSW Steel	Asia	2/5	20.0%	20.0%	20.0%	20.0%
Kobe	Asia	9/11	18.2%	27.3%	54.5%	9.1%
Ansteel	Asia	1/2	50.0%	0.0%	50.0%	50.0%
HBIS Group	Asia	5/7	28.6%	28.6%	71.4%	42.9%
ArcelorMittal	EU	15/15	46.7%	20.0%	46.7%	53.3%
SSAB	EU	3/3	100.0%	0.0%	100.0%	66.7%
ThyssenKrupp	EU	6/10	20.0%	40.0%	50.0%	30.0%
Voestalpine	EU	5/5	60.0%	20.0%	100.0%	40.0%
BlueScope Steel	Oceana	6/10	40.0%	10.0%	0.0%	30.0%
Nucor Steel	US	6/6	66.7%	33.3%	50.0%	33.3%
US Steel	US	3/8	25.0%	50.0%	25.0%	12.5%

Sources: Company data, ACCR

Steelmakers' decarbonisation projects differ markedly across regions, with European companies leading in quality and transparency. Our analysis, detailed in Table 6, evaluates the decarbonisation initiatives based on their clarity of objectives, green potential, and the level of investment disclosure.

- European steelmakers stand out for their commitment to high-quality, transparent projects. They lead in initiating projects with clear objectives and green potential, advancing more projects to the pilot phase, and disclosing investment details more frequently.
- In the United States, steelmakers show divergent approaches. Nucor distinguishes itself with greater transparency and a focus on projects with substantial decarbonisation potential, unlike U.S. Steel, which undertakes a broader array of projects but with less clarity and potential for emissions reduction.
- Quantity of projects does not always indicate their quality. SSAB, despite developing the fewest projects, ensures each one has explicit objectives and significant green potential. On the other hand, Nippon Steel is pursuing the most projects, but half of its initiatives lack

clear goals, more than half only offer limited emissions reduction potential, and there is no investment disclosure attached to any project.

Whilst the quantity of decarbonisation projects is positive, it is the quality and transparency of these initiatives that will genuinely propel decarbonisation. Transparent disclosure of objectives and investments is crucial for effective emissions reduction, serving both as a measure of accountability and as a key driver of decarbonisation efforts. Steelmakers must enhance their disclosures to prioritise both quality and transparency.

Timelines for green steel production

While it remains unclear when the majority of legacy companies analysed in this report will fully transition to green steel production, the industry is witnessing a spectrum of initiatives, from Memorandums of Understanding (MoUs) to large-scale demonstration plants, and even a few projects reaching commercial stage. This indicates a gradual but definitive shift in the industry's approach to decarbonisation.

Table 7 offers only a cross-section of the projects announced and analysed, yet it serves as a representative snapshot of the overall momentum and stage of development within the industry. It shows that while there are key projects with defined stages and project types, the overall landscape is one of varied maturity and uncertain timelines for large-scale green steel production.

Table 7: Global green steel ventures

Green steel ventures	Plant/facility location/s	Production forecast	Technology	Raw material and quality required	Money raised/invested	Expected time operation commences
H2 Green Steel	Boden, Sweden	5Mt/yr by 2030	Green H2-based DRI-EAF	High grade iron ore in pellet/lump form	EU 2.1bn in equity since launch in 2021	2025
Hybrit	Gällivare, Sweden Oxelösund, Sweden	1.2Mt/yr	Green H2-based DRI-EAF	High grade iron ore in pellet form	EU143M from EU under Innovation Fund, EU30M from SSAB and EU5M from LKAB	2026
Blastr	Inkoo, Finland	2.5Mt/yr steel 6Mt/yr pellets	Green H2-based DRI-EAF	High grade iron ore	- US$10M from Cargill in ongoing series A funding round - Inkoo is expected to be EU4bn investment total	2027-2028
Boston Metal	Woburn, Massachusetts Minas Gerais, Brazil	A plant will make 1-2Mt/yr	Molten Oxide Electrolysis	All iron ore grades	Over US$350M as of Sep 2023	Commercial deployment 2026; Industrial production 2028
Electra	Bolder, Colorado Boston, Massachusetts	A plant will make ~300,000t/yr	Low Temperature Electrolysis	Low iron ore grades (<55% Fe)	US$85M as of Oct 2022	Demonstration plant expected by the second half of this decade.
Element Zero	Port Headland, Western Australia	2.7 Mt/yr iron	Low Temperature Electrolysis	All iron ore grades	US$10M in seed funding	Not yet disclosed

Sources: Company announcements and news

The green steel market is materialising rapidly, with substantial investments and ambitious production forecasts coming from emerging green steel ventures. These initiatives are small-scale, but these new players are poised to significantly disrupt the traditional steel industry this decade, potentially unlocking larger-scale green steel production using their substantial financial backing.

4. Company Analysis - Iron ore companies

ACCR reviewed four iron ore companies, representing 41% (1.1 Gt) of global iron ore production. The collective Scope 3 emissions of these four companies represent 54% of the global steel sector's emissions. We selected these companies as they represent the four largest global producers of iron ore. ACCR uses the same methodology as for the analysis of the steelmaking companies. (See Appendix 1).

Table 8. Overview of iron ore companies: location and production (2022)

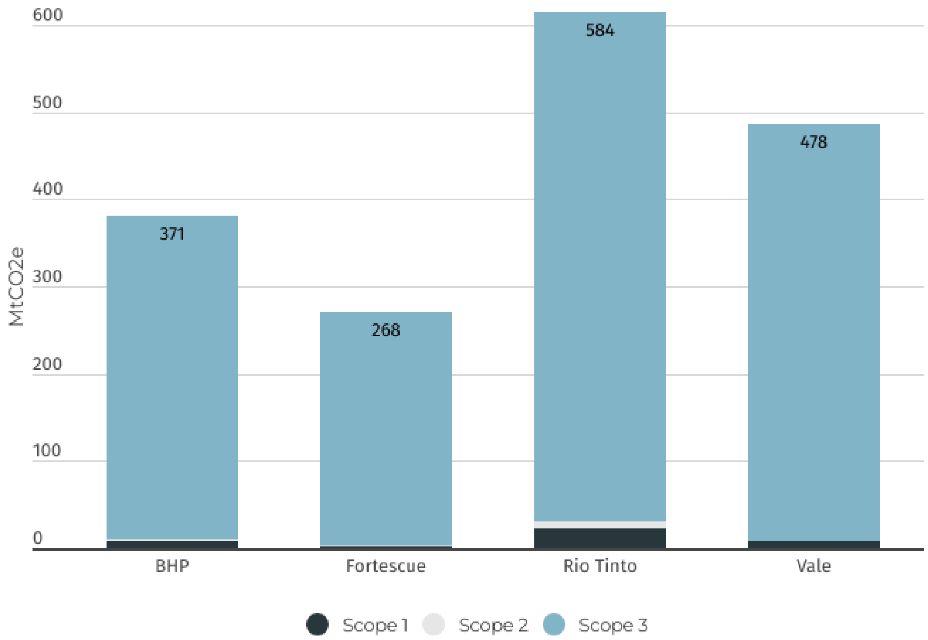
Company	Headquartered location	Production (Mtpa)
BHP	Australia	257
Fortescue	Australia	229
Rio Tinto	Australia	273
Vale	Brazil	308

Sources: Company data; numbers are rounded.

