VIEWPOINT

Decarbonising steel: redefining the value chain and the role of iron ore miners

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- Steel production is highly greenhouse gas-intensive, making up between 7% to 9% of annual global emissions; reducing its environmental impact is technologically and economically challenging.
- The need to decarbonise is driving innovation in the steel sector, which in turn is reshaping the global value chain for one of its key inputs – iron ore.
- Higher-grade, lower-impurity, iron ore, which only makes up a tiny fraction of the market today, is needed to produce green steel. A potential shortage of suitable ores threatens the scalability of low carbon production routes.
- In October 2023 we visited Fortescue Metal Group's new high-grade iron ore mine in Australia. Here we draw from that experience to discuss how iron ore miners can position themselves to benefit from, and contribute to, the steel sector's decarbonisation.

Picture of Fortescue's Hercules truck taken at its Green Energy Hub located at Christmas Creek. At the hub we were also shown The Road Runner, which is a test battery truck.

The energy transition is a commodity transition.

The global steel industry is currently responsible for about 7% to 9% of annual global CO_2 emissions. In some countries like China, South Korea, and Japan, emissions from the steel sector are nearly double the global average, at 15%, 14% and 12% respectively.[1] Demand for steel is expected to grow. However, vast amounts of capital are needed to bring this heavy-emitting sector down toward zero emissions – as foreseen in the climate roadmaps of large steel-producing regions such as China, the US, and the EU. This has major implications for iron ore as the key feedstock for steel production.

Based on the scale and urgency of steel decarbonisation, we believe an important (and often overlooked) climate transition topic is the role of iron miners in decarbonising steel. Miners have an opportunity to contribute to real-world emissions cuts by working with the steel sector to provide the 'ingredients' of green steel and support decarbonisation.

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How is steel made?

Making steel green

Reconfiguring the supply chain

Scarce high-grade iron ore

How is steel made?

How is steel made and how can it be decarbonised?

One tonne of steel produces an average of 1.9 tonnes of CO_2, but there are significantly different emissions profiles depending on the production route.[2]

There are two key processes in steel production (see Figure 1): ironmaking and steelmaking. In the first step, iron is extracted from the ore and converted into alloys (pig iron or sponge iron). This is traditionally the most carbon-intensive part of the process, and often relies on metallurgic coal. In the second step the iron is converted into steel in a furnace. Both steps require significant energy, with the emissions profile dependent on the choice of coal, gas or hydrogen.

Recycled scrap can replace pig/sponge iron, skipping the most carbon-intensive step and creating recycled (or secondary) steel. Virgin (or primary) steel has a higher carbon footprint than scrap steel (recycled); globally, however, scrap costs more than lower grade iron ore, which disincentivises recycling over investing in cheap virgin steel.[3]

Why does the carbon footprint of steel vary by country and company?

The integrated Blast Furnace-Basic Oxygen Furnace (BF-BOF) production route is both the most common (accounting for 71% of global steel generation) and the most carbon-intensive way to make steel, with an average 2.3 tCO_2/tonne steel.[4] The second 'primary' steel route (accounting for 7% of global generation) replaces blast furnace pig iron with Direct Reduced Iron (DRI or sponge iron) – a process using gas or coal as the reducing agent, that emits roughly 1.4 tCO_2/tonne steel.[5] To make 'recycled' steel an Electric Arc Furnace (EAF) using scrap has average emissions of 0.7 tCO_2/tonne steel – depending on the carbon intensity of the grid (21% global generation).[6]

A country's steel emissions will be determined by the availability of raw materials and energy. For example, the North American steel market has one of the lowest carbon dioxide (CO_2) emissions, which is due to the high amount of scrap-EAF and a relatively low CO_2 intensity grid. China, responsible for 54% of global production, and India, 6%, rely on cheap coal to produce steel. As a result, one tonne of steel produced in India or China is more than twice as carbon-intensive as steel produced in the US – with Indian steel being the most carbon-intensive globally. Shifting demand dynamics will also impact the global emissions profile of the sector.[7] For example, most analysts see domestic steel demand reducing in China over the next decade, with India emerging as the main growth market. Indian steel on average produces more emissions than Chinese, and shifting production areas could drive changes to the overall sectoral emissions.

1.9 tonnes of CO_2

One tonne of steel produces an average of 1.9 tonnes of CO_2

Table 1: CO_2 emissions and energy intensity, as measures and calculated by the World Steel Association, 2023.

