IndianSteel
ASSOCIATION

CRISIL
An S&P Global Company

Pathway to low carbon emission steel

November 2022

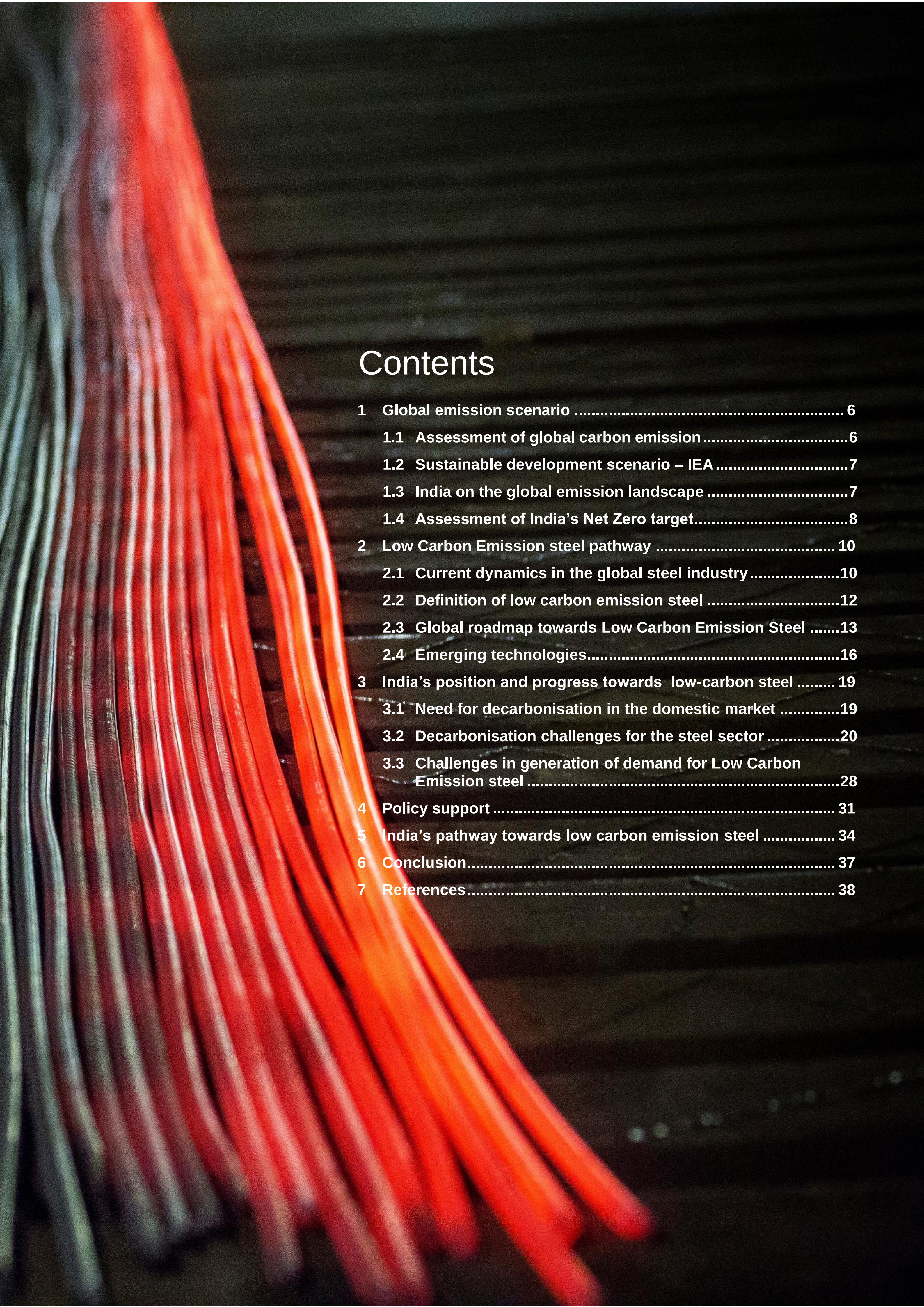
Analytical contacts

Hetal Gandhi
Director
CRISIL MI&A Research
B: +91 22 3342 3000
hetal.gandhi@crisil.com

Koustav Mazumdar
Associate Director
CRISIL MI&A Research
B: +91 22 3342 3000
koustav.mazumdar@crisil.com

Vamsi Arni
Senior Analyst
CRISIL MI&A Research
B: +91 22 3342 3000
vamsi.arni@crisil.com

Meet Mehta
Analyst
CRISIL MI&A Research
B: +91 22 3342 3000
meet.mehta@crisil.com



Contents

Foreword

Climate-linked calamities have become more frequent globally over the past decade — forest fires, rising sea level, and higher temperatures, to name some. Flooding and drought have become commonplace.