Emissions profile

Scope 3 emissions, predominantly from steelmaking, significantly dominate the total emissions profiles of iron ore miners, accounting for more than 95% of their total emissions footprint (see Figure 12).

Figure 12. Iron ore miners' emissions by scope ($MtCO_2e$) according to the latest available disclosures.



Sources: Company data, ACCR

These emissions pose significant business risks, including regulatory pressures, loss of market share, reputational damage, and threats to financial stability. The global shift towards green steel production, particularly through DRI-EAF processes, presents clear challenges. The predominant ores mined globally, exported by the miners examined in this report, do not meet the high-grade requirements for these processes.

This leaves iron ore miners with limited options: they can either improve the ore quality for export and produce green iron in alignment with the industry's low-emission goals, or opt to invest in CCS technology. The latter option does not require significant changes to current operations but is unlikely to meet the long-term needs of a decarbonising global economy.

Efforts to tackle Scope 3 emissions

Miners are beginning to make strategic investments and form partnerships aimed at reducing their Scope 3 emissions. Their unique position within the supply chain grants them substantial influence over the decarbonisation of ironmaking, the most carbon-intensive phase of steel production.

To accelerate the adoption of cleaner technologies and practices upstream of the steel supply chain, iron ore miners will need to strategically leverage their geographical locations, natural access to renewable energy and technological capabilities. This could help decouple ironmaking from integrated steelmaking, allowing ironmakers to supply green and low-carbon iron to steelmakers in regions such as Japan and South Korea, who have limited access to the renewable energy capacity required to green their entire steelmaking process.

As the demand for green steel grows, proactive engagement and innovation from iron ore miners to reduce their Scope 3 emissions can not only shape their future in a low-carbon economy, but also influence the overall trajectory of the steel industry's decarbonisation efforts.

Targets

Given the significant risk and impact associated with Scope 3 emissions in the mining sector, establishing robust climate targets is crucial. BHP, Fortescue, Rio Tinto and Vale are exploring opportunities to decrease Scope 3 emissions, but ambition and clarity in Scope 3 targets varies.

Table 9. Iron ore miners' quantifiable Scope 3 emissions reduction targets and goals related to steelmaking.

Company	Mid-term (2025-2035)	Long-term (2036-2050)
BHP	**Goal**: to support technologies capable of 30% emissions reduction in steelmaking by 2030 (FY20 baseline)	Net zero **goal** by 2050
Fortescue	**Target:** 7.5% emissions intensity reduction in steelmaking by 2030 (FY21 baseline)	Net zero **target** by 2040
Rio Tinto	**Targets:** - support customers to reduce emissions from blast furnaces by 20-30% by 2035 - 50% reduction in Scope 3 emissions from Iron Ore Canada by 2030 (7Mt CO_2), subject to technical feasibility and funding approval.	None
Vale	**Target**: 15% reduction for all scope 3 emissions by 2035 (FY18 baseline)	None

Sources: Company climate reports

- While Fortescue sets a precedent with a net zero by 2040 target, its interim target of only a 7.5% reduction in emissions intensity by 2030 seems modest against the backdrop of the urgent need for climate action. The decade-long gap between the 2030 target and 2040 net zero target raises questions about the pace and feasibility of its proposed emissions reduction pathway. Despite this, Fortescue's explicit long-term commitment does reflect a level of ambition that is commendable.
- Rio Tinto and Vale have not articulated long-term Scope 3 emissions targets, focusing instead on medium-term strategies. This lack of long-term vision reflects a cautious approach to perceived uncertainties around technological and regulatory developments, and does little to assure investors of their commitment to substantial, long-term climate action.

    - Rio Tinto is further pursuing "non-quantifiable" targets in the short term, including the commissioning of the BioIron™ continuous pilot plant, delivering a DRI and electric smelting pilot plant with a steelmaker (BlueScope Steel), and finalising a study on a beneficiation pilot plant in the Pilbara by 2026.[71] Despite these positive steps, the absence of a long-term Scope 3 emissions target contributes to further market uncertainty about the extent of the company's commitment to reducing emissions.
    - Vale's Scope 3 target for 2035 uses a FY2018 baseline – The year before the Brumadinho dam disaster, which killed 270 people and led to a significant 22% drop in iron ore production in 2019. As the first mining company to set a quantifiable Scope 3 target in 2020, Vale's efforts signal a commitment to climate action. However, the context of the baseline year necessitates a critical assessment of the target's ambition and the company's dedication to achieving meaningful Scope 3 emissions reductions.
- While BHP has set both medium-term and long-term goals, its use of specific language to describe its 'goals' pertaining to Scope 3 emissions seems to temper its commitments with significant caveats. By stating that a goal is an "ambition for which there is no current pathway", BHP appears to hedge its commitment, emphasising the aspirational rather than the actionable.[72] While we recognise the challenge of steel sector decarbonisation, BHP's language implies a significant degree of uncertainty and lack of ambition for achieving its goals.

Capital allocation

BHP, Fortescue, Rio Tinto and Vale have disclosed their financial commitments towards decarbonisation, offering a glimpse into the scale and focus of their efforts. However, there is a growing need for these companies to provide more detailed disclosures, especially around the allocation of capital towards steel decarbonisation.

[71] Rio Tinto, 6 December 2023, Investor Seminar 2023.
[72] BHP, "Climate change - Our GHG emission reduction targets and goals"

ACCR

Table 10. Iron ore miners disclosed capital allocations for decarbonisation

Company	Decarbonisation Expenditure
BHP	- BHP expect to spend **US$4 billion** on operational decarbonisation by 2030. - Annual capex on decarbonisation will be between **US$200-600 million** over the next 5 years. - BHP has committed to invest up to **US$75 million** in research and development of steel decarbonisation pathways.
Fortescue	- Fortescue estimate an investment of **US$6.2 billion** is required to eliminate operational emissions by 2030. - FY24 guidance for decarbonisation capital expenditure is between **US$300-500 million**.
Rio Tinto	- Rio's estimated investment on decarbonisation was recently revised down from **US$7.5 billion** to **US$5-6 billion**, in capital between 2022 and 2030 (approximately **US$1.5 billion** by 2025). - Capital expenditure on decarbonisation in FY22 was **US$94 million**, **US$24 million** of which was on steel decarbonisation.
Vale	- Estimated investment on operational decarbonisation between **US$4-6 billion** by 2030. - Since 2020, expenditures on climate change have totaled **US$810 million**, of which **US$543 million** was in this last year.