Profile of steel production processes (2021-2022)		
Production route	Share of Global Production (%)	Tonnes CO_2/Tonne Steel
Blast Furnace-Basic Oxygen Furnace (BF-BOF)	72	2.33
Scrap-Electric Arc Furnace (scrap-EAF)	21	0.66
Direct Reduced Iron-Electric Arc Furnace (DRI-H2-EAF)	7	1.39

Making steel green

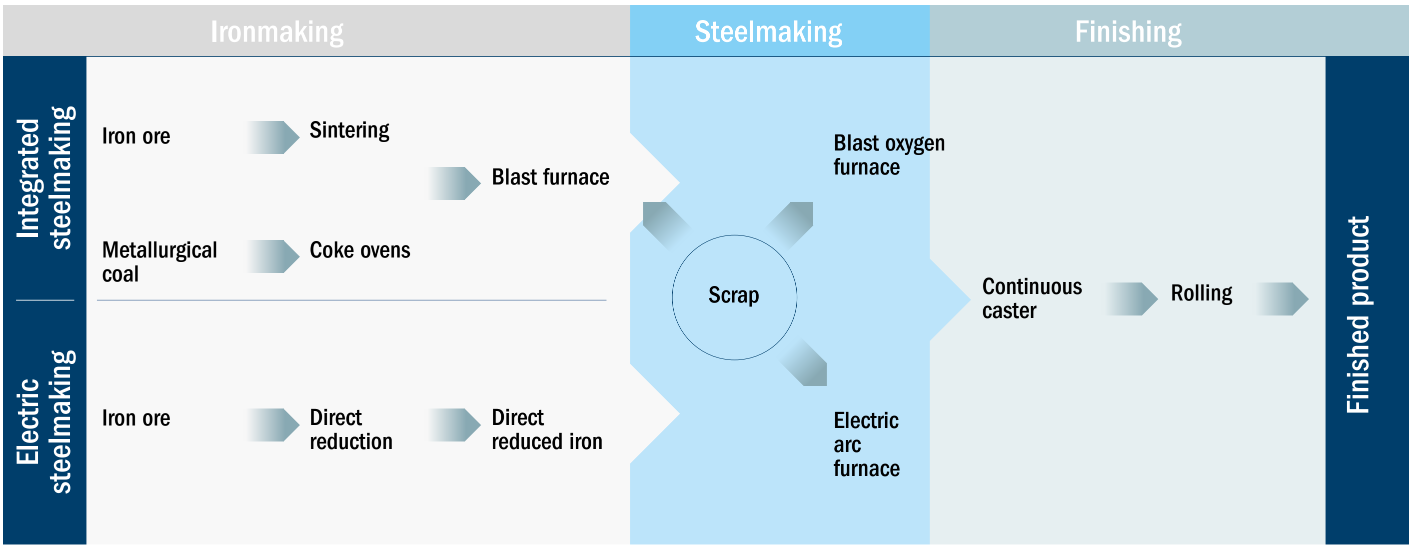
How to make 'green steel,' as recycling can only get us halfway there.

Increased recycling and improved energy efficiency is key to steel decarbonisation. However, there is not enough scrap to go around and there are limits to energy efficiency improvements. Even in ambitious projections scrap will likely only make up 50% of global steelmaking by 2050, which is up from 30% today.[8] Recent acquisitions of scrap businesses by steel majors like ArcelorMittal,[9] Steel Dynamics,[10] and Salzgitter indicates that recycling is seen as a key carbon-reduction lever.[11] However, it is abundantly clear that green virgin steel is needed for the sector to reduce overall emissions while sustaining growth.

To produce green virgin steel there are two main contending technologies: 1), the DRI-H2-EAF route, which can be near-zero-emissions if green hydrogen is used in the Direct Reduction and green electricity to power the electric arc furnace. Or 2), by using Carbon Capture and Storage (CCS). In the IEA's net-zero scenario, 8% of global steel will be produced by one of these two routes by 2030, up from zero percent today.[12] As CCS is challenged by a lack of infrastructure, pipelines, and high capital costs in many regions, the DRI-H2-EAF is widely seen as the most promising.

Most analysts see domestic steel demand reducing in China over the next decade, with India emerging as the main growth market

Figure 1: Ironmaking and steelmaking production routes



Source: BHP, Pathways to decarbonisation episode two: steelmaking technology (2020)

Reconfiguring the supply chain

Decarbonising steel production will reconfigure the iron ore supply chain.

