INDUSTRY STUDY

SUSTAINABILITY IN THE STEEL INDUSTRY

TIPS industry studies aim to provide a comprehensive overview of key trends in leading industries in South Africa. For each industry covered, working papers will be published on basic economic trends, including value added, employment, investment and market structure; trade by major product and country; impact on the environment as well as threats and opportunities arising from the climate crisis; and the implications of emerging technologies. The studies aim to provide background for policymakers and researchers, and to strengthen our understanding of current challenges and opportunities in each industry as a basis for a more strategic response.

This industry study examines the sustainability of the South African steel industry, focusing on carbon intensity, sustainability risks, and the evolving policy landscape. It is the fourth in a series of studies on the steel industry. The previous studies explored various aspects of the sector, including mapping the steel value chain, analysing economic trends and their national impact, assessing international trends with a focus on global and South African trade by country and product, and examining technological advancements and their implications for the industry.

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ABBREVIATIONS

AMSA	ArcelorMittal
BCAs	Border Carbon Adjustments
BF	Blast Furnace
BOF	Basic Oxygen Furnace
CO_2	Carbon Dioxide
DRI	Direct Reduced Iron
EAF	Electric Arc Furnace
EU	European Union
EU CBAM	European Union’s Carbon Border Adjustment Mechanism
GHG	Greenhouse Gas
Gt	Gigatons
LCoS	Levelized Cost of Steel
tCO_2e	Tonnes of Carbon Dioxide Equivalent
PPS	Price Preference System
UK	United Kingdom
US	United States

INTRODUCTION

Steel is an integral product in modern economies and forms a key input into important value chains such as automotives and construction, and other infrastructure. The demand for steel is anticipated to grow over the coming decades in order to meet the needs of growing economies and rising social and economic welfare needs (World Steel Dynamics 2024). Against this imperative, meeting this demand presents challenges for the iron and steel sector as it seeks to plot a more sustainable pathway while remaining competitive. The global iron and steel industry is a significant emitter of greenhouse gas (GHG) Emissions and carbon dioxide (CO_2) specifically, given its energy intensity and production processes, with the use of coking coal in certain production paths.

To understand emissions within the iron and steel value chain, it is essential to first examine the steelmaking production processes. There are two dominant methods: 1) Blast Furnace (BF) – Basic Oxygen Furnace (BOF): This integrated approach consists of two key stages—the reduction of iron ore to molten iron in a BF and the subsequent conversion of that molten iron into steel in a BOF. This method relies on coking coal and iron ore as primary feedstocks. Due to its energy-intensive nature, it is the largest emitter of greenhouse gases in steel production and remains the dominant technology (72% of global steel production) in the industry (World Steel Dynamics 2024; World Economic Forum 2024). 2) Electric Arc Furnace (EAF): This modern steelmaking method prioritises efficiency, flexibility, and sustainability. Unlike the BF-BOF route, EAF primarily uses scrap metal as its raw material, significantly reducing carbon emissions and energy consumption. This method constitutes 21% of global steel production (World Economic Forum 2024). Other innovative ironmaking technologies, such as Midrex and Corex, which focus on producing direct reduced iron (DRI) and molten iron with greater efficiency and lower carbon emissions, are also utilised. However, these methods account for only a small fraction of global steel production.

The global steel industry emitted over 2.8 gigatons (Gt) of CO_2 in 2023, representing over 7% of total global GHG emissions and more than 11% of total global CO_2 emissions in 2023 (World Economic Forum 2024). The BF-BOF process emits 2.3 tonnes of CO_2 per tonne of steel, while the scrap-based EAF process emits only 0.7 tonnes, and the DRI-EAF process emits 1.4 tonnes (World Economic Forum 2024). Steel production methods vary by regions, for example China and India primarily rely on the BF-BOF route, using coal as the main fuel; the European Union (EU) employs BF-BOF with advanced technologies to reduce emissions intensity; and the United States (US) has the highest share of scrap-based EAF steel production, resulting in the lowest emissions intensity globally (World Economic Forum 2024). In 2022, the South African iron and steel industry emitted 6.3 million tonnes of CO_2, accounting for 1.3% of South Africa's total emissions (DFFE 2024).