Resultantly, the narrative on climate change across small and big, developed and developing, economies has pivoted, with countries committing to quickly lower emissions.

Countries have deepened their commitment to reducing emissions across sectors, with policies being shaped on decarbonising the economy while ensuring growth. This is being reflected in various forums, including the Paris Agreement and the United Nations Climate Change Conference (COP26) where countries have committed to Net Zero emission to slow global warming to 1.5 degrees Celsius (C) by 2050.

Net Zero commitments were emphasised during COP27, which focused on implementation of the Paris Agreement, Further, COP27 envisaged enhanced availability of funds for implementation of measures to tackle climate change, adhering to the principles of transparency and accountability.

To achieve the commitments, the gaze has shifted to micro-focusing, first on easy-to-target lowering of emissions by increasing fuel efficiency, recovering top gas or optimising existing technologies. The second stage would, however, be crucial as the key lies in identifying long-term transitions for hard-to-abate sectors with high power intensity, such as steel and its value chain, with permanent and significant reductions in carbon emission levels. Lastly, focus would shift to methods such as carbon trading or carbon capture technologies to enable achieving Net Zero.

The focus, globally, has shifted to long-term sustainability of the steel sector, which has recovered sharply from the Covid-19 pandemic-induced slowdown.

Reducing emissions and improving efficiencies will, however, be long-drawn, and will depend on the age of the existing technology installed at the plants, the quality of coal and iron ore available, the generation of scrap, and the logistics infrastructure for natural gas. India will have its own unique journey with relatively young blast furnace–basic oxygen furnace (BF-BOF) capacities and limited scrap availability. As it is a key economic driver, achieving Net Zero without affecting growth or product availability will be a key challenge.

The domestic steel industry accounts for ~12% of India's overall emissions[9] against the global standard of ~8%. With domestic demand set to grow at a moderate pace over the next two decades, its share in overall emissions is unlikely to subside, necessitating large-scale investments to decarbonise the sector.

In 2018, the Indian Steel Association (ISA) successfully launched its flagship event, the 'ISA Steel Conclave', as a platform for the government, senior industry leaders, and consultants, to gain insights on the steel industry in India and the challenges before it. ISA is now organising 'ISA Steel Conclave 2022', for which CRISIL Research is a knowledge partner.

This knowledge paper highlights the efforts, global and domestic alike, to decarbonise steel, and identifies key challenges.

1 Global emission scenario

Despite stringent steps taken by most developed economies, global emissions have continued to rise in line with rapid economic growth.

According to the World Meteorological Organization, average global temperature rose 1.00º C above preindustrial (1850-1900) level for the first time in 2015 and 1.11º C in 2021 due to increased industrial activity and coal usage. Effectively, annual carbon emission rose to 36.3 billion tonne in 2021.

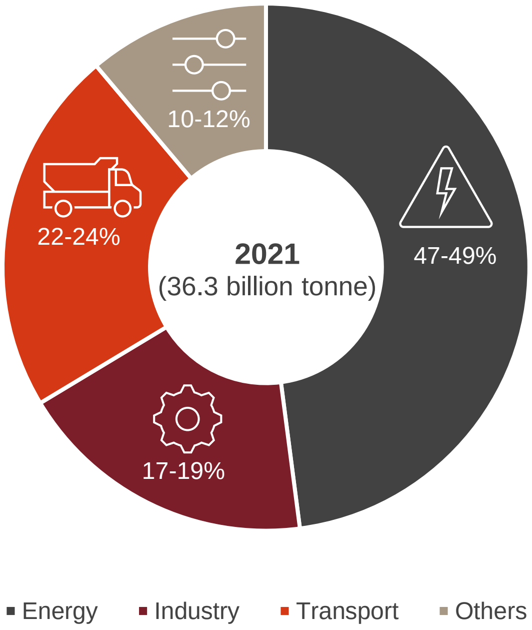
The Paris Agreement signed by 195 countries in 2015 was a landmark in the global response to climate change. The United Nations announced in 2019 that more than 60 countries committed to achieve carbon neutrality by 2050. Developing countries such as India also committed to a Net Zero target by 2070 at COP26 in October 2021. These agreements have provided further push to all industrial sectors to become carbon-neutral.