Fossil fuels have historically been an integral part of steel production. However, recent innovation has rendered low (and zero) emissions steel a reality by replacing fossil fuels with green hydrogen and renewable electricity. Crucially for the miners, producing 'green steel' using hydrogen requires no coal – but does need higher-grade, lower-impurity iron ore. Today, high-grade iron ore is a small fraction of the overall mined. For example, only between 2% to 4% of iron ore on the seaborne market is >67% Fe, indicating a potential future deficit.[13]

A transition to green steel will place suppliers of high-grade (and low-impurity) iron ores in a strategic position and will reduce demand for metallurgic coal. For the big iron ore miners, like Rio Tinto, Vale, BHP, and Fortescue Metals Group (FMG) there is a strategic opportunity to be a green steel iron ore supplier of choice, while involvement in the green steel chain will also significantly reduce their scope 3 emissions.[14]

The reality of the shifting supply-chain was made clear to us on a recent trip to Iron Bridge, FMG's new mine in Western Australia. Iron Bridge is the group's first entry into the high-grade iron ore segment, and FMG have stated that the intention is to provide iron ore to the green steel market and to get the industry worldwide "rolling with green steel".[15] FMG is also one of the first major iron ore miners to set a measurable scope 3 emissions target, aiming to enable a 7.5% reduction in emissions intensity from its steel customers by 2030.

The trip was a crucial illustration of how iron ore miners can position themselves to benefit from – and contribute to – a green steel shift.

Demand for low-carbon steel is driven by carbon prices and regulation.

The capital needed to transition to greener steel is immense. Redesigning the production process will be both costly and time consuming as new equipment, materials and energy sources will be required. Estimates by Morgan Stanley Research suggest that the capital expenditure required could exceed $1200 per metric ton of capacity.[16] Japanese steel giant, Nippon Steel, reports that it alone needs somewhere between $2634 billion (¥5-4 trillion) in capital expenditure, plus more than $3 billion in R&D (¥0.5 trillion), to decarbonise its operations.[17]

These figures are, of course, rough estimates, as changing carbon prices and supply dynamics in a net-zero transition will also shift input costs of raw materials over time. Most price assumptions do not include any future punitive carbon taxation or consider that companies may be able to extract a green premium to cover some of the costs – particularly from buyers like automakers who have set their own net-zero targets. And in Europe – as Morgan Stanley puts it – where targets are ambitious and carbon prices are growing "the cost of not evolving [is] likely far steeper than going green".[18]

Europe is ground zero for green steel. Pressure from regulators, policymakers, investors and customers has led to the majority of steelmakers in Europe setting net-zero targets, with most countries aiming to achieve between 30% to 35% emissions cut by 2030.[19] As a result, Europe is on track to see the largest transformation[20] of its steel sector since the industrial revolution, driven by country targets, fiscal incentives, carbon pricing via the EU's Emissions Trading Scheme (ETS) and the Carbon Border Adjustment Mechanism (CBAM).[21] Implementation of CBAM will see the sector's free ETS emissions allowances phase out between 2026 and 2034, with a carbon tariff applied to imports in its place.

These policies are already shifting global dynamics: CBAM could increase the import price of carbon-intensive steel produced in India and China by 50% or more.[22] There are also indications that similar levies will be applied in other geographies; the UK is set to introduce its own carbon import tax by 2027 and countries such as Australia, Canada and the US are discussing ways of matching

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the policy.[23] As a result, India and China are warning that exports worth billions of dollars – including steel – will be affected by steep tariffs.[24] Meanwhile, domestic policy may also shift, with China looking to include iron and steel in its own domestic ETS.

Scarce high-grade iron ore

The miners' opportunity: a lack of high-grade iron ore a headwind for steel decarbonisation?

Insufficient supply of high-grade, low-impurity iron ore could significantly challenge the scalability of green steel: supply of high-grade ore would have to nearly double by 2030 to meet the demand of DRI steel projects announced, according to IEEFA estimates.[25] Today, a premium already exists for higher-grade ore, as less energy is needed to process it. How this premium develops in a market deficit is a key question for the miners.