As carbon intensity and GHG emissions from the steel industry continue to rise (although at a decreasing rate due to the struggling steel industry), technological innovation in steel production is gaining momentum globally. However, commercial viability remains a significant challenge. Amid these advancements, South Africa lags in technology adoption. Although it is not among the top 20 global importers or exporters of steel, South Africa's steel industry plays a crucial role in the country's industrialisation, ranking between 32nd and 35th globally depending on the year (World Steel Association 2024).

Despite consistent performance over time, the South African steel industry is struggling to adapt to structural shifts, including changing steel demand, domestic issues, such as energy and logistics, as well as the long structural issues in production of long steel – which is leading to a closure of ArcelorMittal (AMSA) long business plants. The sector operates below capacity, and its economic contribution has been declining, as highlighted in the overview paper in the series of steel industry studies[1] (Maimele 2025). One key challenge is the delayed adoption of advanced technologies. The industry remains heavily reliant on BF-BOF technology through AMSA, which depends on coking coal (mostly imported), iron ore, and coal-based electricity, resulting in high carbon intensity and reduced global competitiveness.

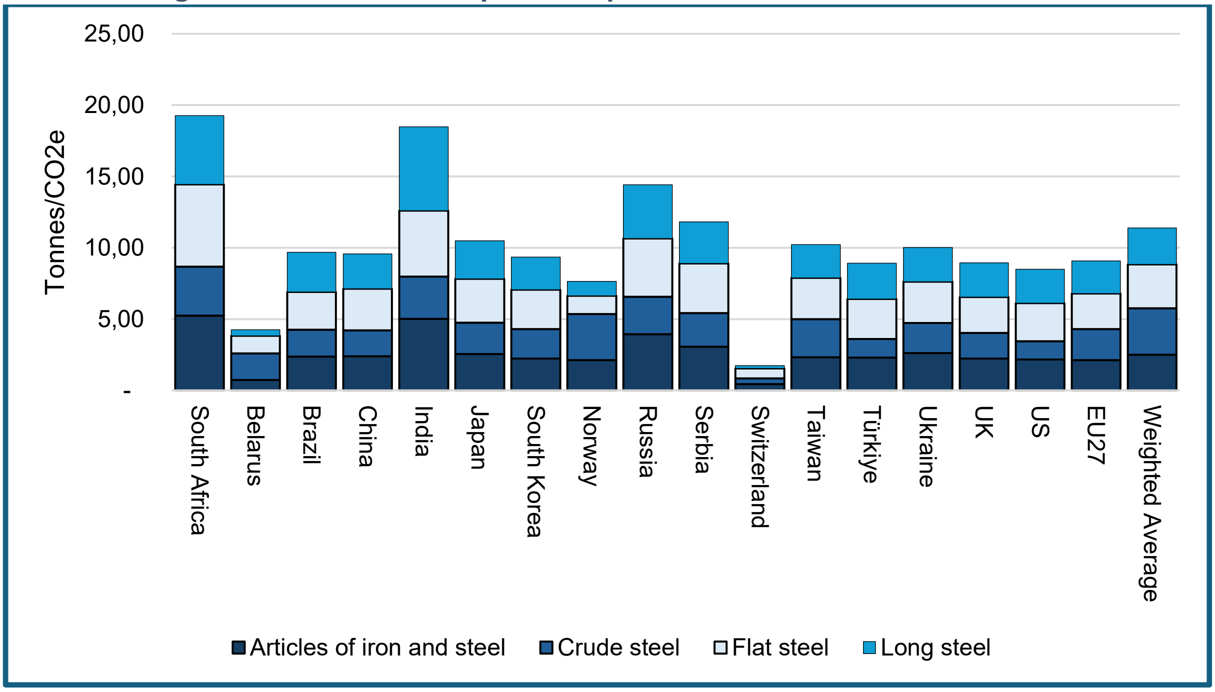
However, there has been growth in the adoption of EAF technologies, particularly in mini mills specialising in long steel production. These developments, alongside investments in decarbonisation measures, indicate a gradual shift. Nevertheless, the South African steel industry faces mounting international pressure, especially from tariff and non-tariff measures like Border Carbon Adjustments (BCAs) amid the need for sustainable development.