Sources: Company annual reporting

Companies have committed to substantial investments in operational decarbonisation by 2030, and these figures reflect a significant financial commitment to reducing emissions. However, Vale and Fortescue have not disclosed their specific steel decarbonisation spend, and while Rio and BHP's steel decarbonisation expenditure is disclosed, the amounts are small when compared to the companies' respective overall decarbonisation budgets and emissions profiles.

Market certainty would be enhanced if all four companies commit more specific funding towards steel decarbonisation – the largest portion of the miners' respective emissions profiles. This would help provide clear signals to shape policy and guide investments. Companies should also disclose breakdowns of their current spend, alongside forward-looking spend forecasts.

BHP, Rio Tinto, Fortescue and Vale's investments thus far are positive, but taking these further steps will enable better assessment of progress and more strategic investment in the technologies and processes that lead to substantial emissions reductions.

Approach to decarbonisation technology

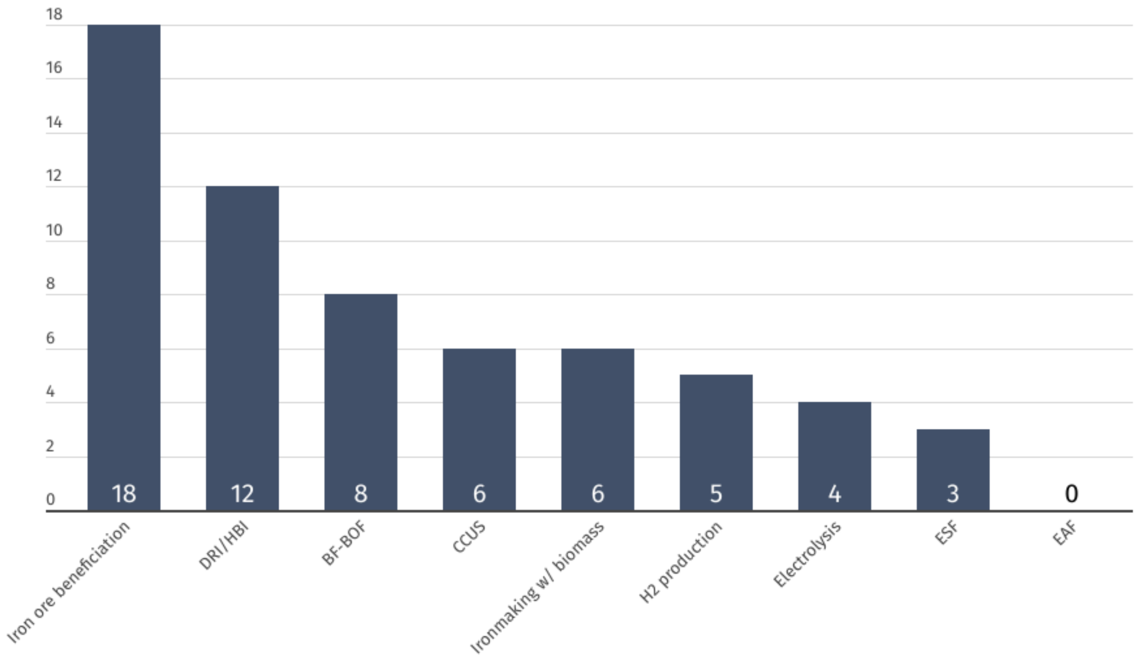
Like the steelmakers, iron ore miners are diversifying their approach across the technology spectrum and investing heavily to mitigate the emissions impact of steel production. The diversification indicates a mix of ambition and caution, with companies hedging their bets by investing in an array of technologies with varying degrees of emissions reduction potential.

ACCR's analysis identified 64[73] steel decarbonisation projects undertaken by the four iron makers as of 22 December 2023. The types of steel decarbonisation projects iron ore miners are pursuing focus on decoupling ironmaking from the rest of the steelmaking process, emphasising green or low-carbon iron production options.

[73] This includes one project which does not have sufficient disclosures for analysis.

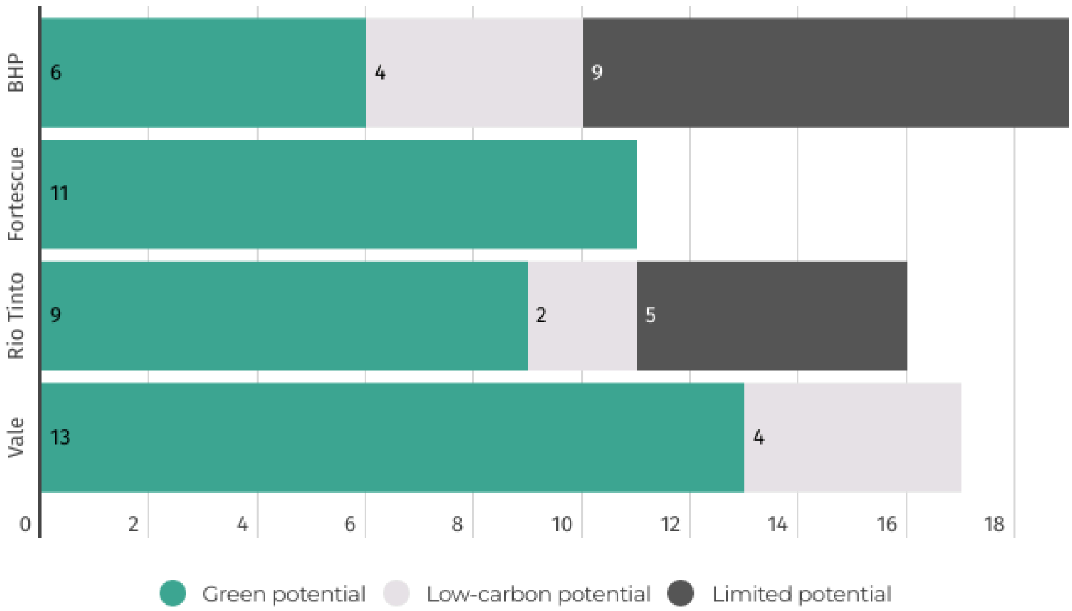
- Direct Reduced Iron/Hot Briquetted Iron (12 projects) and iron ore beneficiation or preparation (18 projects) account for more than half the projects. In addition to the three ESF projects, these methods:
    - are pivotal in enhancing the quality and efficiency of iron production, and reducing its carbon footprint
    - allow lower quality iron ores to be used in a DRI-EAF pathway
    - indicate a strategic move towards more sustainable yet commercially viable steelmaking processes.
- Blast furnace optimisation (eight projects) and CCUS technologies (six projects) are also being pursued, though not to the same extent as in the past. This suggests that miners, particularly those with lower quality iron ores, might be using a hedging strategy to continue blast furnace use.
- The focus on biomass (six projects) and hydrogen production (five projects) suggests a real desire from companies for alternatives to traditional coal-based processes, albeit the decarbonisation potential of the two methods vary greatly.
- Electrolysis, a method with potential for zero-carbon steel production that can utilise low grade iron ore, is explored in four projects, with ironmakers showing a growing interest in this area, like steelmakers.
- The absence of any projects with EAF technology suggests the iron ore miners' focus is squarely on the ironmaking side of the steel production process.