There are new high-grade mines becoming operational this decade – such as Rio Tinto's Simandou mine[26] in Guinea or FMG's Gabon mine – but it is uncertain how new projects will balance the demand-supply deficit, and on what timeline.[27] It is not as simple as just opening new mines: suitable high-grade deposits are rare, often found in geopolitically challenging regions, and mines have decade-long development times. BHP's CEO stated in 2021 that there "simply is not enough high-quality iron ore to meet global steel demand".[28] The average quality of mined iron ore has in fact decreased over the last decade, as mines expanded to rapidly meet growing Chinese demand. In 2006, average iron content in Rio Tinto, Vale, BHP and FMG ores was more than 62%, but this had fallen to 61% ten years later, according to IEEFA and the Minerals Council of Australia.[29]

Miners are investigating new ways to make lower-grade ores fit for purpose. For example, Australian Rio Tinto and BlueScope steel are conducting a joint concept study,[30] adding an additional 'melting' step to the process, while BHP announced in March 2023 an Memorandum of Understanding to develop a similar pilot project with engineering firm Hatch.[31]

Further on the horizon is the potential for new steelmaking technologies to emerge that could significantly disrupt the steel sector and iron ore miners. One such innovation is iron ore electrolysis. A technology spearheaded by Boston Metals – Molten Oxide Electrolysis – would completely remove the need for fossil fuels in the process, use any grade of iron ore, and eliminate several steps in the steelmaking process.[32] However, scalable versions of this technology could still be over a decade away.

The miners: towards more value chain integration in a decarbonising world?

The green steel transition could see a shift to more integrated mining and steel value chains. Today, the vast majority of iron and steel are produced in integrated steel mills, with the steelmaker acquiring the iron ore and the metallurgic coal from the miner.[33] However, the need for innovation is necessitating collaboration.

The combination of new policies, technologies, and access to new raw materials (like high-grade ore, green hydrogen, and renewable power) will likely dictate where and who will be involved in production.

A prime example of industry collaboration is the Hydrogen Breakthrough Ironmaking Technology (HYBRIT), being piloted in Sweden by steelmakers SSAB – state-owned iron ore miner and energy company – LKAB and Vattenfall. The companies are all coming together to pilot the production of zero-carbon steel using green hydrogen made using Vattenfall's renewable power and high-grade iron ore from LKAB mines. The project has received capital from the Swedish government, a potential win-win, as the HYBRIT technology could reduce Sweden's annual emissions by 10%.[34]

Another example is Rio Tinto's new high-grade iron ore mine Simandou, which is a template for the "new era in co-development" necessitated by a green shift.[35] The project is a partnership between Rio Tinto and at least seven other companies, including Chinese steel giant Baowu and the state of Guinea.[36]

On process integration, Vale announced in 2021 that it would invest $185 million in "green briquette" manufacturing. Produced by agglomerating its high-grade iron ore at low temperatures, these "briquettes" can replace the first step in the steel production process (sintering) while, the company claims, reducing average product emissions of the BF-BOF route by 10%. Vale's first plant started production in December 2023 in Brazil,[37] with the company announcing that the product has the potential to "revolutionise the steel industry".[38]

Vale has also signed an agreement with Saudi Arabia, the United Arab Emirates and Oman to create "Mega Hubs" to produce another green intermediate product: hot-briquetted iron.[39] This product can be used directly in EAFs and, if the EAFs are run on green energy, it can produce zero-emission steel. Vale have made clear that the region is ideal for the project, due to the cheap and abundant natural gas, which over-time can be converted to hydrogen to support green steel; geography is a driver for green steel deals. Analysts agree: IEEFA have suggested that the MENA region could become the new hub of 'green steel' due to its access to cheap solar, ability to produce hydrogen, and proximity to India.[40]

Another example is FMG's trial green iron project, which was approved for funding in November 2023.[41] The project, based in

2030

Supply of high-grade iron ore would have to nearly double by 2030 to meet demand of DRI steel projects

the Australian Pilbara, is working on a way to produce near-zero-emissions iron that can then be converted to steel with an EAF. This process would mean FMG completes the first step of the integrated steel production process in Australia. Exactly how this will be done is still unclear, as FMG indicates that access to ample solar power in the Pilbara combined with close access to the iron ore mines makes Western Australia the ideal place to produce 'green iron' – the company has nonetheless kept its cards close to its chest. Also interested in Western Australia, South Korean steelmaker POSCO and French energy giant ENGIE are set to conduct a pre-feasibility study for a green hydrogen project in the Pilbara, which will be used to make hot briquette iron products, greening the ironmaking and putting POSCO a step closer to green steel.[42]

A green steel transition means new opportunities.

A transition means new opportunities (as well as risks) for the whole steel and iron supply chain. Innovation originating in Europe could translate to India and China, while the increasing politics around carbon prices and import levies has the potential to shift pricing dynamics and the industry quicker than consensus expects.