This study examines the sustainability of South Africa's steel industry, focusing on its carbon intensity, sustainability risks, and evolving policy landscape. It begins by assessing the carbon intensity of the steel value chain, followed by an analysis of policy developments and the associated sustainability challenges.

1. CARBON INTENSITY OF THE STEEL VALUE CHAIN

Globally, South Africa's steel products are considered "dirty" due to their high carbon intensity, driven by a heavy reliance on coal, through coal-based electricity and the use of coking coal in blast furnaces, through the BF-BOF route. Figure 1 illustrates the emissions intensity of the steel industry across the South African value chain in comparison to key competitors. As shown in Figure 1, South Africa stands out as an outlier in carbon intensity compared to its competitors. Following South Africa are India, Russia, and Serbia, all of which exceed the global weighted average.

Figure 1. Carbon intensity of steel products across selected countries



Source: Adapted from the European Commission, 2023, JRC report.

1. Industry Study – Steel and related products. Overview. Trade & Industrial Policy Strategies (TIPS). The other two reports in the series are: Industry Study: International trends in the steel industry and Industry Study: Technological change in the steel industry.

South Africa’s steel products generally have higher embedded carbon intensity, apart from long steel products, where India surpasses it. For articles of iron and steel, South Africa emits 5.25 tonnes of carbon dioxide equivalent (tCO_2e) per tonne of product—more than double the weighted average.

Regarding crude steel and flat steel products, South Africa emits 3.42 tCO_2e compared to the weighted average of 3.28 tCO_2e for crude steel and 5.77 tCO2e compared to the weighted average of 3.05 tCO2e for flat steel products. South Africa's emission intensity is higher due to emissions from iron ore agglomeration and steel production, which predominantly relies on the BF-BOF process. This method uses coking coal as a primary feedstock, along with coal for energy and coal-based electricity, contributing significantly to overall emissions.

1.1. Raw material sourcing

In the upstream segment, this phase encompasses the collection and preparation of input materials for steel production. These materials include mined iron ore, coking coal (primarily imported and used in metallurgical processes), limestone (used mainly in crude steel production), and recycled scrap for steelmaking.

The technologies employed in the upstream phase include concentrators for the beneficiation of iron ore (producing agglomerated iron ore), direct reduced iron (DRI) plants, and pellet plants for producing DRI and iron pellets. While emissions in this part of the value chain are relatively minimal, CO_2 is released during ore preparation processes.

1.2. Metallurgical beneficiation and shaping

In the midstream phase, metallurgical beneficiation and shaping occur. This stage involves producing pig iron, which is then refined into crude steel, including slabs, billets, and ferroalloys. In South Africa, crude steel production is primarily conducted in blast furnaces. These include the Basic Oxygen Furnace (BOF), which relies heavily on coking coal and iron ore, and the Electric Arc Furnace (EAF), which predominantly uses scrap metal.

To produce slabs and billets, the steel must undergo desulfurization and degassing to ensure quality. Following these processes, the material is processed in ladle furnaces, slab casters, and billet casters to produce sellable crude steel. This stage is highly emission intensive. South Africa’s reliance on coal for electricity—82% of the country’s electricity is coal-generated (Department of Mineral Resource and Energy (DMRE) 2024))—further contributes to the carbon intensity of the steel production process, especially for mini mills, which depend heavily on electricity to produce steel.

The steel industry in South Africa accounts for 16% of the country’s total energy demand (Department of Mineral Resource and Energy 2024). The energy breakdown within the steelmaking phase consists of 57% coal, 36% electricity, and 7% natural gas. Mini mills primarily use electricity (coal produced) and natural gas for steel production, while coal is predominantly used for primary steel production in traditional BOF processes. Globally, approximately 89% of the BF-BOF route's energy input comes from coal, 7% from electricity, 3% from natural gas, and 1% from other gases and sources. In contrast, the EAF route derives 11% of its energy from coal, 50% from electricity, 38% from natural gas, and 1% from other sources (World Steel Association 2021).

1.3. Fabrication and conversation

Once crude steel is produced, value is added by converting or fabricating it into finished steel products. This stage of the value chain involves transforming crude steel into flat and long steel products. Flat steel includes sheets and roll coils, while long steel comprises profiles, bars, and rods. These products are further processed into specialised steel items such as tubes, pipes, coated steel, and wires.