Figure 13. Iron ore miners steel decarbonisation project counts



Source: Company data, ACCR

Figure 14. Iron ore miners steel decarbonisation projects by green potential



Source: Company data, ACCR

When looking at the individual commitments of the four iron ore miners, Fortescue and Vale are pursuing a significant number of green potential solutions, while BHP and Rio Tinto are pursuing a portfolio of solutions with a range of potential emissions reduction levels.

- Vale is demonstrating a significant commitment to reducing its Scope 3 carbon footprint with 13 green potential projects. Its focus on high-grade iron ore production and pelletisation, crucial for efficient DRI/HBI production, and its agreement with Saudi Arabia, the UAE and Oman[74] to supply HBI from iron ore reduced with natural gas, makes this particularly evident.
- Rio Tinto's balanced mix of nine green, two low-carbon and five limited potential projects shows some commitment to decarbonisation, yet there is room for reassessment of its limited potential investments to ensure optimal impact and value for money.
- Vale and Rio Tinto are also exploring the production of iron by substituting coal with biomass. This is a questionably sustainable solution, which may necessitate the use of problematic decarbonisation methods such as offsets or CCUS.
- Fortescue's 11 green potential projects are indicative of a clear decarbonisation pathway, especially given the company's involvement in magnetite ore and its ongoing focus on green hydrogen production.
- BHP has six projects in the green potential category, but with nine projects in the limited potential category, predominantly in CCU/CCS, investing significantly into a technology with limited potential for emissions reduction. Notably, BHP remains the sole major iron ore miner among the big four to continue mining metallurgical coal, following Rio Tinto and Vale's divestments in 2018[75] and 2022[76] respectively.

Table 11: Analysis of the quality and transparency of iron ore miners steel decarbonisation projects

Company	Total projects with clear research areas and objectives	% projects with clear objectives and green potential	% projects with limited potential	% progressed to pilot	% projects with next steps disclosed	% projects with spend/ investment disclosed
BHP	7/19	15.8%	42.1%	26.3%	0.0%	52.6%
Rio Tinto	8/17	35.3%	41.2%	23.5%	58.8%	11.8%
Fortescue	10/11	90.9%	0.0%	36.4%	72.7%	54.5%
Vale	7/18	35.3%	0.0%	23.5%	35.3%	29.4%

Sources: Company data, ACCR

[74] Vale, "Vale signs agreements to develop Mega Hubs fin the Middle East and provide decarbonisation solutions for steelmaking," 11 November 2022
[75] Rio Tinto, 1 August 2018, "Rio Tinto completes sale of remaining coal assets"
[76] Vale, 25 April 2022, "Vale concludes sale of its coal assets."

Projects undertaken by iron ore mining companies vary significantly in terms of potential emissions reductions and the transparency of their initiatives. In Table 11, we assess decarbonisation projects that offer explicit research areas and objectives, along with the allocated spend. Regarding the projects with defined research objectives:

- Fortescue is engaged in a smaller number of projects compared to its peers but excels in performance metrics, with 90% of its projects having well-defined objectives and green potential.
- In contrast, BHP is involved in the highest number of projects among its peers, yet only 16% of these projects feature well-defined objectives and green potential. Moreover, none of BHP's projects provide detailed next steps.
- Rio Tinto outlines clear next steps for over half of its projects but offers the least information on project spend.
- Vale, while not initiating any projects with limited reduction potential, does not provide sufficient disclosure and clear objectives for the majority of its projects.

Geographic constraints

Three of the four major iron ore companies mine in the Australian Pilbara region, creating challenges and opportunities for Fortescue, Rio Tinto and BHP, because the vast majority of iron ores in the area, particularly the hematite-goethite ores, are low grade iron (Fe) content (<67 Fe%), and too friable for commercial Hot Briquetted Iron (HBI) production.

It is worth noting Rio Tinto and BHP, who are historically market competitors, have recently announced a joint collaboration with BlueScope Steel to develop a DRI facility with electric smelter technology, designed to utilise low-grade iron ores.[77] This partnership not only underscores the significant momentum towards addressing the challenge of steel decarbonisation, it highlights how the risk to revenue and market share from decarbonisation is fostering unprecedented collaborations.

Additionally, both Rio Tinto and Fortescue maintain a competitive and strategic edge in this evolving market due to their access to higher-grade iron ore (see Table 12).

[77] Rio Tinto, 9 February 2024, "Australia's leading iron ore producers partner with BlueScope on steel decarbonisation"; BHP, 9 February 2024, "Australia's leading iron ore producers partner with BlueScope on steel decarbonisation"

Table 12: Overview of iron ore operation by location, type and grade

	Region/Country	Iron ore mining operation	Iron ore type	Average grade (Fe %)	Source
BHP	Pilbara, Western Australia, Australia	Western Australia Iron Ore	Haematite	62.5%*	FY23 Annual Report p. 228
Rio Tinto	Pilbara, Western Australia, Australia	Australian Pilbara Operations	Haematite-goethite	60.7%	FY22 Annual Report p. 286
	Newfoundland and Labrador, Canada	Iron Ore Company of Canada	Itabirite	65%	FY22 Annual Report p. 286
	Republic of Guinea	Simandou	Itabirite	65.3%	Rio Tinto Simandou update
Fortescue	Pilbara, Western Australia, Australia	Chichester, Solomon and Western Hubs	Haematite	57.4%	FY23 Annual Report p. 51
	Pilbara, Western Australia, Australia	Iron Bridge	Magnetite	67.3%	FY23 Annual Report p. 50
	Belinga, Gabon	Belinga Iron Ore Project	Itabirite	-	FY23 Annual Report p. 25
Vale	Carajás, State of Pará, Brazil	Northern system, Brazil	Haematite	66.1%	2022 20-F Report p. 38, 94
	Iron Quadrangle, State of Minas Gerais, Brazil	Southern system, Brazil	Itabirite (majority), haematite	48.5%	2022 20-F Report p. 41, 94
	Iron Quadrangle, State of Minas Gerais, Brazil	Souteastern system, Brazil	Itabirite (majority), haematite	47.4%	2022 20-F Report p. 40, 94

*Sources: Various company annual reports; *calculated as an average of ore reserve Fe grades weighted by reserve tonnage.*

In response to the Pilbara's geographic constraints:

- Rio Tinto is investing in solutions such as pelletisation, biomass substitution, and electric melter technology.
- Fortescue is actively investing in research and development to optimise its production processes, improve the quality of its iron ore products, and develop green hydrogen electrolysers.
- BHP faces a more precarious and risky situation because it currently does not have access to high-grade iron ore reserves and only recently initiated collaborations to develop electric smelter technology.[78] To remain competitive globally, BHP must accelerate its investment in innovative green iron production technologies, reduce its focus on CCS/CCU,[79] foster partnerships and engage in collaborative solutions that address the unique geographical and resource-related challenges it faces.

