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Steel Decarbonisation in India

Early days, but time to take the right decisions to lay the foundation for a successful transition to net zero

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Glossary

Abbreviation	Definition
AMGPL	ArcelorMittal Green Energy Pvt Ltd
ACC	Advance Cell Chemistry
BF	Blast Furnace
BOF	Basic Oxygen Furnace
BAT	Best Available Technologies
°C	Celsius
CAGR	Compound Annual Growth Rate
CO_2	Carbon Dioxide
COP26	26th Conference of the Parties
COP27	27th Conference of the Parties
CCUS	Carbon Capture, Utilisation and Storage
CCC	Carbon Credit Certificates
CBI	Cold Briquetted Iron (CBI)
CBAM	Carbon-Based Adjustment Mechanism
DCs	Designated Consumers
DRI	Direct Reduced Iron
ESCerts	Energy Saving Certificates
EAF	Electric Arc Furnace
EIF	Electric Induction Furnace
ETS	Emission Trading System
FY	Financial Year
GHG	Greenhouse Gas
GrInHy2.0	Green Industrial Hydrogen
GDP	Gross Domestic Production
GW	Gigawatt
H_2DR	Hydrogen Direct Reduction
HBI	Hot Briquetted Iron
IF	Induction Furnace
IEX	Indian Energy Exchange
IIT	Indian Institute of Technology
ISP	Integrated steel plants
JPC	Joint Plant Committee
JSPL	Jindal Steel and Power Ltd
KgH2	Kilogram of Hydrogen

KWH	Kilowatt Hour
MOE	Molten Oxide Electrolysis
MT	Million Tonne
MTPA	Million Tonne Per Annum
MNRE	Ministry of New and Renewable Energy
MOU	Memorandum of Understanding
MoEF&CC	Ministry of Environment, Forest and Climate Change
NEDO	New Energy and Industrial Technology Development Organization
NGHM	National Green Hydrogen Mission
PCI	Pulverised Coal Injection
PLI	Production-Linked Incentive
PAT	Perform, Achieve and Trade
R&D	Research and Development
REC	Renewable Energy Certificates
SOEC	Solid Oxide Electrolysis Cell
SAIL	Steel Authority of India Limited
SG	Siemens Gamesa
SSI	Secondary Steel Industries
TCS	Tonne of Crude Steel
TPD	Tonne Per Day
UNFCCC	United Nations Framework convention on climate change
6R	Reduce, Reuse, Recycle, Recover, Redesign and Remanufacture

Key Findings

We expect green hydrogen to become the primary route of steelmaking in India only by 2050. This is because the cost of green hydrogen needs to reduce and there needs to be a price penalty on carbon emissions for Indian steelmakers to switch to hydrogen-based steelmaking.

A legal definition for green steel can help guide the industry in making the right investments for decarbonisation.

Strict enforcement of renewable purchase obligations on the steel sector can also help in the greater use of clean energy in the steel sector.

IEEFA and JMK Research estimate that the steel industry will replace around 25-30% of its grey hydrogen requirements with green hydrogen in the early part of the 2030-2050 period. This will increase to 80% by 2050.

Executive Summary

India's steel industry contributes to around 2% of its gross domestic product, but also accounts for 12% of its carbon dioxide (CO2) emissions. The decarbonisation of the sector is at a nascent stage. To aid the industry in making the right investments, the government needs to define green steel since there is no legal definition for the same. It also needs to create a market and demand for green steel, since all current technologies will substantially increase costs. A penalty on carbon emissions will also help bridge the cost of green steel and traditionally produced steel. The government can mandate the use of green steel in public infrastructure and nudge the private sector through the use of green steel certificates, tradable in the national carbon market, to offer them a new revenue stream. Given all the challenges, we expect coal to be dethroned as the primary route for steelmaking only in the latter part of the 2030 to 2050 period. Adopting the green hydrogen route to produce steel can substantially cut emissions. But we do not expect green hydrogen to become the primary route of steelmaking in India anytime before 2050.

In India, the steel industry contributes to around 2% of the Gross Domestic Product (GDP) and is critical to the country's progress. In the fiscal year (FY) 2023, the production of finished steel in India was 122.3 million tonnes,[1] an increase of about 7.6% over the previous year.[2]

India's steel sector accounts for about 12% of India's carbon dioxide (CO_2) emissions, with an emission intensity of 2.55 tonne of CO_2/tonne of crude steel (tCO_2/tcs) compared with the global average emission intensity of 1.85 tCO_2/tcs.[3] The steel industry is responsible for around 240 million tonnes of CO_2 emissions annually and we expect this to double at an exponential rate by 2030, considering the Indian government's infrastructure development targets.

There are multiple technology pathways that could help in the transition from traditional methods to low emission intensity technology like green hydrogen, renewable energy, carbon capture, usage and storage technology with Blast Furnace (BF)/Basic Oxygen Furnace (BOF) or Direct Reduced Iron (DRI)-Electric Arc Furnace (EAF), scrap-based Electric Arc Furnace (EAF) etc. Of these technologies, the green hydrogen-based route is the cleanest method of producing steel. However, green hydrogen is expensive and investing in the technology could render steelmakers uncompetitive as they sell a highly commoditised product.

[1] Ministry of Steel. Press Release. 7 June 2023.
[2] Ministry of Steel. Monthly Summary for the Cabinet. March 2023.
[3] Ministry of Steel. Year-end Review-2022 Ministry of Steel. December 2022.

The government has taken initiatives to decarbonise the steel sector, including the Steel Scrap Recycling Policy 2019, the Perform, Achieve and Trade (PAT) scheme and the announcement of 13 task forces by the Ministry of Steel for developing a green steel roadmap.

The most important initiative though is the National Green Hydrogen Mission (NGHM), under which the Ministry of Steel has been allocated 30% of the pilot project budget, i.e., Rs14.66 billion (US$177 million), to promote the use of green hydrogen in steelmaking.

Under this mission, the Solar Energy Corporation of India (SECI) has issued two tenders under Strategic Interventions for the Green Hydrogen Transition (SIGHT) programme in July 2023. The first is a 1.5 gigawatts (GW) tender for scaling up localised manufacturing in the electrolyser space, and research and development in indigenous stack technology. The second tender is for producing 450,000 tonnes of green hydrogen per annum on technology-agnostic and biomass pathways. The tenders are aimed at bringing down the price of green hydrogen.

> **To switch from coal-based steelmaking to hydrogen, the cost of green hydrogen needs to reduce and there needs to be a price penalty on carbon emissions.**

For Indian steelmakers to switch from coal-based steelmaking to hydrogen-based steelmaking, the cost of green hydrogen needs to reduce and there needs to be a price penalty on carbon emissions.

According to industry estimates, to make hydrogen technology viable for expansion, the required price should be around US$1-2/kg[4] and a carbon penalty of at least US$50 per tonne of emissions should be applicable on steel manufactured through traditional methods. This can make green steel competitive and catalyse a 150 million tonne shift from coal-based to hydrogen-based steelmaking.

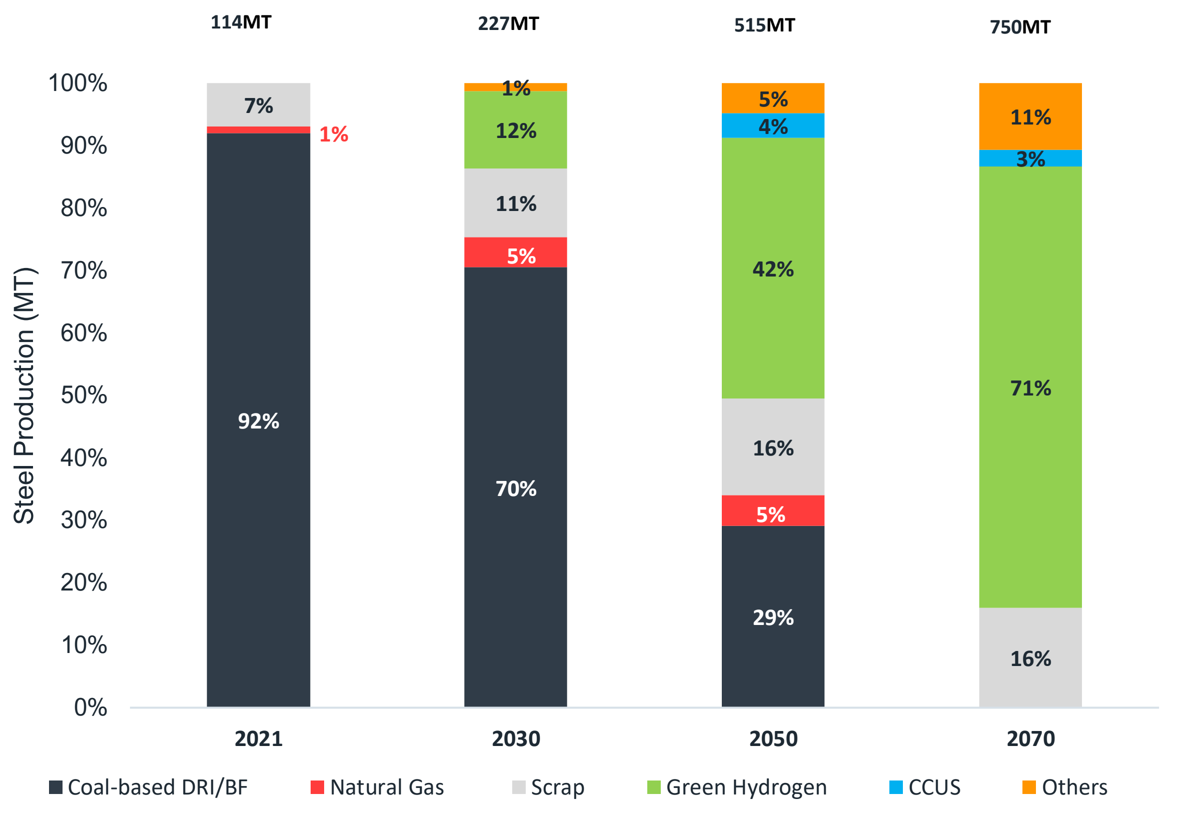
Based on our analysis, we expect India's steel sector decarbonisation trajectory until 2070 to be the following:

- **Up to 2030**: The sector is likely to see a reduction in the share of coal-based technologies, i.e., BF/BOF and coal-based DRI-EAF/Electric Induction Furnace (EIF) route from 92% in 2021 to 70% by 2030. This transition is possible by replacing coal-based DRI process in EAF technologies with green hydrogen. Several pilot projects and trials for green hydrogen projects started in India in 2020. By 2030, green hydrogen production is likely to start on a commercial scale in India.
- **2030 to 2050**: In this period, green hydrogen projects will be deployed on a large scale across India due to high demand. This is likely to phase out coal-based routes like BF/BOF and DRI-EAF at a faster pace. IEEFA and JMK Research estimate that the steel industry will replace around 25-30% of its grey hydrogen requirements with green hydrogen. This will increase to 80% by 2050.
- **From 2050-2070**: During this time, large projects using the green hydrogen-based route will be available across India, and the cost of green hydrogen will be significantly reduced due to

[4] The Hindu BusinessLine. Decarbonizing the steel sector will pay off. May 2023.

a highly competitive market. The green hydrogen-based route is, therefore, likely to completely replace coal and natural gas-based conventional technology.

Percentage Share of Different Technologies in Steel Production by 2070



Source: Industry Reports, JMK Research
Note: Coal-Based processes including DRI-EAF, DRI-EIF and BF-BOF route. Others can include Molten Oxide Electrolysis, Electrowinning etc.

As low-emission technologies like green hydrogen become economically feasible, funding to support Micro, Small and Medium Enterprises (MSMEs) will also start coming into the sector. This funding will be in the form of loans, bonds or schemes that are tailor-made for the steel sector. Such instruments include sustainability-linked bonds and loans (SLBs and SLLs) and blended finance mechanisms.