International agencies such as the World Bank, the International Monetary Fund and the International Energy Agency (IEA) have also taken note, embedding in their policies climate change mitigation.

1.1 Assessment of global carbon emission

Greenhouse gases (GHGs) are considered major causal agents for global temperature rise, with CO_2 accounting for 65% share. Of the global CO_2 emission of 36.3 billion tonne in 2021, the energy sector accounted for almost half (47-49%), with transport and industry sectors other large-scale emitters.

Industry-wise break-up of global emissions



Source: IEA, CRISIL Research

In fact, CO_2 emission from energy generation has grown at a steady pace in the past decade despite a shift towards renewable energy. The primary reason is the continued increase in coal usage in developing countries. In countries such as India, despite rapid increase in renewable capacity on a low base, steep increase in power demand in line with economic growth drove additions in the conventional space, while leading to a rise in overall emissions. However, most large industries (especially steel, cement and aluminium) have seen lower increases owing to deployment of energy efficiency measures like WHRS (waste heat recovery system), CDQ (Coke dry quenching) and Top-Pressure Recovery Turbine Plant (TRT)

The transport segment, which is the second largest contributor of CO_2 emission, has seen the fastest growth at over 1% CAGR despite introduction of efficiency norms such as Corporate Average Fuel Economy in the US and pick-up in electric vehicle sales. The main reason is rising penetration of automobiles in developing countries.

1.2 Sustainable development scenario – IEA

IEA defines three climate scenarios at differing temperature changes: the current policy scenario (1.5º C by 2022), the new policy scenario (2.7º C by 2050) and a sustainable development scenario (1.5º C by 2100).

The sustainable development scenario is a pathway designed by the IEA that would allow the world to meet climate, energy access and air quality goals in line with the Paris Agreement without compromising on the reliability and affordability of energy for a growing global population.

The base assumption in this scenario is that all the current Net Zero pledges are fully achieved. All advanced economies reach Net Zero emission by 2050, China by 2060 and all other countries by 2070, thus limiting the global temperature rise to 1.65º C with some negative emissions post 2070, capping the temperature rise to 1.50º C by 2100.

The key assumptions for the scenario are:

- Population growth: It is assumed to be 0.7% CAGR between 2020 and 2050
- GDP growth: Real GDP growth is assumed to grow at 3.0% CAGR between 2020 and 2050, with India printing 5.3% CAGR
- Fossil fuel prices are assumed to fall by 2050
- CO_2 prices: These are calculated by dividing CO_2 emission with real GDP in $ per tonne. Under a sustainable development scenario, CO_2 prices are assumed to reach $160 per tonne for advanced economies and $95 per tonne for emerging economies by 2050

The scenario has a sector-wise roadmap as well to achieve Net Zero CO_2 emission:

Energy: One of the main pathways to achieve Net Zero CO_2 emission by 2050 will be increasing the share of renewable energy sources in overall power generation. Also, the life span of existing nuclear power plants will need to be extended as well as new nuclear power plants will need to be built, along with deploying carbon capture, utilisation and storage (CCUS) on a large scale. Additionally, better emission standards will need to be implemented to prevent refurbishment of old inefficient fossil fuel plants.

Building: Least efficient appliances such as light bulbs and heating/cooling equipment will need to be phased out by 2030, and mandatory energy performance standards for appliances and cooling equipment introduced. Net Zero emission requirements for all new buildings will need to be introduced by 2030, as well as energy efficiency and CO_2 emission reduction measures such as retrofits, heat pumps and direct usage of solar for various applications for existing buildings.

Transport: CO_2 emission intensity from passenger vehicles will be limited to 50g CO_2 per km for countries with Net Zero pledges and 130g CO_2 per km for other countries by 2040. Two stroke engines for two-/three-wheeler segment will be phased out. Biofuels will be scaled up and fuel intensity will be reduced by 3% per year for the aviation segment. The annual emission trajectory will need to be 50% below 2008 levels in 2050 as per the International Maritime Organization emission reduction strategy.