Key participants in this stage include rolling mills, industrial processors, and service centres. Service centres add additional value by performing processes such as cutting, bending, and painting. While these entities contribute to emissions, their emission levels are significantly lower than those of metallurgical beneficiation and shaping processes.

1.4. Consumption and end market

The final stage of the steel value chain involves the consumption of steel products in their finished or intermediate forms. Key sectors utilising steel include building and construction, machinery, mining, and automotives. Steel is also extensively used in industries such as oil and gas, aviation, shipbuilding, appliances, and wind tower production. South African steel is consumed both locally and internationally, with the industry supported by financial and logistical services.

During the transportation of steel products, both domestically and internationally, carbon dioxide emissions occur, with methane also emitted. In addition, scrap steel is collected at this stage, which re-enters the value chain as a vital input for mini mills (in the South African case). At this stage of the value chain, steel transportation is the largest source of CO_2 emissions. While rail and maritime transport contribute to emissions at varying intensities, ports and rail infrastructure remain critical to the steel industry. However, inefficiencies and capacity constraints in the rail system often force producers to rely on road transport, which is significantly more carbon-intensive – for example the case of AMSA.

Since 2020, challenges with Transnet's rail and port services have significantly increased AMSA's transportation costs for iron ore and coal (Makgetla 2024). These disruptions caused major delivery delays, leading to plant shutdowns and a shift to more expensive and higher-emission road transport. By 2023, approximately one-third of AMSA's bulk input shipments were transported by road—considerably more than in 2022 (Makgetla 2024). In contrast, before 2021, the company relied almost entirely on Transnet for moving iron ore, coal, and steel. In the third quarter of 2023, Transnet-related disruptions forced the Newcastle blast furnace to shut down for over a month, with AMSA estimating the direct financial impact at R116 million (Makgetla 2024).

Water also plays a critical role throughout the steel value chain. It is extensively used for cooling purposes, including coke quenching, blast furnace cooling, and continuous casters. Water is also utilised to clean off-gas in blast furnaces, for descaling in hot rolling mills, and as a resource for steam production (Conejo et al. 2020).

2. THE POLICY LANDSCAPE AND SUSTAINABILITY RISKS

The global steel industry is undergoing significant transformation, driven by climate change policies and geopolitical tensions. Key factors include the rising demand for green steel and the urgency to decarbonise production, and the introduction of carbon taxes – both domestically and internationally. This section examines some of these policies, exploring the associated risks and opportunities for the industry.

The discussion begins with an analysis of decarbonisation trade measures such as border carbon adjustments and their local impact on the steel industry. It then transitions to the role of domestic carbon taxes, highlighting their implications. Next, it addresses the surging demand for green steel, spotlighting countries already leading in green steel production. Finally, the section delves into local decarbonisation efforts, focusing on the adoption of electric arc furnace technology and the decarbonisation roadmap of South Africa's largest steel producer, AMSA.

2.1. Border Carbon Adjustments (BCAs)

The global shift towards low-carbon production processes has intensified, particularly in hard-to-abate sectors such as the iron and steel value chain. Decarbonisation of steel production is being explored and implemented worldwide to address the environmental challenges posed by traditional, carbon-intensive methods. As the global shift toward sustainability accelerates, South African steel firms are expected to report GHG emissions from their production processes – leading to the creation of a GHG accounting system. Additionally, with the introduction of BCAs, they will face import-environmental tariffs imposed by EU and United Kingdom (UK) importers.

The European Union's Carbon Border Adjustment Mechanism (EU CBAM), introduced in 2023, is the first BCA and is set for full implementation in 2026. Similarly, other jurisdictions—including the UK, the US, Japan, Australia, and Canada — are considering similar mechanisms (Maimele 2024a). The UK's CBAM is scheduled to take effect in 2027, a year after the EU's (Maimele 2024b). These global policy shifts are driving technological innovation in the steel industry, accelerating its transition toward sustainability. However, they are leaving developing countries behind.

The introduction of BCAs will increase the cost of South African steel products, making them less competitive in international markets (lowering their demand) amid the push for sustainable development. This lack of competitiveness could lead to market fragmentation, where late adopters struggle to keep pace, ultimately impacting their socio-economic stability.