Transparent disclosures showing investors how they are addressing Scope 3 emissions and the challenges of low-grade ore are crucial for iron ore miners. Such disclosures will enable investors and other stakeholders to verify effective strategies are in place and to ensure accountability.

[78] BHP, 23 March 2023, "BHP and Hatch commence design study for an electric smelting furnace pilot"; BHP, 9 February 2024, "Australia's leading iron ore producers partner with BlueScope on steel decarbonisation"
[79] Nicholas, S., 15 December 2023, "BHP quotes outdated figures as efforts to prop up carbon capture for steel start to get desperate"

5. Policy, Initiatives and Benchmarks

Policy initiatives provide both the regulatory framework and financial incentives that are fundamental to steering the steel industry towards decarbonisation. By setting standards and targets, policies can influence industry practices, guiding investments and technological innovations towards real world emissions reductions. This regulatory environment is crucial for ensuring that the steel sector, a significant contributor to global CO_2 emissions, aligns with broader climate goals and sustainability objectives.

Effective policies should aim to:

- increase the access and use of renewable energy in steel production
- reduce the cost of capital for emerging green steel technologies that will meaningfully reduce emissions
- implement taxation or penalties on fossil fuel-based production methods.

The role for positive advocacy

Companies in the steel sector and value chain, along with their investors, wield substantial influence in shaping policy directions. Investors can play a role in ensuring policies work to the geographical strengths of different regions across the steel value chain, enabling rapid and efficient investments towards a zero emissions steel industry.

- Steelmakers, as significant underwriters to energy, have the power to solidify demand for renewable energy, providing a clear demand outlook for power generators and governments. By advocating for renewables, steelmakers can help drive investments in renewable energy infrastructure, ensuring a reliable supply of green energy for their operations. This could include advocating for a comprehensive build-out of renewable energy capacity, the development of necessary infrastructure, and mechanisms to reduce the costs associated with green hydrogen production.
- Nations with strong economies and industrial capabilities have a substantial role in leading global decarbonisation efforts through technology innovation and policy development. Compared to countries across Asia, Europe and the USA have had a competitive advantage due to earlier industrialisation, more scrap steel availability and policy environments that support better corporate access to renewables. Policies that encourage collaboration and support technology sharing will be important in achieving widespread adoption of green steel practices.

- Asia-based steel producers would benefit from policy conditions that support greater access to renewable energy and high quality green iron, helping to enable the use of EAFs in primary steel production.
- For major iron ore producing nation-states such as Australia, access to cheap renewable energy is required to supply high-grade iron ore and green hydrogen-powered green iron that is EAF-ready for the major demand centres. Governments should prioritise policies that facilitate access to cheap renewable energy, supporting the transition towards green steel production.

Current policy settings on steel decarbonisation

Currently, several policy measures are in place, primarily in more developed economies. These include the EU's Carbon Border Adjustment Mechanism (CBAM), the USA's Inflation Reduction Act (IRA) - with its substantial financial incentives for clean energy, and various green public procurement policies. These policies exemplify efforts to mitigate emissions and promote sustainable industrial practices, yet they also highlight a geographical disparity in policy application and effectiveness.

China is the world's leading steel producer, accounting for a significant portion of global output. The implementation of decarbonisation policies within China, and Asia more generally, is crucial for achieving worldwide sustainability targets in the steel industry.

There is a need for policies that address the unique challenges and opportunities across different regions. For emerging economies specifically, policies need to facilitate access to renewable energy and quality green iron for EAF-based production. International collaboration and funding mechanisms are also crucial to support these regions in overcoming technological and financial barriers to decarbonisation.

Table 13 provides an overview of the pivotal policy measures used by regulators to help enable the decarbonisation of the steel industry. It outlines the types of policy mechanisms used, key examples of their application, and analyses how those mechanisms have shaped investment.

Table 13. Types of policies applicable to steel decarbonisation

Enabler	Policy Type	Policy Instruments	Key Examples	Impact & Investment Insight
Technology	Incentive-based	Direct R&D funds/grants	EU Clean Steel Partnership: $1.7 billion for TRL 8 by 2030 Japan Green Innovation Fund: $1.5 billion for innovative steelmaking technologies	High potential for ROI on investments in technologies achieving TRL 8 Focus on innovative steelmaking can offer competitive advantage
Market	Market-based	Carbon pricing (ETS)	EU-ETS, California ETS, South Korea ETS	Moderate impact due to free allowances and low carbon prices. Future tightening could enhance the incentive to reduce emissions
	Market-based	Border adjustment tariff	EU CBAM (pending)	Increased costs for non-EU exporters; opportunity for EU and compliant producers Demand for transparent carbon accounting standards
Infrastructure	Incentive-based	Direct funding support	IRA tax-credits for clean power	Accelerates US clean power generation; significant for investors as 80% of power mix could be clean by 2030, benefiting 70% of US steel production
Demand	Incentive-based	GPP (Green Public Procurement)	Federal buy clean initiative (US), IDDI membership	Creates demand for near-zero-emission steel, leveraging public procurement which constitutes 25% of demand
	Mandate-based	Product standards	GSA low embodied-carbon standards (US)	Sets clear guidelines for green procurement, enhancing market for low-carbon steel products
Capital	Incentive-based	Direct funding, Tax credits, Subsidies	EU public funding for hydrogen-based DRI plants IRA tax-credits for clean power, green hydrogen, CCUS	Potential cost reduction up to 35% for near-zero-emission steel. Highlights importance of accessing international funds in developing economies

Sources: World Economic Forum,[80] ACCR; ROI = return on investment, TRL = technology readiness level, ETS = emissions trading systems.

The EU's Carbon Border Adjustment Mechanism (CBAM)

The EU's Carbon Border Adjustment Mechanism (CBAM), which began on 1 October 2023 and will be fully implemented in 2026, is a tariff on carbon intensive products imported by the European Union. The steel industry is one of six carbon-intensive industries targeted in the first phase of the initiative.

By imposing a carbon price on steel imports based on their emissions, the CBAM:

- ensures that domestic producers, especially those investing in technologies with green potential, remain competitive against foreign counterparts from regions with less stringent environmental regulations
- drastically improved EU steelmakers' ambitions to drive down emissions, as no company wants to be penalised

[80] World Economic Forum, 28 November 2023, "Net-Zero Industry Tracker 2023," p.62

- encouraged cleaner production methods worldwide, as foreign steel producers are incentivised to reduce their carbon footprint to maintain market access
- generated revenue from carbon costs on imports, which can be reinvested in supporting the industry's transition to technologies with green and low-carbon potential, further accelerating decarbonisation efforts
- necessitated a robust system for monitoring, reporting, and verifying emissions associated with steel imports, enhancing transparency, accountability, and trust among stakeholders.