Development in any sector brings opportunities and challenges at the same time, and so is the case with the steel sector. The steel sector has its own set of challenges on the technical and commercial fronts. To address these challenges, policymakers need to think of innovative steps that will aid the decarbonisation of the steel sector.

IEEFA and JMK Research have identified some policy actions that can accelerate the decarbonisation of India's steel sector. One of the key policy decisions that the government needs to take is to define green steel. Currently, there is no legal definition for green steel in India, and without it, the technology track that the industry should follow remains unclear. We recommend that the government define green steel as steel that does not use fossil fuels in the production process. All other technologies that reduce emissions should be termed low-carbon steel.

We note that the government has recognised the need for a clear taxonomy for green steel and has set up a task force for developing a taxonomy, definitions, benchmarks, scoping and certifications for it.

Steel remains a highly commoditised product and the high cost of green steel implies that there is insufficient demand for it in the absence of policy action. We recommend that the government look at mandating some quantity of green steel in public sector purchases. It can also extend the mandate to private consumers. For creating demand in the private sector, the government can also look at using Green Steel Certificates, which consumers of green steel can trade for additional income through trading on the carbon market.

> **At the same time, policies should also look at progressively penalising steel produced from traditional high-emission technologies.**

At the same time, policies should also look at progressively penalising steel produced from traditional high-emission technologies. This will help bridge the gap between the prices of green steel and traditionally produced steel.

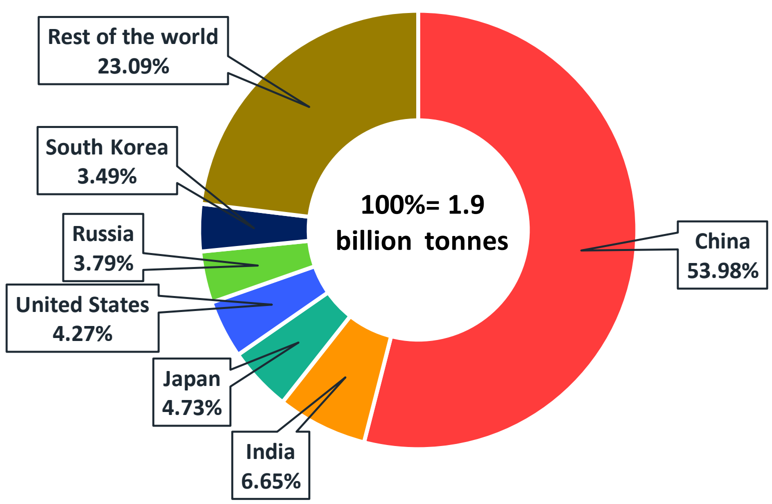
Finally, to ensure sustained investments in green hydrogen production, which can bring down its cost, the government can look at introducing a green hydrogen purchase obligation mechanism for the steel sector. This will ensure there is demand for green hydrogen and steelmakers invest in green hydrogen-based technologies. Similarly, strict adherence to renewable purchase obligations can also help in the greater use of clean energy in the steel sector.

We believe that with the right policies in place, India can successfully decarbonise its steel sector by 2070.

Steel Sector in India

Steel plays a pivotal role in major sectors like infrastructure, automobile, engineering, construction and defence. According to the World Steel Association, global crude steel production in 2022 was 1.9 billion tonnes. India is the world's second-largest producer of crude steel with a 6.65% share in global production in 2022, while China leads with a 53.98% share.

Figure 1: Global Crude Steel Production in 2022



Source: World Steel Association, 2022

The steel sector has been crucial to India's progress and is one of the oldest industrial sectors, with production beginning as early as 1911. It still contributes to around 2% of India's Gross Domestic Product (GDP).

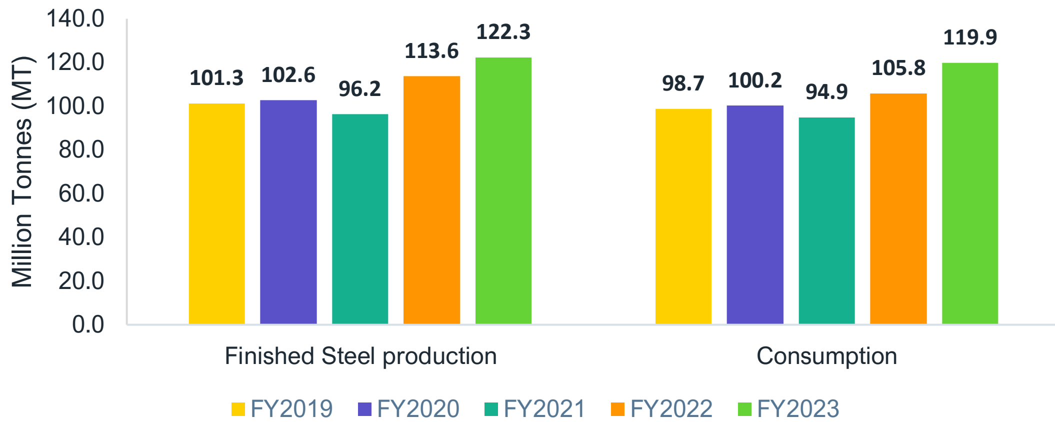
Over the last decade, the Indian steel sector has been in a growth phase, with nearly every major steelmaker adding production capacity.

According to data from the Joint Plant Committee (JPC), an arm of India's Ministry of Steel, finished steel production increased from 101.3 million tonnes in the fiscal year (FY) 2019 to 122.3 million tonnes in FY2023, representing a compounded annual growth rate (CAGR) of 4.8%. However, finished steel production declined in FY2021 to 96.2 million tonnes due to the Covid-19 pandemic. After the pandemic, production rose sharply by 18% to 113.6 million tonnes in FY2022 and further by 7.6% to 122.3[5] million tonnes in FY2023.[6]

[5] Ministry of Steel. Press Release. 7 June 2023.
[6] Ministry of Steel. Monthly Summary for March 2023. 13 April 2023.

Similarly, finished steel consumption in India has increased steadily over the years, from 98.72 million tonnes in FY2019 to 119.9 million tonnes in FY2023, representing a CAGR of 5%. Consumption of finished steel in FY2023 increased by 13.3% from FY2022.

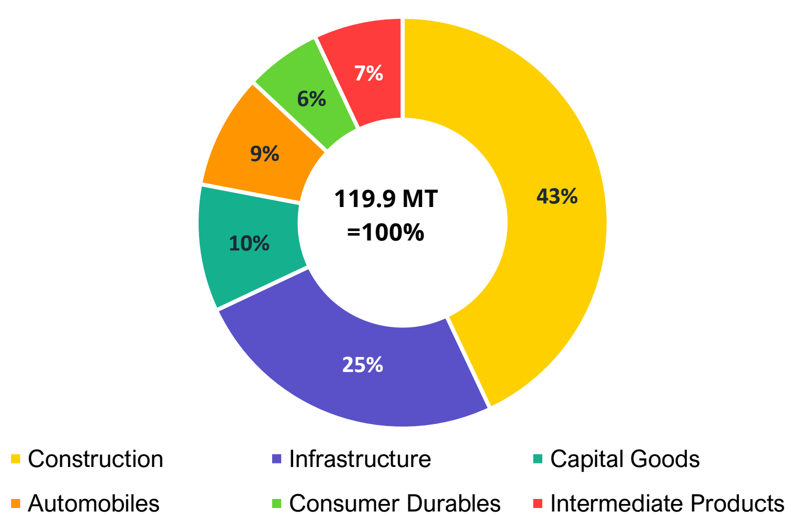
Figure 2: Year-wise Finished Steel Production and Consumption



Source: Ministry of Steel

The largest steel-consuming sectors in India are construction, infrastructure, capital goods (industrial machines, equipment and tools) and automobiles. Together, these sectors account for 87% of the total steel demand in the country. The construction and infrastructure sectors are witnessing strong demand, buoyed by economic growth and increasing demand for urban infrastructure and government housing schemes. The automobile industry is also witnessing a revival in sales, both domestically and in the export market, after a few years of sluggish growth.

Figure 3: Largest Steel-consuming Sectors in India FY2023

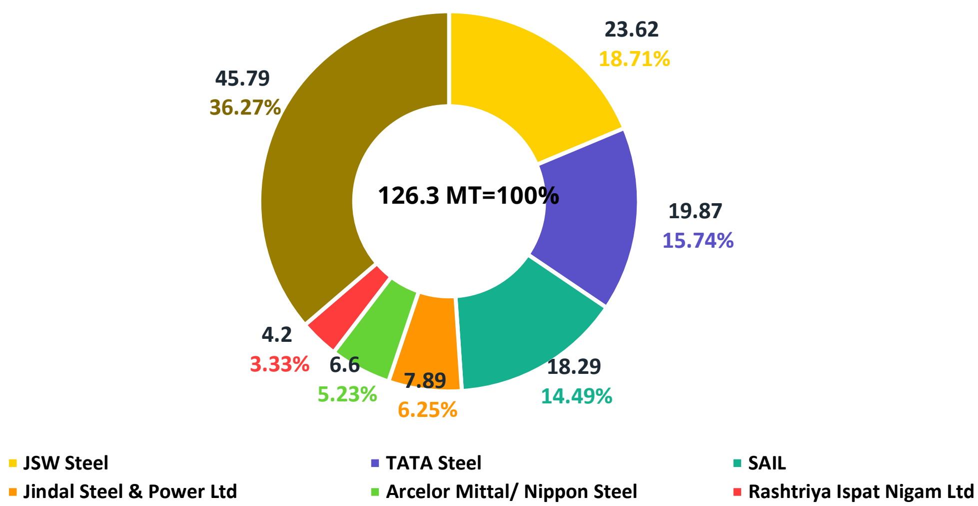


Source: Industry reports, JMK Research

Key Steelmakers

Large corporates, both in the private and public sector, dominate the Indian steel sector. Six companies – JSW Steel Limited, Tata Steel Limited, Steel Authority of India Limited (SAIL), Jindal Steel & Power Limited (JSPL), ArcelorMittal/Nippon Steel India (AM/NS) and Rashtriya Ispat Nigam Limited (RINL) – produced 63.7% of the total crude steel in India in FY2023.

Figure 4: Top Steel Manufacturers by Actual Output for FY2023



Source: Company websites, JMK Research

Outside the top six companies, other large conglomerates have also entered or are looking to enter the industry. Mining mogul Anil Agarwal's diversified natural resources group Vedanta entered the steel sector after it acquired Electrosteel Steels Limited in 2018[7] although debt woes have forced the company to consider options to exit the business.[8]

Edible oils-to-airports conglomerate Adani Group has also signed an agreement with the world's seventh largest steelmaker, South Korea's Posco, for setting up a "green, environment-friendly integrated steel mill".[9]

The steelmaking landscape in India is peppered with several medium, small and micro enterprises (MSMEs). These MSMEs have plants in various parts of the country.

In terms of the split between the public and private sector, the steel industry is by and large led by the private sector, which had more than an 82% share in crude steel production in FY2023.[10]

[7] Business Standard. Vedanta enters steel with acquisition of Electrosteel Steels, to hold 90%. 5 June 2018.
[8] Times of India. Vedanta will take relook at alloy biz. 1 July 2023.
[9] Adani. POSCO & Adani Sign MoU For Integrated Steel Mill. 13 January 2022.
[10] Joint Plant Committee. Trend Report. April 2023.