To mitigate these challenges, South Africa is developing infrastructure to monitor, report, and verify embedded GHG emissions in products like steel. However, further efforts are needed in diplomacy, economic policy, energy policy, and international trade regulations to ensure a smooth transition and maintain competitiveness of steel products.

2.2. South Africa's carbon policy

Alongside the BCAs, South Africa passed a Carbon Tax Act in 2019, which came into effect from June 2019. The carbon tax is a tax on the CO_2 equivalent of greenhouse gas emissions, emitted in sectors that emit CO_2 emissions. The main objective of the tax is to limit or disincentivise emitting sectors and internalise the cost emitting of carbon dioxide. The South African Carbon Tax Act No. 15 or 2019 covers a wide range of sectors – covering 80% of the country's emissions (a significantly higher share than many other carbon pricing schemes worldwide). Some of the sectors included in the tax include the energy sector specifically looking into fuel combustion activities, such as electricity production, petroleum refining; manufacturing in industries such as iron and steel, and chemicals; transport; oil and natural gas; and emissions from energy production, such as coal-to-liquids processes and gas-to-liquids processes, among others. The carbon tax will operate in conjunction with the Climate Change Act No. 22 of 2024 (Republic of South Africa 2024), which introduces mandatory carbon budgets as a key provision. Under the Act, the Minister is required to allocate a carbon budget to any entity emitting carbon through activities specified in Section 26(2) of the Act. This will also impact the iron and steel industry.

With the introduction of BCAs and the expected shifts associated with carbon taxation, South Africa's carbon tax remains relatively low by both global and EU standards, in both nominal and effective terms. Currently, the nominal carbon tax in South Africa stands at R190 tCO_2e (approximately US$10/$tCO_2e$) (Maimele and Tutani 2024). The effective carbon tax rate remains low by global standards, in 2022, the effective rate ranged from R6 to R48 per tCO_2e (US$0.30 to US$2.60), well below the global average of US$6 (Montmasson-Clair & Patel 2024).

According to the National Treasury, the carbon tax is expected to increase to R462/tCO_2e by 2030 (approximately US$25-US$30/tCO_2e) (National Treasury 2024). To fully leverage the opportunities presented by BCAs, South Africa should align its carbon pricing with the levels set by jurisdictions implementing these measures. In addition, ring-fencing revenues from carbon taxes and levies for green industrialisation initiatives should be considered to support a sustainable transition.

2.3. Green steel production

Amid the technological advancements in the steel industry, incorporating green hydrogen into steelmaking is a promising and close-to-commercial option. This includes the Green Hydrogen Direct Reduced Iron-Electric Arc Furnace) process. This technology significantly reduces emission intensity in steel production, utilising green hydrogen produced from renewable energy or zero-carbon electricity. It offers a transformative pathway for greener steel production with substantial emission reductions.

The rising demand for green steel has prompted steel firms worldwide to invest in and explore greener solutions at a lower cost to stay competitive. In South Africa, AMSA took significant steps in 2022-2023 as the push towards sustainable development intensified. The company entered into a collaboration with Sasol to explore the revitalisation of its Saldanha Steel Midrex facility (currently under care and maintenance) at the Saldanha Works plant, as part of its decarbonisation roadmap (AMSA 2023). However, in 2025 as the steel crisis in South African intensified, this project has been shelved (Van Diemen 2025).

Other global actors, like the Climate Group's Clean Steel Buyers Alliance, bring together key players from the construction industry in the UK (Mete 2021). In other parts of the world, companies such as Volvo Trucks plan to purchase hydrogen-based steel from Sweden's industrial scale HYBRIT steel plant; and car manufacturer Volkswagen announced plans to produce electric cars with a 100% carbon neutral value chain (Mete 2021). National and local governments – including those of Germany, the Netherlands, California and South Africa – have included steel in green public procurement policies that set sustainability standards for products and materials purchased using government funds (Mete 2021). Amid the rising demand in green steel, Leadership Group for Industry Transition (LeadIT 2024) developed a green steel tracker and, as of December 2024, 65 green steel projects were active around the world. As much as there is increased demand in green steel, the adoption of green hydrogen DRI-EAF technology depends on financial factors that vary by country, including the cost of hydrogen and the impact of carbon pricing mechanisms. A study by Hasanbeigi et al. (2024) examines its feasibility across several countries, including China, Japan, South Korea, the US, the EU, Brazil, and Australia.