The CHIPS Act and Inflation Reduction Act (IRA) in the USA

Leveraging its historical industrial advantage and rich natural resources for renewables, the USA is currently modernising its steel industry. Legislative efforts like the Creating Helpful Incentives to Produce Semiconductors (CHIPS) Act and the Inflation Reduction Act (IRA) are part of this.

The CHIPS Act indirectly supports steel decarbonisation through technological innovation and energy efficiency within manufacturing processes, potentially leading to emissions reductions through encouraging the adoption of technologies such as EAF.[81] The Act will also address the microchip shortages faced by USA automakers, which may drive demand across the entire automotive supply chain, including the American steel industry.[82]

The IRA introduces substantial financial incentives for decarbonisation, including a $US5.8 billion Advanced Industrial Facilities Deployment Programme (AIFDP) and significant hydrogen subsidies.[83] These measures, including increased tax credits for renewable energy investments, encourage steel manufacturers to reduce reliance on fossil fuels. However, the IRA's provisions for CCUS have sparked debate over resource allocation, potentially shifting focus from renewable energy solutions. There are also concerns about the efficiency of CCU/CCS in delivering material emissions reductions.[84]

Green public procurement policies

Many nation states, including almost all OECD countries, have announced strategies to support green public procurement (GPP) in some form,[85] attempting to leverage their substantial purchasing power. For instance:

[81] The White House, "9 August 2022, "Fact Sheet: CHIPS and Science Act will lower costs, create jobs, strengthen supply chains, and counter China"
[82] American Iron and Steel Institute, 28 July 2022, "AISI applauds passage of CHIPS Bill"
[83] The White House, January 2023, "Building a clean energy economy: A guidebook to the inflation reduction act's investments in clean energy and climate action," p. 67
[84] The White House, January 2023, "Building a clean energy economy: A guidebook to the inflation reduction act's investments in clean energy and climate action," p. 68
[85]OECD, "Green public procurement"

- The United States, the world's largest direct purchaser, has implemented the Buy Clean Initiative. It targets key construction materials, including steel, aiming to reduce up to 10 million tons of CO_2 emissions directly from the steel industry.[86]
- Japan has established the Green Purchasing Law and the EcoLeaf label for steel products.[87]
- India has focused on transparency and competition in public procurement, with a Task Force in Sustainable Public Procurement including steel among its primary industrial focuses.[88]
- In the EU, where approximately 5% of emissions are attributable to the steel industry, and public procurement accounts for approximately one fifth of GDP, most countries have set voluntary approaches to GPP.[89]
- Some European countries have established mandatory GPP, including the Netherlands,[90] the UK and Austria. In France, mandatory GPP applies to some product groups.[91]

Globally, the Industrial Deep Decarbonisation Initiative (IDDI)[92] was launched in 2021[93] and led by the UN Industrial Development Organisation (UNIDO). Member states[94] are aiming to drive global demand for low-carbon steel by spurring investment.

At COP28 in December 2023, the UK, Canada, USA and Germany – all IDDI member nations – made a joint Green Public Procurement pledge, “to create a market demand for low and near-zero emission steel, cement and concrete, helping to drive the global decarbonization of these heavy industries”.[95]

The Paris Agreement and COP momentum on steel

The Paris Agreement, adopted in 2015 at COP21, urges signatory countries to limit global warming to well below 2C, preferably to 1.5°C, compared to pre-industrial levels.

At COP26, held in Glasgow in 2021, over 40 world leaders signed up to the ‘Breakthrough Agenda’, including the USA, India, EU, China, Japan, Australia and many developing economies, representing more than 70% of the world’s economy.[96]

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[86] Hasanbeigi, A. & Sibal, A. 2023, “What is green steel? Definitions and scopes from Standards, Initiatives, and Policies around the world,” p.65
[87] Ibid, p.71.
[88] Ibid, p.76.
[89] Ibid, p.63.
[90] In 2019, Hasanbeigi and colleagues compared GPP programs across 22 countries, and nominated the Netherlands' program as international best practice
[91] Hasanbeigi, A. & Sibal, A. 2023, “What is green steel? Definitions and scopes from Standards, Initiatives, and Policies around the world,” p.63
[92] UN Industrial Development Organisation, “Industrial Deep Decarbonisation.”
[93] United Nations Industrial Development Organisation, 1 June 2021, “Major global economies announce collaboration to drive the global decarbonization of steel and cement”
[94] India, UK, Canada, Germany, Japan, Saudi Arabia, Sweden, UAE and the USA.
[95] United Nations, Industrial Development Organisation, 5 December 2023, “Seven key governments generate demand for cement and steel decarbonisation technologies via UNIDO-lead Green Public Procurement campaign”
[96] United Nations Climate Change Conference UK 2021, 11 November 2022, “The Breakthrough Agenda”

The agenda includes two key components relevant to steel decarbonisation:

1. Steel - Near-zero emissions steel is the preferred choice in global markets, with efficient use and near-zero emissions steel production established and growing in every region by 2030.
2. Hydrogen - Affordable renewable and low-carbon hydrogen is globally available by 2030.

Initiatives and benchmarks

While a unified vision remains elusive, there are various standards, protocols, and initiatives that aim to define, label and certify green steel.

When assessing these standards and initiatives, Global Efficiency Intelligence's 2023 research provides three vital points of focus essential to quantifying the effectiveness of measures that aim to benchmark what decarbonisation is when pursuing 'green' steel:[97]

- Alignment with the Paris Agreement 1.5°C goal

Policies, protocols, definitions and standards must adhere to the Paris Agreement's 1.5°C goal. According to the IEA's NZE 2023 update, absolute steelmaking emissions need to fall 27% by 2030 and 91% by 2050, accounting for increases in steel production from a 2022 baseline.

- Comprehensive emissions boundaries

Emissions guidelines should encompass Scope 1, 2, and 3 emissions, with precise boundary definitions. Key emissions from primary processes like blast furnaces, sintering, and coking must be included, as they account for a significant proportion of primary steelmaking's CO_2 output. Indirect emissions, especially from electricity use, and Scope 3 emissions, such as those from purchased pig iron and methane releases from coal and natural gas, must also be addressed.

- Enhancing data reliability

There's a need to bolster the trustworthiness and accessibility of product and plant-level data within the steel industry. While much of this data is collected by steel companies and governments, it's essential to make it more publicly available to monitor industry progress and pinpoint areas needing improvement.