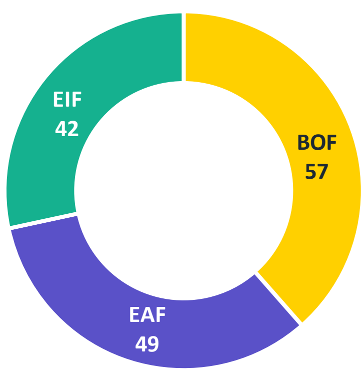
Traditional Steelmaking Technologies in India

Steel required for industrial use is not found naturally. Steel is made from iron ore, a compound of iron, oxygen and other minerals present in nature. It can be produced by mixing carbon with iron at very high temperatures using two different processes:

- **Blast Furnace/Basic Oxygen Furnace (BF/BOF) route, also known as the oxygen route**: Most integrated steel plants (ISPs), such as JSW Steel, Tata Steel, SAIL and JSPL, use the BF/BOF route of steelmaking. These plants are large in capacity, ranging from 1 to 5 million tonnes per annum (MTPA), covering a relatively large area of 4-8 square kilometres.[11]
- **Electric Arc Furnace (EAF) and Electric Induction Furnace (EIF) route, also known as the electricity route**: The EAF and EIF methods require scrap/direct reduced iron (DRI)[12] or sponge iron. These methods are typically used in mini steel plants ranging from 0.5 to 2MTPA, covering an area of up to 2 square kilometres. The exception is ArcelorMittal/Nippon Steel India, which operates a 9.6MTPA EAF at its Hazira plant.[13] Among EAFs and EIFs, the latter are typically smaller, inefficient and more energy-intensive.

According to the chart below, 38.5% of India's steel production capacity in 2021 was from the oxygen route, i.e. BOF, while the EAF and EIF routes together account for 61.5% of the capacity. It is worth noting that EIF's share in total capacity (28.5%) is the highest in India compared to other countries.

Figure 5: Steelmaking Production Capacity by Processes in million tonnes



Source: 'Achieving Green Steel: Roadmap to a Net Zero Steel Sector in India' – The Energy and Resources Institute (TERI, 2022)

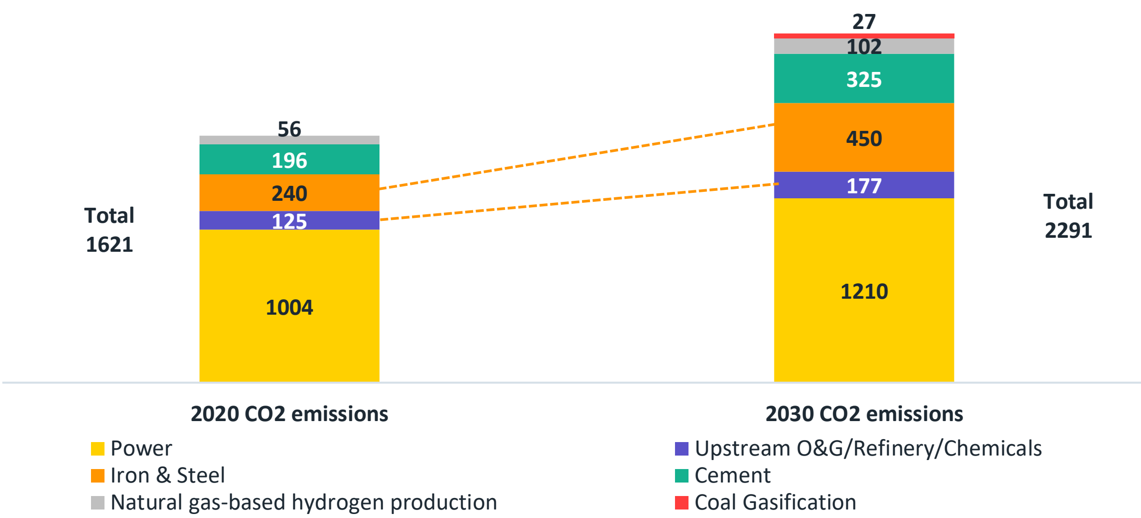
[11] Indian Bureau of Mines. Indian Bureau of Mines, Iron & Steel Vision. 2020.
[12] DRI is produced by the direct reduction of iron ore or other iron bearing materials in the solid state by using non-coking coal or natural gas. It is produced in many forms like lump, pellets, hot briquetted iron (HBI), fines and cold briquetted iron (CBI). DRI is then used in EAF as a source of clean iron units for steelmaking due to its low residual and high iron quality.
[13] ArcelorMittal. Investor Presentation. 27 September 2022.

The Case for Decarbonising the Steel Sector

India's steel sector accounts for about 12% of India's carbon dioxide (CO_2) emissions, with an emission intensity of 2.55 tonne of CO_2/tonne of crude steel (tCO_2/tcs) compared to the global average of 1.85 tCO_2/tcs.[14] The steel industry is responsible for around 240 million tonnes of CO_2 emissions annually.

India's 2023 Union Budget states that the government plans to spend US$1.4 trillion on infrastructure over the next five years, and will need to double steel production from FY2023 levels over this period.

Figure 6: Sector-wise CO2 Emissions in India (in MTPA)



Source: NITI Aayog

Unless India switches from coal-based steel production to cleaner technologies, the sector's CO_2 emissions will also double from the current levels. This could be a worrying sign for India and its zero-emission target set at the United Nations Climate Change Conference (COP26) in Glasgow in 2021.

Although the Indian government has not clearly defined "green steel", for the purpose of this report, we use the term to mean steel produced without using fossil fuels. Green steel can be the solution to India's ambitions of meeting its climate goals. Steel produced using green hydrogen is one of the solutions for decarbonisation. Another option can be using EAFs powered by renewable sources. Transitioning to green steel will help reduce carbon emissions in the steel sector.

However, what is worrying is that India seems inclined to use BF/BOFs in future to bolster its steelmaking capacity. This will further reduce the average age of India's already relatively young fleet

[14] Ministry of Steel. Year-end Review-2022 Ministry of Steel. December 2022.

of BF/BOFs, which is currently 15 years.[15] The typical age of BF/BOFs is 40 years, including a refurbishment investment equal to half the original installation cost at 25 years.

Table 1: Emissions Intensity of Steel Production Technologies in India

Steel production technology	Description	Emissions intensity (tCO_2/tcs)
Coal-based BF/BOF	A vertical cylindrical vessel with a closed bottom and an open upper cone through which a water-cooled oxygen lance can be raised and lowered. The BOF converts pig iron (pig iron is obtained from iron ore and comprises about 94% iron and 6% combined impurities, such as carbon, manganese and silicon) into steel with as little as 1% combined impurities.	2.78
Coal-based DRI - EAF	The main feedstock for an EAF is steel scrap, but it can also smelt solidified iron or sponge iron. The key components of this furnace include graphite electrodes. The heat necessary for melting the metal comes from an electric arc created when the electrodes come into contact with the metal.	2.79
Coal-based DRI - EIF	This is a type of steelmaking furnace that uses electrical energy. The principle of melting in an EIF is that a high-voltage electrical source from a primary coil induces a low-voltage, high current in the metal or secondary coil.	2.79

Source: RMI Report, JMK Research

Apart from helping meet India's climate commitments, a business case is emerging for Indian steelmakers to opt for producing green steel rather than investing more in traditional technologies.

Recent policy developments in India can open new revenue streams for steelmakers who cut carbon emissions, while key export markets are implementing policies that will hurt those who do not. Soon, cutting carbon intensity from steel production may not just be the right thing to do but become imperative for business.

India’s Carbon Credit Trading Scheme Can Open New Revenue Streams

Recently, India’s central government issued the first amendment to the Energy Conservation Act, 2001, known as the Energy Conservation (Amendment) Act, 2022. This Act empowers the government to formulate a carbon credit scheme to establish a domestic market in India. In June 2023, the government announced a trading scheme for setting up a carbon credit market in the country.

[15] IEA. Iron and Steel Technology Roadmap. October 2020.

Under the scheme, the central government will constitute a National Steering Committee for an Indian carbon market. The committee will give recommendations to the Bureau of Energy Efficiency (BEE) on various functions, including the formulation and finalisation of rules and regulations of the Indian carbon market, greenhouse gas emission targets and trading guidelines.

- The Carbon Credit Trading Scheme assigns a carbon credit to each tonne of carbon dioxide equivalent (tCO_2e)/greenhouse gas emissions reduced or avoided. Obligated entities can buy, sell or trade these within the country's carbon market framework.
- Any obligated entity under the Energy Conservation Act may have a carbon credit certificate (CCC) issued against any saving of per tCO_2e. Non-obligated entities can also claim these certificates by registering for this scheme voluntarily.

Steel industries have a major incremental carbon footprint, and they also fall under the ambit of this proposed act. These new CCCs will motivate steelmakers to transition towards greener steel production methods. Thus, they can avoid unnecessary penalties and earn more revenue by trading CCCs on power exchanges.

Previously, energy saving certificates (ESCerts) were introduced under the PAT scheme, which mandates designated consumers covering steel industries to consume non-fossil fuels to a certain extent to reduce their carbon footprint. One ESCert was equivalent to one tonne of oil savings.

> **Another way for steel industries to earn excess revenue by saving greenhouse gas emissions are renewable energy certificates (RECs), which come under the ambit of the Electricity Act 2003.**

Another way for steel industries to earn excess revenue by saving greenhouse gas emissions are renewable energy certificates (RECs), which come under the ambit of the Electricity Act 2003.

Through ESCerts, RECs and CCCs, the government is trying to achieve decarbonisation on a larger scale in line with the Paris Agreement. These instruments will make the transition towards green steel more viable commercially by offering new avenues of revenue for developers and consumers.

Exporting will be a Challenge for Carbon Emitters

Developed countries are increasingly looking at policies that penalise carbon emitters in order to protect and promote green technologies. On 14 July 2021, the European Commission released a package of regulatory proposals as part of its "Fit for 55" initiative that aims to achieve the European Green Deal target of 55% net reduction in GHG emissions by 2030. The package includes a proposal for a Carbon Border Adjustment Mechanism (CBAM) and revisions to the EU's Emission Trading System (ETS).

CBAM will apply to steel products imported into the European Union (EU), affecting steel exports from India. Almost half (46.8%) of India's 6.72 million tonnes of steel exports were to countries in the EU during FY2023.[16]

Between 2023 and 2025, non-EU steel producers will need to report both direct and indirect emissions. From 2026, importers will need to declare and purchase CBAM certificates to cover GHG emissions associated with the production of imported steel products.

According to rating agency ICRA's estimates, CBAM compliance requirements will pull down the profits of Indian steel exports to the EU by US$60-US$165 per tonne between 2026 and 2034. The implementation will impact 15-40% of India's annual steel exports to Europe.[17]

> **India must reduce the average emission intensity, which is 12% higher than the global average, to mitigate the impact on profits and market share.**

India must reduce the average emission intensity, which is 12% higher than the global average, to mitigate the impact on profits and market share. We discuss some other impacts of CBAM on India.

I. **Higher carbon emissions intensity**
The EU is India's third largest trading partner, accounting for €88 billion in goods traded in 2021, which is 10.8% of the total trade in India. The proportion of coal-based power in India would be close to 75%, much higher than the EU (15%) and the global average (36%). Therefore, higher emissions would convert to higher carbon tariffs to be paid to the EU.

II. **Impact on exports**
India's major iron and steel exports to the EU will face a significant threat due to the imposition of carbon tax ranging from 19.8% to 52.7%,[18] starting from 1 January 2026.

Another policy that will have an impact on India's export at a later stage is the US Inflation Reduction Act (IRA) 2022, having an outlay of US$370 billion. The outlay will be used to incentivise the US manufacturing sector and lower dependency on imports. India has always been a prime exporter of steel to the US, with a 10%[19] revenue share in 2022. Despite India's steel export in 2022 slumping to a five-year low of 6.7 million tonnes, a decline of 50% over 2021, the export valuation of iron and steel to the US has shown a 25%[20] increase.

[16] Ministry of Steel. Monthly Summary for March 2023. 13 April 2023.
[17] ICRA. ICRA flags CBAM hit to steel cos, profit. June 2023.
[18] Drishtiias. Carbon border adjustment mechanism. May 2023.
[19] Trading Economics. India export of iron and steel. August 2023.
[20] Trading Economics. India exports of iron and steel to United States. August 2023.