The study reveals significant variations in the Levelized Cost of Steel (LCoS) across countries for both traditional and green hydrogen-based production methods. Countries like Brazil, China, and Australia demonstrate a lower LCoS for the green hydrogen DRI-EAF process. In contrast, Japan, South Korea, and the EU face higher LCoS for the same method (Hasanbeigi et al. 2024). This indicates that, while the global potential for cost competitiveness exists, the economic viability of this technology heavily depends on local hydrogen costs and the comparative costs of steel production using traditional methods. So, despite increasing demand in green steel, it is not economically and commercially feasible.

2.4. Decarbonisation and the rise of the mini mills/electric arc furnace route

The local steel industry is actively implementing decarbonisation measures to transition away from carbon-intensive processes, even as it addresses its own local challenges. These measures are further driven by the increasing implementation of carbon taxes, including the recently introduced EU CBAM, the upcoming UK CBAM, and South Africa's domestic carbon tax.

In 2023, AMSA, the largest steel producer in the country, unveiled its decarbonisation roadmap aimed at achieving carbon neutrality. The roadmap sets ambitious targets, including a 25% reduction in carbon intensity by 2030, from a 2018 baseline of 2.90 tCO_2e per tonne of crude steel to 2.16 tCO_2e/t. By 2050, AMSA aims to reduce carbon intensity by 86%, reaching 0.40 tCO_2e/t of crude steel (AMSA 2023).

Alongside its decarbonisation efforts, South Africa's steel industry has experienced a rise in mini mills, reflecting a global trend outside China and India (Makgetla 2024). These mini mills, if they utilise scrap and renewable energy, could produce significantly lower greenhouse gas emissions. Since 2013, their adoption has been supported by several policies, including the introduction of a price preference system (PPS) to prioritise local scrap metal buyers, a temporary ban on scrap exports in 2020 to address domestic shortages, an export tax in 2021, and additional measures implemented from 2022 onwards.

By late 2024, debates over the 2021 export tax on scrap metal, set at approximately R1000 per tonne, intensified. The tax aims to replace the PPS system, which required scrap to be offered locally at discounted prices before export. This policy has sparked tensions between mini mills and AMSA, South Africa's largest crude steel producer. Mini mills, relying on electric arc furnaces and cleaner production methods, argue the tax promotes industrial sustainability, job creation, and market competitiveness. Conversely, AMSA views the tax as protectionist and advocates for open scrap exports to raise prices for mini mills. Despite these debates, mini mills continue to require modest investment and provide flexibility for future adaptation (Makgetla 2024).

Globally, excluding China, the share of electric arc furnaces in steel production increased from 23% in 1982 to 50% in 2022. In the Global South, excluding China, electric arc furnaces accounted for 60% of steel production in 2022 (Makgetla 2024). In South Africa, the share of electric arc furnaces surpassed 45%, driven primarily by the highly competitive production of low-cost long steel products by mini mills. This increase, however, coincided with stagnant demand for long steel, leading to a decline in market share and demand for AMSA's products (Makgetla 2024). Despite their growth, mini mills in South Africa face significant challenges. The rising cost of electricity during the 2010s hampered the adoption of electric arc furnaces, with AMSA notably shutting down some of its electric arc furnace operations. However, this trend began to reverse nationally in the late 2010s (Makgetla 2024).

3. CONCLUSION

The global steel industry continues to contribute to greenhouse gas emissions, hindering global efforts to reduce GHG emissions. While technological innovations in steel production are emerging worldwide, commercial viability remains a significant challenge. South Africa lags in adopting advanced technologies, with its primary steel sector heavily reliant on carbon-intensive Blast Furnace-Basic Oxygen Furnace processes that depend on imported coking coal, iron ore, and coal-based electricity. Despite declining economic performance and undercapacity, the South African steel industry remains crucial for industrialisation and job creation. It must adapt to the evolving global steel landscape by shifting towards green steel and cleaner production processes, such as adopting Electric Arc Furnace technologies in mini mills and prioritising decarbonisation investments in the primary steel production. Amidst these challenges, the sector must also respond to international pressures, such as Border Carbon Adjustments (BCAs), in the short to medium term.

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