[97] Hasanbeigi, A. & Sibal, A. 2023, "What is green steel? Definitions and scopes from Standards, Initiatives, and Policies around the world," p.4

Table 14. Overview of standards, protocols, and initiatives that aim to define, label and certify green steel[98]

Organisation/Group	Name	Focus	Intensity for Green Steel (t CO2e/t crude steel)	Scope
ResponsibleSteel	Making Net-Zero Steel Possible	Measurement, standards, definitions and thresholds	Primary steel: 0.4 Secondary steel: 0.05*	1, 2 and 3
Science-Based Target Initiative (SBTi)	Steel Guidance	Measurement, standards, definitions and thresholds	0.11 by 2050 (both primary and scrap steel)	1, 2 and 3**
Climate Bond Initiative	Steel Criteria	Measurement, standards, definitions and thresholds	Primary steel: 0.5	1 and 3
Global Steel Climate Council (GSCC)	The Steel Climate Standard	Measurement, standards, definitions and thresholds	0.12 by 2050 (both primary and scrap steel)	1, 2 and 3
International Energy Agency (IEA)	Achieving Net Zero Heavy Industry Sectors in G7 Members	Standards, definitions and thresholds	Primary steel: 0.4 Secondary steel: 0.05	N/A
Mission Possible Partnership	Net-Zero Steel Initiative (NZSI)	Standards, definitions and thresholds	Primary steel: <0.25*	1 and 2
First Movers Coalition	Steel Commitment	Definitions and thresholds	<0.4 (0% scrap inputs) <0.05 (100% scrap inputs)*	1 and 2

* Thresholds are not fixed to a specific year.
** Scope 3 emissions are included if it makes up 40% or more of total emissions.
Adapted from Centre for European Policy Studies report, A POLICY FRAMEWORK FOR BOOSTING THE DEMAND FOR GREEN STEEL IN THE AUTOMOTIVE INDUSTRY, Jan 2024.

Sources: Organisational websites

Steel decarbonisation policy gaps

Identifying policy gaps is crucial for a comprehensive understanding of the steel industry's decarbonisation efforts. While the EU's CBAM and the USA's IRA set solid frameworks for incentivising clean energy use and penalising carbon-intensive production, they represent only a portion of the global equation. These measures, alongside green public procurement policies and international agreements like the Paris Agreement, demonstrate the progress made by developed economies. However, policy gaps are still evident across a significant portion of the steel value chain, particularly in China and other emerging economies.

One notable gap is the absence of comprehensive carbon pricing mechanisms outside of the EU and parts of North America. Although China has announced its emissions trading scheme, its impact and breadth in driving significant decarbonisation in steel production is yet to be fully seen. This disparity in carbon pricing mechanisms creates unequal pressures on steel producers worldwide, and can lead to 'carbon leakage'," where production moves to regions with less stringent regulations, undermining global decarbonisation efforts.

[98] NB: The Steel Climate Standard from the Global Steel Climate Council is criticised for lacking comprehensive stakeholder involvement and a nuanced approach to production methods. Its generalised application potentially favours secondary producers, highlighting the necessity for a more detailed and equitable decarbonisation strategy in the steel industry. See: Global Steel Climate Council (GSCC), "The Steel Climate Standard", August 2023

Furthermore, the financial incentives and support for transitioning to green steel technologies, similar to those offered by the IRA, are lacking in many steel-producing nations. This deficiency impedes the adoption of EAF technology and the development of infrastructure for renewable energy and green hydrogen production, particularly in countries that could most benefit from these solutions.

International collaboration and funding mechanisms intended to address these gaps are still in their infancy. For example, while the Industrial Deep Decarbonisation Initiative (IDDI)[99] aims to stimulate global demand for low-carbon steel, the effective implementation of supportive policies and investments in necessary infrastructure across major steel-producing regions remains inconsistent. This highlights a pressing need for policies that facilitate access to renewable energy and quality green iron for EAF-based production globally, not just in developed economies.

Role for investors

Companies and investors play pivotal roles in driving the decarbonisation of the steel industry through policy advocacy and strategic investments. Their actions can significantly influence the pace and effectiveness of the transition towards green steel.

The key actions investors can take to encourage positive policy settings include:

- driving positive advocacy and using influence to push for policies that consider geographical strengths, enabling efficient investments towards green steel
- underwriting renewable energy, solidifying the demand outlook for power generators and governments
- advocating for industry-wide policies, including consistent global carbon pricing and emissions standards
- supporting initiatives that bridge policy gaps between developed and emerging economies
- advocating for the implementation of green procurement policies to create demand for low-emissions steel products
- supporting international collaboration by participating in global forums and partnerships, including with industry association groups and civil society organisations (e.g. ACCR, IGCC, AIGCC, etc.)
- advocating for policies that support technological and financial mechanisms which accelerate steel decarbonisation and assist emerging economies.

[99] The IDDI is coordinated by UNIDO and led by the UK and India. Current members include Canada, Germany, Japan, Saudi Arabia, Sweden, the United Arab Emirates, and the United States.

6. Recommendations

There are technologies with clear emissions reduction potential that can support iron producing and steelmaking companies to decarbonise by 2050 or sooner. Further, there are clear steps that companies, investors can take to address any remaining hurdles to decarbonisation. Technologies with limited decarbonisation potential, and therefore higher risk to companies and shareholders, are not well placed to be the focus for investment where proven pathways for significant emissions reductions exist.

We set out five crucial steps to undertaking the transition to low-emissions iron and steelmaking, with recommendations for companies and investors, plus asks that companies and investors can put to policymakers for action now.

1. **Reallocate capital away from coal-dependent blast furnaces and towards processes with high decarbonisation potential**

   For companies:

   - Disclose a clear transition pathway from high-emissions iron and/or steelmaking to technologies with green and low-emissions potential, detailing the contribution of each technology to emissions reduction. In instances where CCUS technology is being trialled, full performance data should be disclosed, including actual versus intended capture rates and their proportion relative to total plant emissions.
   - Include disclosure of capital allocation for this transition pathway, specifying the approximate proportion of capex for each technology along a forward-looking timeline.
   - Provide regular and detailed reporting on the progress and outcomes of these investments.
   - Set comprehensive Scope 3 targets.
   - Work towards partnerships and collaborative investments in technologies with green potential.

   For investors:

   - Engage with companies, using escalation where necessary, to ask for the disclosure of their transition pathway to low-emissions iron/steelmaking, along with a detailed outline of the capital allocation for the transition.
   - Direct investments towards regions lagging in green steel production capability, specifically to accelerate decarbonisation efforts.
   - Engage with policymakers directly and indirectly to encourage positive policy settings for steel decarbonisation.

Asks for policymakers:

- Implement mechanisms to reduce the cost of capital for necessary green steel infrastructure, including green hydrogen production.

2. **Increase renewable energy capacity to enable the green electricity and green hydrogen required for low-emissions steelmaking**

   For companies:

   - Provide signals to power suppliers to solidify demand for renewable energy (which may be formal, such as offtake agreements, or informal, such as public advocacy).

   For investors:

   - Fund renewable energy projects, particularly in developing countries with steelmaking operations.

   Asks for policymakers:

   - Implement mechanisms to increase renewable energy capacity through incentives for investment in infrastructure, which will help ensure a reliable supply of green energy for steel operations.