Current Technologies that Reduce Carbon Emissions in Steelmaking

Before discussing the initiatives that the government and the private sector have taken so far to decarbonise steelmaking in India, it is important to understand the technologies available to enable the transition.

Green steel technologies are still largely in their nascent stage around the world. While process innovations in developed markets are helping to reduce carbon emissions involved in steelmaking, near-zero or zero-emissions steelmaking processes are still largely in the pilot phase.

Multiple technology pathways could help transition from traditional methods to low-emission intensity technology. Some of the pathways under consideration include improving the efficiency of the conventional BF/BOF process, adopting green hydrogen, adopting renewable energy and adopting carbon capture utilisation and storage (CCUS) technology with BF/BOF or DRI-EAF. Table 2 provides details on low-carbon steelmaking technologies being considered globally, as well as in some pilot projects in India.

Table 2: Summary of Technologies Required for Transitioning to a Green Steel Economy

S.no.	Steelmaking routes	Description	Emissions intensity (t CO_2/tcs)	CO_2 emission reduction potential %	Companies using this technology
1	Best Available Technology (BAT) BF/BOF	Adopting best-in-class technologies to improve the efficiency of conventional BF-BOF technology	2.08	25	JSW Utkal Steel, Odisha [21]
2	BAT BF/BOF + CCUS	Adopts CCUS in BAT BF-BOF to further reduce emissions intensity by capturing carbon. The capture efficiency for CCUS is 90%.	0.61	75	
3	DRI-EAF + Green Hydrogen	Primary reductant coal or natural gas is replaced with hydrogen. However, some natural gas is needed to keep the system running.	0.67	85	LKAB, Vattenfall and SSAB's HYBRIT project at Lulea, Sweden
4	DRI-EAF + Natural Gas	Natural gas is the primary source of energy. However, it requires significant equipment changes, such as shafts.	1.38	50	Arcelor Mittal, Hamburg, Germany
5	DRI-EAF + CCUS	The DRI-EAF running on natural gas is equipped with CCUS with a capture efficiency of 90%.	0.41	85	The Al Reyadah Project, Abu Dhabi, Emirates Steel Industries
6	Scrap-Based EAF	Scrap instead of iron ore is processed in the EAF to produce steel.	0.53	85	Nippon Setouchi Works, Japan
7	Smelting Reduction (Hisarna)	Smelting reduction is a process by which liquid hot metal is produced from iron ore and coal, eliminating the coke-making step required for a traditional BF	2.35	30	Tata Steel, Rio Tinto and ULCOS (ultra-low CO2 steelmaking) research programme developed this technology in Netherlands' North Sea Canal Area.
8	Smelting Reduction + CCUS	Smelting reduction is coupled with CCUS technology with 90% capture efficiency.	0.36	80	

Source: RMI Report on Decarbonisation of Steel, JMK Research

[21] JSW Steel. JSW Utkal steel media release . April 2022.

JMK Research and IEEFA does not believe that CCUS is a solution for decarbonisation as our analysis of several projects implemented across sectors has shown that while CCUS projects promise a drastic reduction in emissions, they always underperform.[22]

As seen from the above table, aside from CCUS, green hydrogen is the only other technology that can bring down carbon emissions from steelmaking to zero or near zero. However, steel produced using green hydrogen is roughly twice as expensive as conventionally produced steel.[23]

Therefore, policy support and stronger carbon policies are imperative to create a market for green steel. Policies to accelerate the reduction in the cost of green hydrogen will also be critical in decarbonising the steel sector. The Indian government has taken important steps regarding green hydrogen, which we discuss later in this report.

The table also highlights that scrap-based EAFs can be another important way to reduce the carbon intensity of the steel sector. The US, which is also progressing well in lowering the carbon intensity of its steel sector, has a large number of EAFs and is considering using more scrap steel as inputs for its large EAF fleet[24] although a 100% switch to scrap-based EAFs is not possible.

The Indian government has also taken steps to improve the quality and quantity of scrap steel availability through various policy initiatives. We discuss them later in the report.

Other Innovative Ways to Decarbonise

Apart from the technologies mentioned in Table 2, research institutes, start-ups and established business owners in many countries are experimenting to find innovative ideas to decarbonise this hard-to-abate sector. If these methods prove commercially viable, then the cost and time incurred to decarbonise the steelmaking processes will reduce to an extent that may be replicated everywhere at scale.

In the sections below, we detail a few innovative methods experimented with by different organisations worldwide.

Hydrogen Breakthrough Ironmaking Technology (HYBRIT)

HYBRIT involves manufacturing DRI using green hydrogen instead of coal, traditionally needed for ore-based steel making. DRI gets converted into steel in an EAF powered by renewable energy sources.

The HYBRIT project in Sweden is a joint venture between steelmaker SSAB, mining company LKAB and energy provider Vattenfall. This project aims to manufacture 1.35 million tonnes of green hydrogen-reduced iron.

[22] IEEFA. The carbon capture crux: Lessons learned. 1 September 2022.
[23] ING. Hydrogen sparks change for the future of green steel production. 19 July 2023.
[24] US Department of Energy. Potential Decarbonization Strategies and Challenges for the U.S. Iron & Steel Industry.

The HYBRIT pilot project's first consignment of zero-emission steel was delivered to Volvo Group, and green steel shows superior mechanical and ageing properties as compared with steel produced from fossil fuels.

Molten Oxide Electrolysis (MOE)

The MOE process can directly use renewable energy to reduce iron ore instead of hydrogen. Here, the electrochemical process takes place inside a squat, two-metre-wide steel vessel lined with alumina-based bricks with an anode inserted through the top and a horizontal cathode on the base.

Inside the vessel, iron oxides get dissolved in a mixture of molten metal oxides, such as silica, magnesia and quicklime, all heated to about 1,600°C by an electric current. At the cathode, this current reduces iron ions to form a pool of liquid metal ready for final refining, and the energy-intensive step of pelletising the ore is unnecessary. One major advantage of MOE is that it works with all ore grades.

US-based start-up Boston Metal is developing a technology that will use renewable-powered MOE to convert iron ore into liquid metal ready for steelmaking.

Hydrogen Plasma

The advantage of hydrogen plasma smelting reduction technology is that it reduces one step needed to convert iron ore to crude steel. This technology uses electricity to shred hydrogen gas as it passes through a hollow graphite electrode into a conical reactor.

In the process, a stream of hydrogen atoms, ions and molecules are produced at temperatures over 20,000°C. The produced plasma melts and reduces finely ground iron ore to create a pool of liquid steel. In this process, pelletising is unnecessary, and the graphite electrode adds just enough carbon to the metal to form crude steel. Therefore, the metal can avoid a trip through an EAF and proceed directly to secondary steel refining.

SuSteel, a leading metal fencing manufacturer in Nigeria, is piloting one project in Donawitz, Austria, that aims to use hydrogen plasma to reduce iron ore.

Electrowinning

In France, the Siderwin project, started under Horizon 2020 – the EU's research and innovation funding programme – is building a three-metre-long pilot plant that will host finely milled hematite ore particles suspended in a highly alkaline aqueous sodium hydroxide solution at about 110°C. Iron metal grows on the surface of a cathode when a current passes through the electrolyte while oxygen gas is liberated at the anode. The iron plate is then removed and fed into an electric furnace to make steel.

This process uses 31% less energy than traditional steelmaking, reducing CO_2 emissions by 87%. Compared with other hydrogen-based routes, electrowinning also relies on less infrastructure; thus, it is less capital-intensive.

Hydrogen-based Fine Ore Reduction (HYFOR)

The HYFOR pilot plant in Donawitz, Austria, is divided into three sections: the preheating-oxidation unit, the gas treatment plant and the actual reduction unit. Fine ore concentrate is heated to approximately 900°C in the preheating oxidation unit before being fed to the reduction unit. A gas supplier supplies the reduction gas, which is 100% H_2, over the fence. A dry dedusting system recycles dust to reduce emissions from the processes involved. The hot DRI exits the reduction unit at approximately 600°C before being cooled and discharged from the HYFOR pilot plant.

The project's main objective is to use iron ore fines and concentrates (particle size <0.5mm) and reduce them to produce iron compared to pellets and lump ore used in current technologies to produce DRI. The pilot plant is undergoing test runs for handling ~800kg of iron ore.

Germany's Green Steel Production Success Story

Overview

The German government is planning to line up US$53 billion as subsidies to help energy-intensive manufacturers transition to climate neutral technologies and expects to reach net zero by 2045.

In 2019, two companies, Salzgitter AG and Sunfire, came together to effectively accomplish carbon-neutral steel production through an initiative called GrInHy2.0. This project has become a landmark pilot and makes for a good case study for the decarbonisation of the Indian steel sector using green hydrogen.

Salzgitter AG is a German company and one of the largest steel producers in Europe with an annual output of around 7MT. Sunfire is an electrolysis manufacturer and expert at producing green hydrogen. Since 2019, they have been working together to produce carbon-neutral steel and have implemented many of their strategies at a commercial level. In FY2022, they successfully completed the EU-funded GrInHy2.0 (Green Industrial Hydrogen) project that aimed to produce 100 tonnes of green hydrogen for the climate-neutral production of green steel.

Outcome

With the GrInHy2.0 project, these companies were able to demonstrate electrical efficiency of 84%, which corresponds to an energy requirement of 39.7 kilowatt-hour (kWh)/kilogram of hydrogen (kgH_2).This project produces up to 200 normal cubic metres (Nm^3) of green hydrogen per hour. No other operator has been able to demonstrate green steel production with such high efficiency before.

Technology used

The electrolyser used in this project is based on innovative solid oxide electrolysis cell (SOEC) technology, which runs at operating temperatures of 850°C. This system uses industrial waste heat and renewable electricity to split steam into its components, hydrogen and oxygen.

Investments

This project received funding from Fuel Cells and the Hydrogen 2 Joint Undertaking (now the Clean Hydrogen Partnership). The EU's Horizon 2020 Research and Innovation programme, Hydrogen Europe and Hydrogen Europe Research, promoted this joint undertaking.

Other success stories from around the world:

ThyssenKrupp has given a go ahead for an investment of €2 billion to replace its blast furnace with a DRI) plant using hydrogen at Germany's largest steelmaking plant.

- H2 Green Steel has started production at Europe's first green steel plant using hydrogen by replacing coal, aiming to go carbon neutral by 2025.
    - H2 Green Steel will produce its own green hydrogen using water from a nearby river.
    - Renewable resources nearby, including hydropower from the Lule River and wind parks in the region, will provide the electricity required for electrolysis and the plant's operations.
    - The process is likely to cut emissions by 95% when compared with traditional steelmaking.

India's Initiatives for Steel Decarbonisation

Both the government and the steel industry have realised the need for decarbonisation. While most efforts are in the nascent stage, the government and the private sector have already taken some key initiatives to cut emissions from this sector. In this section, we discuss some of these steps.

Government Initiatives for Steel Decarbonisation

Over the last few years, the central government has taken various initiatives to decarbonise the steel industry. Given that the Ministry of Steel needs to depend on other ministries for implementing certain policy measures, the initiatives encompass those taken by various government departments. The steps include:

- In 2012, the PAT Scheme was introduced under the National Mission for Enhanced Energy Efficiency to incentivise the steel industry to reduce energy consumption. The sector has achieved 5.5 million tonnes of oil equivalent (MTOE) and a corresponding CO_2 reduction of 20 million tonnes from 2012-20.[25] The government introduced a total of seven PAT cycles from 2012-24.
- In 2013, the Indian steel industry adopted the Best Available Technologies (BAT) available globally to improve energy efficiency and mitigate GHG emissions. This resulted in a considerable reduction in CO_2 emissions from around 3.1tCO_2/tcs in 2005 to around 2.5tCO2/tcs in 2020. In 2016, India and Japan's New Energy and Industrial Technology Development Organization (NEDO) signed a memorandum of understanding (MoU). The project model was implemented in steel plants for energy efficiency improvement.
- In 2019, the government introduced a Steel Scrap Recycling Policy to enhance the availability of domestically generated scrap and reduce coal consumption in steelmaking.
- In September 2021, the government issued The Motor Vehicles (Registration and Functions of Vehicles Scrapping Facility) Rule 2021 to increase scrap availability in the steel sector.
- In January 2023, the Ministry of New and Renewable Energy (MNRE) announced the NGHM for green hydrogen production and usage. It made the steel sector a stakeholder in the mission.
- In March 2023, the Ministry of Steel signed 57 MoUs with 27 companies for specialty steel under the Production-Linked Incentive (PLI) Scheme.
- The government has allocated Rs63.22 billion (US$763.9 million) under PLI to boost the steel sector.