In the extraordinary heat of western Australia, it was evident that FMG sees the potential to be a key innovator in a decarbonising world, with their eyes set on becoming a pivotal green steel player. As capital and knowledge is poured into decarbonising, the iron ore miners who can provide the materials, research, and innovation, will be at an advantage.

1 'Hydrogen sparks change for the future of green steel production,' ING, 2023.
2 'Sustainability Indicators 2023 report,' World Steel Association, 2023.
3 'Ferrous scrap, metallics markets gear up for low-emissions steel shift,' S&P Global, 2023.
4 World Steel Association, 2023.
5 World Steel Association, 2023.
6 World Steel Association, 2023.
7 'Steel Climate Impact,' Blue Green Alliance, 2022.
8 'Why ferrous scrap is emerging as a key strategic raw material,' ING, 2023.
9 'ArcelorMittal acquires Dutch scrap metal recycling business Riwald Recycling', Arcelor Mittal, 2022.
10 'Steel Dynamics Completes Acquisition of a Mexican Metals Recycling Company,' PR Newswire, 2022.
11 'Salzgitter Group expanding regional scrap recycling,' Salzgitter AG, 2023.
12 'Steel,' International Energy Agency, 2023.
13 'Green steelmaking will need technology and mining advances,' Institute for Energy Economics and Financial Analysis, 2022.
14 'Big mining's downstream steel emissions,' Institute for Energy Economics and Financial Analysis, 2023.
15 'Fortescue ships first magnetite product from Iron Bridge,' Fortescue, 2023.
16 'Greening the Steel Industry: A Tale of Cost and Opportunity,' Morgan Stanley, 2023.
17 'Collaboration with society, policy proposals, and industry activities to achieve carbon neutrality,' Nippon Steel, 2024.
18 'Carbon Price Tracker,' Ember, 2024.
19 'Low-CO_2 emissions projects in the EU steel industry,' Eurofer, 2022.
20 'Green Steel Tracker,' Leadership Group for Industry Transition, 2024.
21 'How the EU's carbon border tax will affect the global metals trade,' ING, 2023.
22 'The implementation of CBAM may lead to an increase in prices for steel imports to the EU,' GMK Center, 2023.
23 'How global trade could fragment after the EU's tax on 'dirty' imports,' Financial Times, 2024.
24 'India aims to safeguard steel trade interest from EU carbon levy,' The Economic Times, 2023.
25 'Iron ore quality a potential headwind to green steelmaking – Technology and mining options are available to hit net-zero steel targets,' Institute for Energy Economics and Financial Analysis, 2022.
26 'Africa's largest mining and related infrastructure project,' Rio Tinto, 2024.
27 'Fortescue ships first product from Belinga iron ore project in Gabon,' Fortescue, 2024.
28 'Iron ore quality a potential headwind to green steelmaking – Technology and mining options are available to hit net-zero steel targets,' Institute for Energy Economics and Financial Analysis, 2022.
29 Ibid.
30 'Sustainability Report, FY 2023,' BlueScope Steel Limited, 2023.
31 'BHP and Hatch commence design study for an electric smelting furnace pilot,' BHP, 2023.
32 'Decarbonizing steelmaking for a net-zero future,' Boston Metal, 2024.
33 'Pig Iron,' International Iron Metallics Association, 2024.
34 'Fossil-free steel – a joint opportunity,' HYBRIT, 2024.
35 'World's biggest mining project to start after 27 years of setbacks and scandals,' Financial Times, 2024.
36 'Work set to resume at Simandou iron ore after Guinea, shareholders agree terms,' Reuters, 2023.
37 'Vale opens the world's first green briquette factory,' The Brazilian Report, 2023.
38 'Revolution in the global steel industry: Vale inaugurates the world's first briquette plant in Vitoria, Brazil,' Vale, 2023.
39 Ibid.
40 'Green iron and steel offer MENA a chance to shine,' Institute for Energy Economics and Financial Analysis, 2023.
41 'Fortescue Board approves 'green pit to product' hydrogen-based iron ore project,' International Mining, 2023.
42 'Major partners for Pilbara green iron renewable hydrogen study,' Government of Western Australia, 2023.

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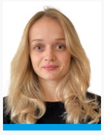

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Albertine joined the Responsible Investment team in the summer of 2022, concentrating on climate change. Albertine's background is in climate science and before joining she worked as a researcher and adviser at a range of academic, third- and public-sector organisations. When not working she enjoys spending her time reading, running, and climbing.

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