3. **Work towards standardised, comprehensive and robust emissions disclosure across the industry.**

   For companies:

   - Disclose a breakdown of operations by steelmaking method, specifying the proportion of operations conducted via BF-BOF, EAF or other processes.
   - Choose a base year which is representative of the company's normalised emissions profile, as opposed to peak production, or a multi-year average.
   - Source independent verification of reported data and progress.

   For investors:

   - Engage with companies to ask for transparent disclosures.
   - Integrate emissions data and trends into investment analysis, so shareholders can invest in companies that demonstrate transparency, lower carbon intensities and a strong commitment to reducing absolute emissions.
   - Update financial risk assessment models to accurately incorporate the physical impacts of climate change, ensuring investment strategies adequately address climate risk.

Asks for policymakers:

- Work towards unifying reporting standards across the industry to ensure the comparability and transparency of Scope 1, 2 and 3 emissions.

4. **Catalyse immediate action towards decarbonisation with short-term climate commitments that are ambitious and science-based.**

For companies:

- Set short-term targets that are clear, ambitious and 1.5°C aligned.
- Adopt more recent and lower emission years as baselines for targets.
- Align and verify targets with rigorous and holistic frameworks like the SBTi.

For investors:

- Engage with companies to ask for the disclosure of short-term targets and alignment with the SBTi, using escalation where necessary.

Asks for policymakers:

- Work with regulators and industry standard setters like the SBTi to drive alignment in frameworks and the analysis of company targets.

5. **Ensure that the transition of iron and steelmaking to green processes is just and equitable, supporting communities and workers**

For companies:

- Implement programs that offer targeted green iron and steel processing training pathways for workers likely to be affected by the transition, including advocating for internal job-matching policies.
- Engage in meaningful consultation with workers and local communities to secure their active participation and support in the transition.

For investors:

- Hold companies to account on providing a just transition timeline, clear framework and outcomes for impacted workers.
- Incorporate just transition metrics and information into investment analysis and decision-making.
- Advocate for policies promoting a just transition.

Asks for policymakers:

- Introduce mechanisms to support a just transition through training programmes, financial incentives and resources.

Appendix 1 - Method for company analysis - steel and iron ore companies

Data collection

We collected data on production volumes, emissions levels and capital investments in green initiatives from the companies' most recent reporting documents. Additionally, we examined each company's public statements, commentary and announcements on steel decarbonisation.

Our research included surveys tailored to understand each company's progress, needs and spending in transitioning to green steel. However, not all companies responded within the study period. Companies that engaged in the research were also given the opportunity to review data collected by ACCR, to ensure accuracy. The information presented in this report is accurate as of 22 December 2023.

Analysis

We undertook a systematic review to comprehensively assess the companies' progress, commitments and contributions to steel sector decarbonisation. This involved the examination of emissions data, climate commitments, capital allocation and the landscape of innovation within the sector and value chain. We kept our analysis of the steelmakers and iron ore miners separate to allow for a nuanced understanding of the respective sectors' overall progress.

Steelmakers

Emissions analysis and carbon intensity

We analysed steel companies' emissions across Scope 1, 2 and 3, aiming to understand their direct and indirect carbon footprints. For companies where carbon intensity figures were not disclosed, we employed the formula:

$$Carbon\ emissions\ intensity\ =\ \frac{tonnes\ CO2\ (Scope\ 1 + Scope\ 2)}{tonnes\ crude\ steel}$$

We cross-referenced our calculated carbon intensity figures with those disclosed by the companies to ensure accuracy and reliability.

Climate commitments

The assessment of climate commitments involved gathering data on targets (short, medium and long-term), their alignment with the Science-Based Targets initiative (SBTi), and aspirations towards net-zero emissions. We collected data on the base year, scopes covered by targets, and the nature of the targets (peak, absolute, intensity-based), among other relevant details.

To categorise these targets, we adopted a colour-coded system:

- Green: targets that surpass the Net Zero Emissions (NZE) pathway or are aligned with SBTi.
- Orange: targets that are in line with the NZE pathway or SBTi.
- Red: targets that lag behind the NZE pathway or are not aligned with SBTi.

Alignment with SBTi/ NZE steel pathways

To evaluate the alignment of steelmakers' targets with the SBTi and NZE pathways, we rebased emissions baselines to 2022 and adjusted target projections to 2050 accordingly. This process included plotting SBTi targets for primary and secondary steelmaking (for those with carbon intensity targets) against the NZE Steel pathway (for those with absolute emissions targets). This comparative analysis aimed to discern whether these targets are in line with trajectories that limit global warming to 1.5°C.

Capital allocation and decarbonisation projects

We then reviewed disclosed capital allocation towards decarbonisation and the specific projects announced by steelmakers. Projects were evaluated and categorised based on their potential to reduce emissions into three distinct groups: green potential, low-carbon potential and limited potential. In this context, 'green' refers to steel production methods that completely avoid fossil fuel use, 'low-carbon' encompasses processes that significantly reduce emissions but may still incorporate fossil fuels or emit some level of carbon, and 'limited' describes technology solutions that offer minimal decarbonisation capabilities on their own. This categorisation facilitated an in-depth assessment of the emissions reduction potential of these initiatives, both at an aggregate level and within specific regions and companies. We scrutinised the clarity of research areas, objectives, progression post-announcement and financial disclosures to understand the quality and transparency of these projects.

Green steel ventures

In recognising the significance of innovation and disruption in the steel sector, we also collected information on emerging green steel ventures. This analysis highlighted the momentum towards sustainable steel production, showcasing ventures that promise to revolutionise the industry with green technologies this decade.

Iron ore miners

Emissions and decarbonisation targets

Our analysis commenced by evaluating the emissions data of iron ore miners, with a particular focus on Scope 3 emissions due to their significant impact on the steelmaking process. We compared the companies' quantifiable Scope 3 targets related to steelmaking, assessing their ambition and alignment with global decarbonisation goals.

Capital allocation and Scope 3 decarbonisation projects

We examined the capital allocation of the miners towards decarbonisation, specifically looking at projects aimed at reducing Scope 3 emissions. These projects were categorised similarly to those of the steelmakers, enabling us to assess each project's scope, objectives, progress and financial commitments. This approach allowed us to gauge the quality of the disclosures and the potential of these projects to contribute to emissions reduction.

Ore quality

The analysis included a review of disclosures on ore quality and the locations of mining assets. This was essential for understanding operational risks and evaluating the efficacy of decarbonisation projects in addressing these challenges.

Data visualisation

Data visualisation was undertaken in Infogram, version 2.1.

ACCR

About ACCR

The Australasian Centre for Corporate Responsibility (ACCR) is a not-for-profit, philanthropically-funded shareholder advocacy and research organisation that engages with listed companies and investors globally, enabling and facilitating active stewardship. Our research team undertakes company-focused research into the climate transition plans of listed companies, offering analysis, research and insights to assist investors understand the risks and opportunities during the energy transition. For more information, follow ACCR on LinkedIn.

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