[25] Ministry Of Steel. Indian Steel Industry Reduces its Energy Consumption and Carbon Emissions Substantially with Adoption of Best Available Technologies in Modernisation & Expansions Projects. February 2022.

- The incentives will create an additional capacity of about 25 million tonnes[26] of specialty steel and generate investment of about Rs300 billion (US$3.62 billion) over the next five years.

Besides policy action, the government also outlined its plan for the steel sector's decarbonisation when it submitted its Long-Term Low Emission Development Strategy (LT-LEDS) at COP27.

The LT-LEDS identified the best use of available technologies to increase energy efficiency and utilisation of scrap as significant strategies for reducing emissions.

The strategy document also recognised the significant role that hydrogen plays in emission reduction despite its high capital expenditure (capex) requirement, which needs to reduce substantially to scale hydrogen usage for green steel.

Electrification of the secondary steel industry (SSI) sector through renewable energy could significantly impact overall emissions from the steel sector.

National Green Hydrogen Mission 2023

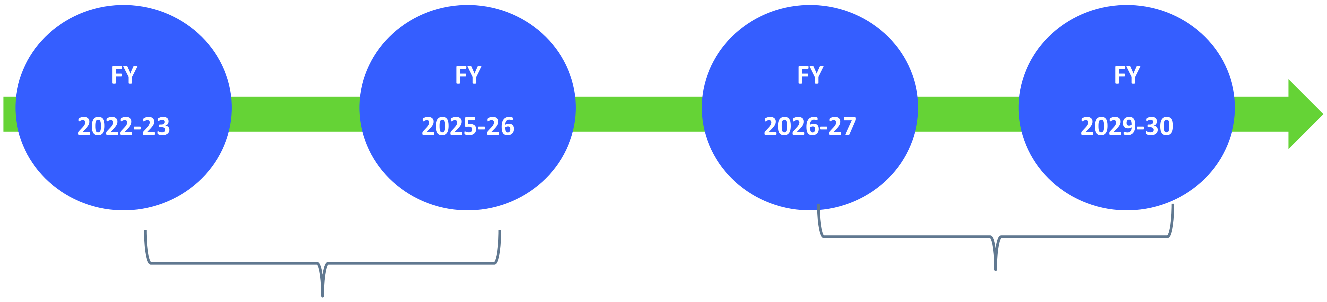
Among the steps taken by the government, the most important is the NGHM. As discussed in the previous section, green hydrogen is essential to most green steel production technologies. Accessibility to affordable green hydrogen will be crucial for Indian steelmakers to maintain their cost competitiveness while transitioning to clean production technologies.

India's Union Cabinet approved the NGHM in January 2023. It framed the objectives of this mission considering India's commitment to net zero targets at COP26 in Glasgow. This mission aims to establish India as a global leader in the supply and production of green hydrogen.

The mission will be implemented in two phases, as described in Figure 7.

[26] Current affairs adda247. Government signs MoU with 27 steel companies. March 2023.

Figure 7: Phased Approach for National Green Hydrogen Mission



Phase I

Demand will be created while enabling adequate supply by increasing the domestic electrolyser manufacturing capacity.

Energy transitions will be facilitated in refineries, fertilisers and city gas sectors as well as in hard-to-abate sectors, such as **steel production**, long-haul heavy-duty mobility and shipping.

Phase II

There will be accelerated growth in the production of green hydrogen.

Commercial-scale green hydrogen-based projects in the **steel**, mobility and shipping sectors will be explored.

It is proposed to undertake pilot projects in other potential sectors like railways, aviation etc. R&D activities will be scaled up for

Source: MNRE

Specifically for the steel sector, the mission has the following provisions:

- Under this mission, the Ministry of Steel has been allocated 30% of the pilot project budget, i.e., Rs14.66 billion (US$177 million).
- The government will also encourage old steel plants to start blending a small amount of green hydrogen in their manufacturing process and progressively try to increase this blend as cost economics improve.
- Upcoming steel plants can produce 100% green steel, and the government will support them with suitable policy measures and subsidy mechanisms.

MNRE has developed the Strategic Interventions for Green Hydrogen Transition (SIGHT) programme to achieve the ambitious goal under NGHM. This SIGHT programme consists of two components – Component 1, with an outlay of Rs44.4 billion (US$536.5 million), is for scaling up localised manufacturing in the electrolysers space and Component 2, with an outlay of Rs130.5 billion (US$ 1.57 billion), is for the production of green hydrogen and its derivatives.

In July 2023, the Solar Energy Corporation of India Ltd (SECI), under MNRE, issued two tenders under the SIGHT programme for both components. The first is a 1.5 gigawatts (GW) tender for scaling up localised manufacturing in the electrolyser space and R&D in indigenous stack technology. The second tender is for producing 450,000 tonnes/annum of green hydrogen on technology-agnostic and biomass pathways.

The insights on the first tender are as follows:

- The bids are invited under two buckets – (i) electrolyser manufacturing capacity based on any stack technology (1,200 megawatts (MW)) and (ii) electrolyser manufacturing capacity based on indigenously developed stack technology (300MW).
- The incentive will get disbursed if eligible, starting from Rs4,440/kilowatt (US$53.65/kilowatt) (kW) in the first year and progressively reduced to Rs1,480/kW (US$17.88/kW) in the fifth year.
- Bidders will be evaluated on two parameters (i) specific energy consumption (SEC), which directly affects the cost of green hydrogen production; and (ii) local value addition ranging from 30% to 80% year by year.
- Bidder must specify their annual manufacturing capacity and guaranteed life of the electrolyser along with the above crucial parameters.

The insights on the second tender are as follows:

- The bids are invited under two buckets – (i) Technology Agnostic Pathways with a total capacity available for bidding at 410,000 tonnes/annum and (ii) Biomass-based Pathways with a total capacity available for bidding at 40,000 tonnes/annum of green hydrogen.
- Under the Technology Agnostic Pathways (Bucket I), the minimum bid capacity would be 10,000 tonnes, while the maximum would be 90,000 tonnes.
- Under the Biomass-based Pathways (Bucket II), the minimum bid capacity would be 500 tonnes, while the maximum would be 4,000 tonnes.
- Winners must commission the projects 30 months from the date of the letter of award.
- The production facilities awarded will be eligible for direct incentives in Rs/kg of green hydrogen production annually for three years from the commencement date.

Steel Scrap Recycling Policy 2019

As highlighted earlier in the report, using scrap-based EAFs for steel production can effectively reduce the sector's carbon emissions. However, the availability of scrap is a major issue in India.

In 2017, India imported seven million tonnes of scrap at a cost of more than Rs245 billion (US$2.96 billion). When the production of steel rises to 250 million tonnes, as the National Steel Policy 2017 envisages, the requirement for scrap will rise to 70-80 million tonnes.

In response to this demand, the government introduced a Steel Scrap Recycling Policy in 2019 to enhance the availability of domestically generated scrap to reduce coal consumption in steelmaking. The policy aims to raise scrap availability for producing finished steel products, thereby promoting a circular economy in the steel sector. It will minimise reliance on imports and develop a responsive ecosystem for high-quality steel production.

Task Forces Approved by the Ministry of Steel

The Ministry of Steel has started pushing for more research into decarbonising the steel sector. It has approved 13 task forces for defining the roadmap for green steel.

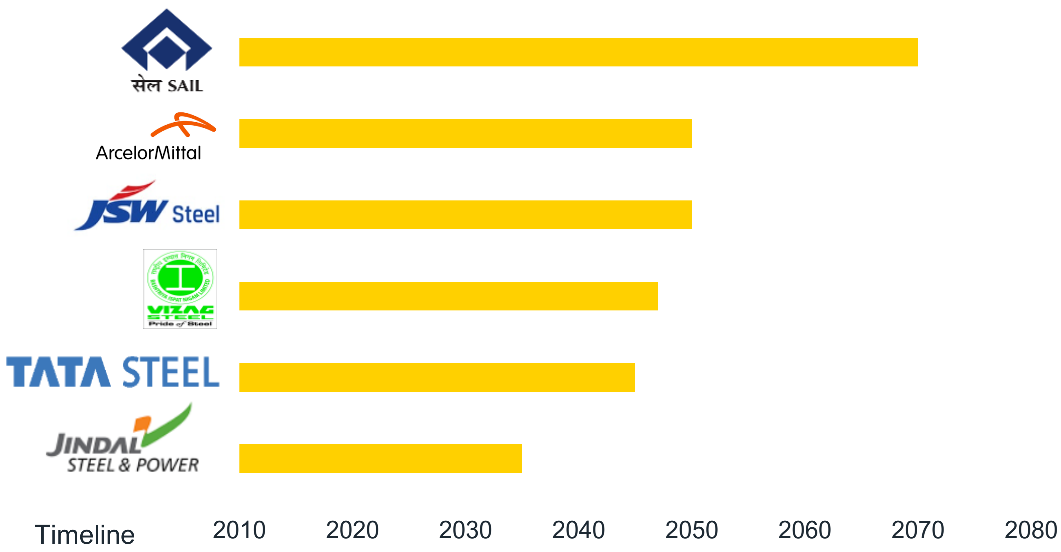
- The task force for “Monitoring of Carbon Emission of Steel Plants” will work on formulating CO_2 emission standards and developing a methodology and institutional mechanism for monitoring.
- The demand-side task force will work on creating a demand-side policy framework.
- The supply-side task force will focus on energy efficiency, renewable energy transition, material efficiency, green hydrogen and CCUS.
- The facilitator’s task force, like R&D, will prepare a research roadmap for the green transition
- The finance task force will explore new financing mechanisms to fulfil the capital requirement for the green transition.
- The skill development task force will provide a framework for reskilling and upskilling of manpower towards green steel production.

Private Sector Initiatives for Decarbonisation

Companies are now actively involved in reducing carbon emissions from steel production. Many are joining the global trend towards setting net zero emissions targets. Those who have set a target are:

- Global steel giant AM/NS aims to reduce 25% of its carbon emission intensity by 2030 and hit net zero emissions by 2050.
- JSW Steel aims for net zero emissions by 2050
- JSPL plans to set an ambitious target of net zero emissions by 2035.
- Tata Steel has set a goal to become carbon neutral by 2045.
- RINL made a specific action plan to achieve carbon neutrality by 2047.
- SAIL announced its commitment to substantially reduce CO_2 emissions, increase the share of renewable/non-conventional energy by 2030, and achieve net zero emissions by 2070.

Figure 8: Net Zero Targets of Indian Steel Manufacturers



Source: Company websites and news articles, JMK Research

Many companies have set net zero targets and have started pilot projects and taking measures to reduce emissions from their production process. We list such companies and their initiatives in the table below.

Table 3: Decarbonisation Initiatives Taken by Key Steelmakers in India

JINDAL STEEL & POWER	JSPL has outlined various measures to achieve its goal of producing green steel, including using hydrogen instead of coal in DRI and adopting CCUS technologies to reduce GHG emissions. JSPL plans to develop its Odisha plant into the largest and greenest facility in the world. It also plans to set up a green hydrogen plant with a capacity of 500MW, which will be used in the steel production process. JSPL has also signed an agreement with Greenko to procure 1,000MW of green power for its steelmaking operations in Angul, Odisha. This arrangement will reduce approximately seven million tonnes of CO_2 emissions annually.
vedanta transforming for good	Vedanta in India has undertaken a pilot project to use hydrogen in pulverised coal injection (PCI) blast furnaces to produce steel, which, depending on results, will be followed by scaling up.

	Vedanta has committed to reducing carbon emissions to zero by 2050 or sooner. Towards this end, it has purchased 354 million kWh of renewable energy power from the Indian Energy Exchange (IEX). In August 2022, Vedanta partnered with the Indian Institute of Technology, Bombay, to develop technology to produce green steel using hydrogen. The company is committed to accelerating the adoption rate of hydrogen as a fuel and seeks to diversify into hydrogen fuel or related businesses. Whether it can go through with its green steel projects remains to be seen, as it has also said it is looking to fully or partially sell its steel business.
ArcelorMittal	Siemens Gamesa (SG) has signed a supply agreement with ArcelorMittal's subsidiary AM Green Energy Pvt Ltd (AMGPL) to supply wind turbines of 166MW in Andhra Pradesh.This wind project will form a part of the 989MW wind-solar hybrid project by AMGPL. It will help meet 20% of its electricity usage for its steel plant in Gujarat and reduce its carbon emissions by 1.5MT per year.
TATA STEEL	Tata Steel is committed to lowering <1.8 tCO_2/tcs by 2030. The company's long-term plans (2030-2050) include increasing sustainable production, and adopting storage and hydrogen use across the steel value chain. Tata Steel has recently commissioned a 5 tonnes per day (TPD) carbon capture plant at Jamshedpur Works. This project has been executed with technology support from Carbon Clean, a global leader in low-cost CO_2 capture technology. Tata Steel is India's first steel company to adopt such carbon capture technology that extracts CO_2 directly from the blast furnace. It will reuse the captured CO_2 on-site to promote the circular carbon economy. Tata Steel commenced the trial injection of hydrogen gas on April 2023 using 40% of the injection systems in the 'E' blast furnace at its Jamshedpur Works. This is the first time in the world that such a large quantity of hydrogen gas is being continuously injected into a blast furnace. Tata Steel has also set up its first steel recycling plant of 0.5MTPA in Rohtak, Haryana, which will enable low-carbon emissions and energy utilisation.

KALYANI STEELS LIMITED KALYANI	Kalyani Group has recently started producing green steel from its EAF plant in Pune, Maharashtra, operated by Saarloha Advanced Materials Pvt Ltd. It aims to manufacture 250,000 tonnes of green steel in 2023-24 from its EAF. The Pune plant will be able to produce long steel of various grades by minimising its GHG emission footprint to 140kg for every tonne of steel produced. Kalyani Group launched two green steel brands, KALYANI FeRRESTA and KALYANI FeRRESTA PLUS. Kalyani FeRRESTA has very low GHG emissions of <0.19 tCO_2/tcs, and Kalyani FeRRESTA Plus has net zero GHG emissions per tonne of crude steel.
JSW Steel	JSW Steel has set ambitious sustainability targets, including reducing its specific CO_2 emissions by 42% by FY2030. JSW Steel has assigned Rs100 billion (~US$1.26 billion) to procure the majority of its energy requirements from green energy sources and replace conventional ones. The company has implemented a CCS facility with a 100 tonnes per day capacity at its DRI plant at Dolvi, Maharashtra. The company has signed an initial deal with German technology company SMS Group to reduce carbon emissions and produce green steel.
JSL JINDAL STAINLESS	Hygenco India, a Gurugram-based company, has signed India's first long-term offtake agreement with Jindal Stainless Steel to sell green hydrogen for 20 years. This project is situated at Hissar, Haryana.

Source: Press releases, JMK Research

Key Challenges

Green steel is important for sustainable development because it helps the steel industry significantly reduce carbon emissions and contributes to global efforts to mitigate climate change. However, there are certain challenges in producing green steel, including the need for investment in new technologies and infrastructure development.

No Definition for Green Steel

The biggest impediment to the decarbonisation of India's steel sector is the lack of a taxonomy for green steel. Although government announcements reference green steel/low-carbon steel, there is no official definition of green steel. Without a definition, the technology track that the industry should follow remains unclear. India needs to define whether green steel will mean eliminating the use of fossil fuels in the production process or whether the industry can use fossil fuels and only reducing emissions to a certain level will be enough.

> **Without a definition, the technology track that the industry should follow remains unclear.**

The Ministry of Steel has formed a task force to develop a taxonomy for green steel, including definitions, terminology, benchmarks, scoping, certifications and others.[27] JMK Research and IEEFA recommend that the government define green steel as steel which does not use fossil fuels in the production process. All other technologies that reduce emissions should be termed as low-carbon steel.

High Cost of Green Hydrogen-based Steel Plants

The high cost of manufacturing hydrogen using renewable energy is the most significant barrier to its adoption in India.

By comparing green and grey hydrogen, i.e., the cost of green hydrogen from electrolysis today is relatively high, between US$4/kg and US$7/kg[28] depending on various technologies, whereas grey hydrogen costs US$1.8/kg. This makes it hard for green hydrogen to compete with the existing grey or brown hydrogen cost.

According to NITI Aayog, green hydrogen prices are largely determined by the electrolyser and electricity costs. SECI has issued a tender with a Rs44 billion (US$537 million) subsidy scheme for domestic electrolyser manufacturing. The total payout of this incentive is only 8% of the capital cost of the electrolyser and may not impact green hydrogen costs for demand aggregation.

The growth of any upcoming industry depends on government support through incentivising and creating demand through favourable policies. Looking at the current price and schemes proposed

[27] The Hindu. Steel Ministry approves 13 task forces for 'Green Steel'. 5 April 2023.
[28] Economic Times. Green hydrogen adoption in India-Opportunities, challenges and way ahead. May 2023.

for electrolysers, the industry needs a substantial push in terms of incentives to make any significant impact on domestic players.

Poor Performance of CCUS

Carbon capture and storage (CCS) is a 50-year-old technology. IEEFA's analysis finds that it has had variable results in capturing and storing carbon dioxide.[29] Project developers have almost always reused the captured carbon for enhanced oil recovery (EOR), producing oil and gas and more emissions. The technology has found limited use in industrial sectors, such as steel. The few projects that have used it do not provide data to prove its viability in reducing emissions.

> **Even if the Indian steel industry considers CCUS, it should study it as an interim partial solution with careful consideration, depending on the outcome of the Ministry of Steel's task force on green steel taxonomy.**

There are also a few critical challenges connected with CCUS, which include:

- High capital cost of CCUS
- The unreliability of storage capacity and capture performance
- There is inadequate data on the availability of potential geological storage sites and their capacities.
- Limited use cases are a challenge in scaling up CCUS technology
- The fossil fuels plants, i.e., BF/BOF paired with CCUS, are likely to get phased out in the upcoming decades, making CCUS infrastructure a stranded asset
- Highly energy-intensive process consuming 30-50%[30] of the power plant's total energy output

JMK Research and IEEFA recommend that the steel industry look into alternative means of decarbonisation. Even if the Indian steel industry considers CCUS, it should study it as an interim partial solution with careful consideration, depending on the outcome of the Ministry of Steel's task force on green steel taxonomy.

Inadequate Availability of Steel Scrap

One of the low carbon emission routes for steelmaking is scrap-based EAF, where emissions are 0.53 tCO_2/tcs compared to 2.79 tCO_2/tcs for the coal-based DRI-EAF route. Scrap-based EAF has a CO_2 emission reduction potential of 85%.

[29] IEEFA. The Carbon Capture Crux: Lessons Learned. 1 September 2022.
[30] Energy Tracker Asia. Carbon capture and storage: Pros and Cons. March 2023.

For more capacity of scrap-based EAFs, India requires high-grade steel scrap as raw material. It currently depends on imports for scraps. India's scrap imports for steelmaking stood at around 9.8 million tonnes[31] in FY2023, a sharp rise from around 3.6 million tonnes in FY2022.

The availability of scrap is a challenge in a country like India because most of the nation's infrastructure is new and 70% is yet to be built. The imported scrap is also cheaper than local scrap, mainly due to the drop in demand for scrap in the global market. Currently, India imports scrap from China. But as China increases scrap-based EAF capacity, India will not get enough scrap through imports and will have to rely on domestic scrap, in which it is deficient.

Diversity of MSME Producers

The Indian steel industry comprises hundreds of MSMEs producing steel using small-capacity coal-based EAFs and EIFs. They contribute to more than 40% of the country's steel production.[32]

The presence of MSME steel producers across the country poses a serious threat to the transition of green steel from conventional routes. This is because MSMEs:

- **Lack capex required for transformation**: MSMEs work on restricted demand-supply scenarios, which restrains them from taking any innovative route.
- **Lack attractive financing options**: One of the main issues with MSMEs is their low credit rating. As a result, banks and other lending institutes find it difficult to provide low-cost financing options to this segment. Transitioning to green steel will require huge capex and a lack of suitable financing options from lenders will make the shift difficult for such companies.
- **Lack R&D support**: MSMEs do not have a robust research and development centre required for testing innovative low-carbon emission technology before scaling.
- **Lack government support**: MSMEs being an informal sector, government support has been sluggish. However, in 2022, an advisory group was constituted by the government to look into ways to support MSMEs in the steel sector. This might provide some relief to MSMEs going forward.

With the introduction of CBAM in EU, most MSMEs will not be able to export their finished steel products using traditional methods, which will attract significant penalties. This will substantially reduce the export market for this segment. Therefore, government support will be crucial.

Young Age of BF/BOFs in India

One of the biggest challenges for decarbonising the steel sector in India is the young age of its BF/BOF fleet.

[31] Steelmint. India's ferrous scrap imports rise threefold in FY23. April 2023.
[32] Ministry of Steel. Annual Report 2022-23.

According to some estimates, the average age of India's BF/BOF fleet is 15 years.[33] These plants have a life of 40 years, with an investment to refurbish them at 25 years. The average age of India's BF/BOF fleet will fall further as the country plans to add at least 153MTPA of capacity through this route by 2030.[34] In fact, India has the largest share (40%) of BF/BOF steelmaking capacity under development across the world.

With BF/BOFs being the hardest to abate,[35] the additional plants will only add to the emissions from the steel sector. In comparison, the relatively cleaner and easier-to-decarbonise EAF route has only 26MTPA of capacity under development in India.[36] According to the Global Energy Monitor, the 153MTPA of BF/BOFs under development in India represents a stranded asset risk of US$153-220 billion.[37]

Lack of Domestic Demand for Green Steel

Since steel is essentially a commodity, manufacturers would need to ensure there is demand for green steel from consumers before investing in costly new technologies to eliminate fossil fuels.

As a result of the new technologies involved in producing green steel and the fresh investments that will need to go into reconfiguring plants or setting up new ones, the product's price will be significantly more than that of conventionally produced steel.

According to ING Research, the cost of steel produced from green hydrogen in Europe is twice as much as that from conventional methods.[38] Morgan Stanley estimates that green steel will need to generate an additional US$115 per tonne just to break even after assuming low renewable energy costs and grants to support the transition.[39] Without demand from customers willing to pay a premium for green steel, decarbonisation of the steel sector becomes even harder.

[33] IEA. Iron and Steel Technology Roadmap. October 2020.
[34] Global Energy Monitor. Pedal to the metal: It's time to shift steel decarbonisation into high gear. July 2023.
[35] Ministry of Steel. Annual Report 2021-22.
[36] Global Energy Monitor. Pedal to the metal: It's time to shift steel decarbonisation into high gear. July 2023.
[37] Global Energy Monitor. Pedal to the metal: It's time to shift steel decarbonisation into high gear. July 2023.
[38] ING. Hydrogen sparks change for the future of green steel production. 19 July 2023.
[39] Morgan Stanley. Greening the Steel Industry: A Tale of Cost and Opportunity. 18 May 2023.

Financing Options Available for Steel Decarbonisation in India

As elaborated upon in the previous sections, currently available technologies for process-level changes in steel decarbonisation are still in a nascent stage. Due to the lack of commercially viable technologies, large-scale capital, especially from private sources, has not come into steel decarbonisation globally. However, as energy transition efforts move beyond the decarbonisation of the power sector to hard-to-abate sectors, like steel, and as technologies like green hydrogen become economically feasible, capital has started to find its way into the sector too.

Several stakeholders in the Indian steel sector are raising capital to finance energy transition efforts.

Large private corporates: From an Indian perspective, large corporates such as Tata Steel and JSW Steel have been at the forefront of technological adoption in steel decarbonisation. These companies are financing their decarbonisation efforts through a mix of internal accruals, domestic capital market issuances, bank loans and raising sustainable finance instruments in the global markets. The choice of financing avenue also depends on the company's investment phase.

Among these options, global sustainable finance markets hold much promise to provide capital at scale for the decarbonisation of these corporates. Sustainability-linked bonds and loans (SLBs and SLLs) have been regarded as apt for financing industrial decarbonisation globally.

Sustainability-linked instruments help finance nascent technologies as their cash flows are not linked to specific projects, but repayment terms are linked to achieving pre-determined sustainability targets. Steel major ArcelorMittal amended its US$5.5 billion revolving credit facility in April 2021 to a sustainability-linked loan,[40] linking its loan margins to achieving sustainability targets. In India, JSW Steel issued an SLB in September 2021, the first by a steel company globally.

> **Companies can also tap into other instruments, such as green bonds and transition bonds, for financing commercially viable investments, with clear emissions reduction potential, such as solar photovoltaic generation.**

Companies can also tap into other instruments, such as green bonds and transition bonds, for financing commercially viable investments, with clear emissions reduction potential, such as solar photovoltaic generation. Media reports suggest that companies like Tata Steel and JSPL plan to tap into the sustainable finance market going forward.

Public Sector Undertakings (PSUs): Indian steel sector PSUs like Steel Authority of India Limited (SAIL) have also carried out energy conversation efforts. These initiatives have been funded through a mix of internal accruals, securities, such as bonds (both domestic and offshore) and diversified bank funding. With the Ministry of Steel endorsing green steel through the use of green hydrogen and CCUS in the medium term[41], PSUs such as SAIL will be in a comfortable position to finance their

[40] ArcelorMittal. ArcelorMittal amends US$5.5bn Revolving Credit Facility. April 2021.
[41] PIB. Green Steel. February 2023.

transition through access to capital markets and bank funding. Given its sovereign backing and strong financial standing, a sustainable finance market is another avenue for SAIL.

MSMEs: These are also important stakeholders in the steel sector. As mentioned earlier, MSMEs constitute a sizeable chunk of the overall industry. Due to their small size and lack of financial resources, the transition of such outfits is the hardest link in the sector's transition.

Moreover, the triggers for MSMEs to transition will vary from those for larger corporates, such as decarbonisation pledges or global competitiveness. MSMEs will require a nudge from the regulatory end of their supply chain partners. There are several financing avenues available for the energy transition of MSMEs.

- The Bureau of Energy Efficiency (BEE) runs financing schemes specifically for MSMEs. One prominent one is Promoting Energy Efficiency and Renewable Energy in selected MSME clusters in India. This scheme is run by the United Nations Industrial Development Organization (UNIDO) in collaboration with BEE and funded by the Global Environment Facility (GEF).[42]
- MSMEs rely heavily on banks and non-banking financing corporations (NBFCs) for their financing needs. Hence, this channel will have to accommodate the requirements of MSMEs. Several state and private sector banks are currently running specific programmes for MSMEs in this regard.[43]
  Another entity that caters to the financing needs of MSMEs is the Small Industries Development Bank of India (SIDBI). SIDBI runs schemes such as the SRIJAN scheme[44] for technological innovation at MSMEs[45], 4E Scheme[46] for implementing energy efficiency measures[47] and the STAR scheme[48] providing loans for rooftop solar, among others.[49]
- Blended finance is another avenue to mobilise capital for non-commercial or risky investments for steel decarbonisation. Blended finance mechanisms help mobilise private capital into technologies and activities that may not otherwise be able to attract commercial capital. One such mechanism active for MSMEs in India is the Partial Risk Sharing Facility for Energy Efficiency (PRSF), run by SIDBI and supported by GEF.[50]
- Several MSMEs in the steel sector are also part of the upstream supply chain of the larger steel sector players. As the bigger corporates move on their energy transition path, supply

[42] EESL. Promoting Market Transformation for Energy Efficiency in Micro, Small & Medium Enterprises (MSME).
[43] BEE. Contact Details of Financial Institutions Dealing in Energy Efficiency Financing.
[44] SIDBI in collaboration with TIFAC has initiated the TIFAC – SIDBI Technology Innovation Fund (SRIJAN) scheme. The scheme intends to support MSMEs towards development, up-scaling and commercialization of innovative technology-based projects
[45] Tifac. TIFAC-SIDBI Technology Innovation Programme (Srijan).
[46] SIDBI has launched the 4E scheme (End to End Energy Efficiency) to promote energy efficiency investments in MSMEs.
[47] SIDBI. Financing Schemes for Sustainable Development.
[48] SIDBI offers financial assistance under STAR Scheme (SIDBI Term loan Assistance for Rooftop solar PV Plant) for units willing to replace existing grid power with solar power.
[49] SIDBI. Direct Loans.
[50] GEF. Partial Risk Sharing Facility for Energy Efficiency.

chain emissions labelled as Scope 3 emissions also become important. Hence, larger corporates may also support MSMEs in decarbonising their operations.

Besides these stakeholders, the central government is also raising funds from sustainable finance markets to finance clean energy transition in different sectors of the economy. India's inaugural green bond issuance of US$2 billion in January 2023 allocated part of the proceeds for India's green hydrogen mission. The mission has earmarked funds to support the domestic steel industry's endeavours to find scalable uses of green hydrogen.[51]

> **While green bonds are not apt for financing current commercially unviable technologies, sovereigns can issue these instruments as in their case, repayments are usually not linked to project-specific cash flows.**

While green bonds are not apt for financing current commercially unviable technologies, sovereigns can issue these instruments as in their case, repayments are usually not linked to project-specific cash flows. Hence, sovereign green bonds and other sustainable finance instruments can be used to finance R&D and pilot projects for steel decarbonisation. Moreover, these proceeds can be used to provide concessional financing and subsidies for de-risking investments in steel decarbonisation.

Innovative financing products, such as blended finance mechanisms, will play an important role in the initial growth of low-carbon solutions for the steel sector in the country. Support in the form of technical assistance grants, guarantees and risk insurance, and concessional capital will be needed at different stages of the technological lifecycle. Players such as philanthropies, development finance institutions, multilateral development banks and private capital providers will have to come together to structure such mechanisms, while the government has to provide the policy-side levers and visibility to grow the sector.

[51] Economic Times. Central aid for R&D to set up pilot using green hydrogen to make steel. June 2023.

Recommendations

The most efficient way to decarbonise India's steel sector is to follow a consortium-based approach, in which the government becomes the lead anchor while interested stakeholders join the consortium to establish a framework to aid the green steel transition.

In 2021, the Indian government announced its target to achieve net zero emissions by 2070. To achieve the target, the government needs to support steel developers, along with independent green hydrogen developers, through the initial life cycle of projects.

> **First mover disadvantages should be covered by creating a market for low-carbon steel demand along with enforcing policy rewards for such initiatives at early stages.**

First mover disadvantages should be covered by creating a market for low-carbon steel demand along with enforcing policy rewards for such initiatives at early stages. Finally, as mentioned earlier, the government should promote easy access to finance for such a green transition through the right measures and tools.

At this nascent stage of the transition, the right policy and regulatory frameworks, along with incentives for both producers and consumers of green steel, will go a long way. This will help in driving low-carbon economic development and ultimately achieving the ambitious net zero goal by 2070.

The decarbonisation of the steel sector will not only depend on the financial implications of the energy transition, but also on a comprehensive decision-making approach from all stakeholders.

Green Steel Taxonomy

To ensure that investment in decarbonising the steel sector goes into the right technologies, a clear definition of green steel is needed. The government should also provide clarity on the classification and standards for green steel in order to distinguish between various types of steel. The government has started taking steps in the right direction by creating 13 task forces for green steel. One of these will work on developing a taxonomy for green steel, including terminology, definition, benchmarks, scoping, certification and others. Another task force, called "Monitoring of Carbon Emission of Steel Plants", will work on formulating standards for CO_2 emission monitoring, development of methodology and its institutional mechanism.

In April 2023, the Ministry of Steel also duly notified[52] 145 Indian Standards applicable to steel and steel products under the ambit of the Quality Control Order (QCO). This step guarantees that the public receives top-notch products regardless of the source materials.

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[52] Mint. Govt sets up task force to drive decarbonisation, quality enhancement in steel industry. August 2023.

Pricing Carbon Emissions

The introduction and calibration of CO_2 pricing in the next few years will encourage investments in low-carbon technologies and accelerate the adoption of hydrogen-based steelmaking. A carbon price of US$50 per tonne of emissions can make green steel competitive by 2030 and can catalyse the shift from coal-based to hydrogen-based steelmaking.

Creating Green Steel Demand

Policy support can create demand for green steel, which is currently absent. It can do so by creating an incentive for the private sector to use green steel.

Initially, in all government and public sector purchases, a certain quantity of green steel should be mandatory. Going forward, the government can extend the percentage of green steel procurement to private consumers as well. In April 2023, the government had also announced the setting up of a demand-side task force that will make a policy framework for creating demand for green steel across key end-use sectors.

> **Green Steel Certificates can be another way to create demand. The government can link green steel purchases with incentives in the form of green steel certificates.**

Green Steel Certificates can be another way to create demand. The government can link green steel purchases with incentives in the form of green steel certificates. It can allow the trading of these certificates in the carbon market for financial gain. This action will support the creation of a green steel market for domestic steelmakers.

International regulations, such as CBAM, can provide further impetus to the private sector to accelerate the transition to green steel. In Europe, some agreements have already been reached between European steelmakers and end consumers, including the automotive sector and white goods manufacturers, for the supply of green steel.

Incentivising First Movers

Apart from incentives to end consumers, the government also needs to support steelmakers who commit to green steel initially.

One way to provide support is viability gap funding (VGF). This will help bridge the gap due to the high initial capital cost of low-carbon steelmaking technology. The government can provide this VGF to urge steelmakers to commit part of their capacity to green steel manufacturing.

Green Hydrogen Purchase Obligations

Green Hydrogen is the prominent green fuel that can replace fossil fuels in the steelmaking process and can help in producing green or low carbon emission steel. To put it in perspective, a 1MTPA steel plant would require around 65,000 tonnes of green hydrogen.[53] As a result, India's market for green hydrogen might grow to US$8 billion by 2030, or nearly 10% of the world's needs.

To fulfil such requirements, the government may create a hydrogen purchase obligation mechanism in line with renewable purchase obligation. This will create a huge influx of capacity addition and, in turn, act as a catalyst for the steelmaking industry. The government can also set year-wise targets in a phased manner at the state and central levels.

Strict Adherence to Renewable Purchase Obligations

Just by replacing fossil-fuel-based electricity with renewable energy power, India can reduce around 22%[54] of its total CO_2 emissions from the steel industry. This can be possible by ensuring strict compliance with renewable purchase obligations from steelmakers (obligated entity).

However, the compliance of obligated entities with RPO targets has been consistently poor across most states. The government should link the fulfilment of the RPO target with heavy penalties in case of non-compliance. This will force all energy-intensive consumers to oblige and contribute to the growth of renewable capacity. In addition, states should also be clear with their RPO regulation by not allowing any carry forward or waiver of RPO target to any obligated entity.

[53] Economic Times. How can India become leader of green steel production. June 2023.
[54] Economic Times. How can India become leader of green steel production. June 2023.

Steel Sector Decarbonisation Roadmap for India

The Nationally Determined Contributions (NDCs) of the steel sector submitted to the Ministry of Environment, Forest and Climate Change projected that the average emissions intensity of the industry would reduce to 2.64 tCO_2/tcs by 2020 and 2.4 tCO_2/tcs by 2030 from 3.1 tCO_2/tcs in 2005, which is approximately a 1% reduction per year.

Capacity addition from coal-based steelmaking to hydrogen-based steelmaking will not be possible without hydrogen costs becoming more affordable and carbon emission penalties pushing the players to switch to greener options.

According to industry estimates, hydrogen prices should fall between US$1/kg and 2/kg[55] to be more viable for expansion, along with a carbon penalty of at least US$50 per tonne of emissions. This can make green steel competitive by 2030 and can catalyse a 150 million tonne shift from coal-based to hydrogen-based steelmaking.

The steel decarbonisation pathway for India is most likely to take multiple routes based on government policy targets and the demand-supply scenario in the steel sector. Based on the initiatives taken by the government and the private sector, IEEFA and JMK Research forecast that green hydrogen-based steelmaking could become the predominant route only by 2050 (see Figure 9).

Our analysis shows that up to 2030, the sector is likely to see a reduction in the share of coal-based technologies from 92% in 2021 to 70% by 2030. This transition is possible with the replacement of coal-based EAF technologies with green hydrogen. Several pilot projects and trials for green hydrogen projects started in India in 2020. By 2030, green hydrogen production is likely to start on a commercial scale in India.

Along with green hydrogen, the scrap-based EAF route and natural gas-based DRI-EAF route are also likely to pick up pace. The 5% share of the natural gas-based EAF route by 2030 is most likely because of the existing industry commitments by various players.[56]

Apart from the government, several private sector players have also started pilot projects and announced huge investment plans by 2030 to decarbonise the steel sector:

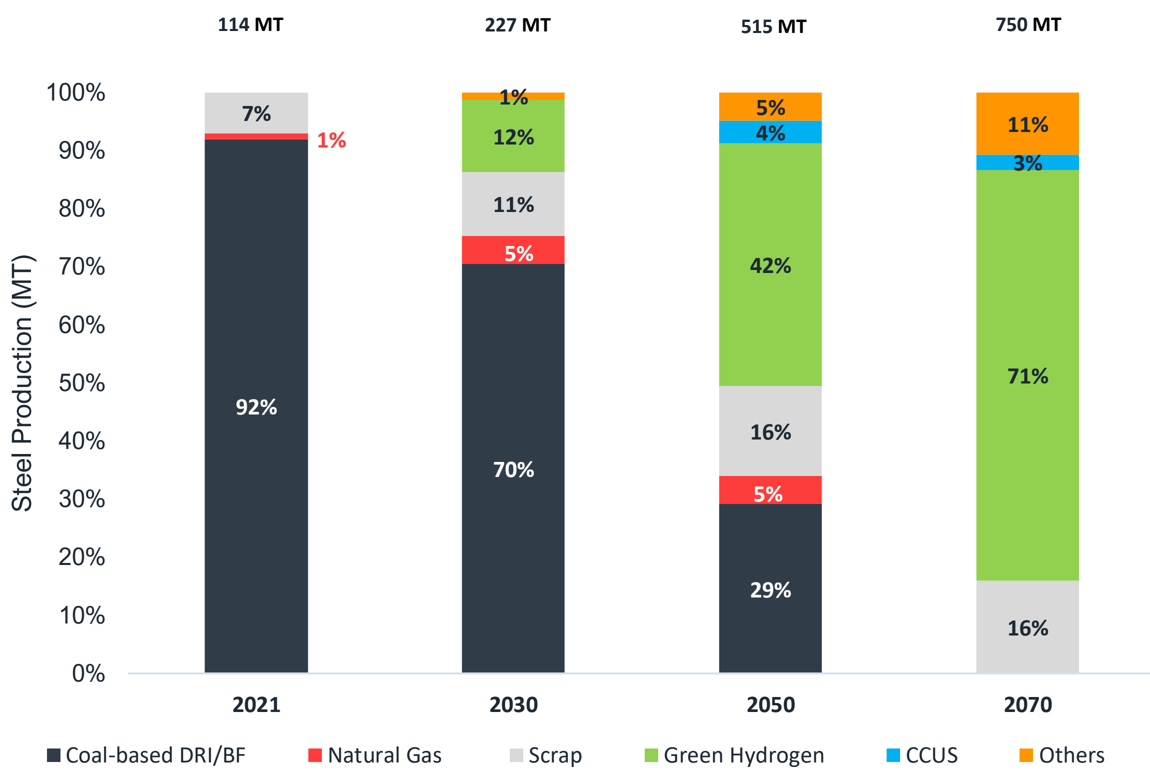
- JSW Steel has announced an investment of Rs100 billion by 2030.[57]
- Tata Steel has announced an investment globally of Rs 160 billion for FY2024 and achieving a CO_2 emission intensity of <1.8 tCO_2/tcs by 2030 in India.[58]
- Reliance Industries has announced an investment of US$75 billion to turn net zero by 2035.[59]

[55] Business line. Decarbonizing the steel sector will pay off. May 2023.
[56] Bloomberg. India's JSW Steel to Spend Over $1 Billion on Cutting Emissions. January 2022.
[57] CNBC TV18. JSW investing 10,000 crores for greener steel. September 2022.
[58] Times of India. Tata steel sets FY24 capex at Rs 16,000 crore. June 2023.
[59] Mint. Mukesh Ambani's $75 bilion plan aims to make India a hydrogen hub. January 2022.

- Adani and POSCO will invest US$5 billion in green steel in Gujarat.[60]

Between 2030 and 2050, we expect green hydrogen projects will be deployed on a large scale across India due to high demand. This is likely to phase out coal-based routes like BF/BOF and DRI-EAF at a much faster pace.

Figure 9: Percentage Share of Different Technologies in Steel Production by 2070



Source: Industry Reports, JMK Research
Note: Coal-Based processes including DRI- EAF, DRI-EIF and BF-BOF route. Others can include Molten Oxide Electrolysis, Electrowinning etc.

According to IEEFA-JMK Research's estimates, the steel industry will replace around 25-30% of grey hydrogen with green hydrogen during the beginning of the 2030-2050 period. Further, we estimate that by 2050, green hydrogen will replace almost 80% grey hydrogen requirements of the steel industry.

Apart from the green hydrogen-based route, the other technologies that will have a minor share during this period will be Carbon Capture, Usage and Storage (CCUS), scrap-based EAF and Molten Oxide Electrolysis (MOE).

[60] Indian Steel Association. Pathway to low carbon emission. November 2022.

The natural gas-based DRI-EAF route is likely to be stagnant from 2030 until 2050, mainly due to the unavailability of natural gas in the domestic market. CCUS-based technology is also likely to have a 4% share in this period owing to the committed plans of various industry players.[61]

> **The natural gas-based DRI-EAF route is likely to be stagnant from 2030 until 2050, mainly due to the unavailability of natural gas in the domestic market.**

The scrap-based EAF technology is likely to increase to 16% owing to progressive scrappage policies but will be limited due to the lack of domestic availability of high-grade steel scrap.

From 2040, new innovative technologies like MOE will coexist with green hydrogen-based routes. Various pilot projects have already been conducted and successfully tested for this technology in the US.

All these low-emission technologies like green hydrogen-based, scrap-based EAF or MOE routes have one thing in common – they depend on renewable energy. Access to favourable and cheaper renewable energy is critical to achieving price parity, where the cost of green hydrogen production is equal to the cost of grey hydrogen.

Between 2050 and 2070, since large projects using the green hydrogen-based route may have already been available across India, the green hydrogen-based route will completely replace coal and natural gas-based conventional technology, thereby retaining the majority share of about 70%.

Furthermore, shares of other renewables-based methods, like MOE, are likely to double from 2050 until 2070. The MOE route is likely to be the most promising technology among all pilot projects that are currently ongoing because it can be used for any type of iron ore.

In addition to this, the CCUS route will most likely start phasing out over this period. This is because CCUS is highly dependent on conventional routes like BF/BOF, and being relatively expensive old technology, it is highly unlikely that CCUS will make any significant impact on the steel sector decarbonisation plan. Additionally, the fossil fuels plants, i.e., BF/BOF paired with CCUS, are likely to get phased out in the upcoming decades, making CCUS infrastructure a stranded asset. All these factors make CCUS an unviable option for a large-scale transition.

[61] PIB. Green Steel. February 2023.

Conclusion

Decarbonising steel production in India requires a vision by policymakers whereby they can encourage the production of green steel. Until 2030 – considering that the techno-commercial feasibility for the transition to the green economy is yet to be established – we do not expect significant commercial-scale green hydrogen demand from the domestic steel industry.

Since steel is a highly competitive commodity market, it is unlikely to absorb the premium without a strong impact on market dynamics. Therefore, changing the existing ecosystem around steelmaking and its usage requires government support in terms of policy initiatives and efficient funding support for first movers.

The DRI-EAF method of steelmaking using green hydrogen as the reducing agent results in a more than 80% reduction in carbon emissions compared to the conventional BF/BOF method. However, it is an expensive process.

The price of green hydrogen production can reduce if the government supports industries by making available low-cost electrolysers and cheaper renewable energy. Thus, the government must promote the local manufacturing of both alkaline and proton exchange membrane (PEM) electrolysers. For such an initiative to succeed, it can look at introducing PLIs as it has done for other emerging sectors like solar and advanced cell chemistry (ACC).

Despite banking being allowed in the production of green hydrogen, states need to operationalise it on an actual basis. The central government should support renewable energy procurement by steel companies through proper coordination to fulfil demand.

The central government should support renewable energy procurement by steel companies through proper coordination to fulfil demand.

Further, decarbonising the steel sector at scale will need transparent government support in both the upstream and downstream value chains of green steel production. Support in terms of viability gap funding for steelmakers to commit part of their capacity to green steel manufacturing is important. Moreover, the government can also give incentives or green certificates for end-users of steel to purchase a certain quantity of green steel as one of the drivers for green steel procurement.

In addition, the government should create a green hydrogen purchase obligation mechanism for all emissions-intensive sectors. This will ensure a huge influx of capacity addition and, in turn, act as a catalyst for the steelmaking industry.

The MSME sector, which constitutes 40% of the Indian steel market, requires the deployment of innovative financing products. One such option is via blended finance mechanisms. This can play an important role in the initial growth of low-carbon solutions for the steel sector in the country. A blended mechanism active for MSMEs in India is the Partial Risk Sharing Facility for Energy Efficiency (PRSF), run by SIDBI and supported by GEF.

Furthermore, Indian steel sector producers need to get competitive in the global market due to the introduction of stricter rules like CBAM. They will have to bring CO_2 emissions to the global level, i.e., 1.8 tCO2/tonne crude steel, in order to make their presence felt globally.

With government support in terms of introducing a suitable regulatory landscape and promotional measures to encourage the use of different green technologies at scale to decarbonise this hard-to-abate industry, India may achieve its net zero emissions target for the steel sector by 2070.

All stakeholders, including government entities and private and financial institutions, must come together in the mission to decarbonise the steel sector. At each step, if the best possible strategies are pushed in a correct way to utilise the available green solutions and techniques, then India can become the world’s green steel ambassador.

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JMK Research & Analytics provides research and advisory services to Indian and International clients across Renewables, Electric mobility, and the Battery storage market. www.jmkresearch.com

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The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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