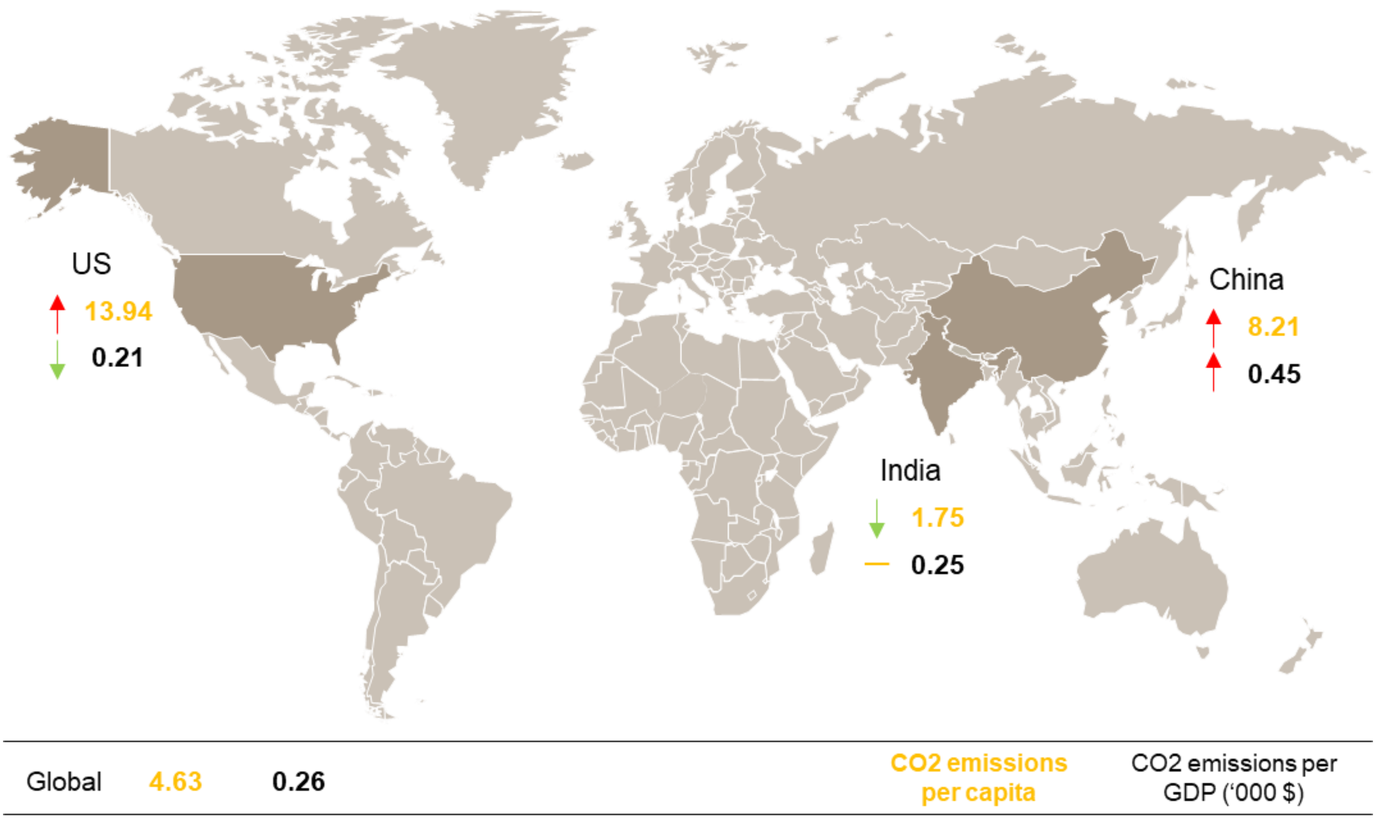
Industry: Policies to support CCUS and hydrogen application in various industries, and recycling of materials and metals will be introduced. Energy management systems and audits will be made mandatory. Minimum energy performance standards for electric motors will be enhanced by 2025 as well.

1.3 India on the global emission landscape

India, the fifth-largest economy of the world, emitted over 2.5 billion tonnes of CO_2 in 2021[3], as per IEA, which is an increase of over 40% in the past decade.

However, while India accounts for a sixth of the global population, its overall carbon emission was below 7% in 2021 as per IEA[1], clearly highlighting the lower per capita emission. In fact, the per capita emission of the two largest economies in the world – the US and China – are ~8 and ~5 times, respectively, India's per capita emission.

India's per capita emission is well below global standards



Source: IEA, CRISIL Research estimates
Note: GDP in on Purchasing power parity (PPP) basis

That said, India's emission per dollar of GDP on a purchase power parity (PPP) basis is similar to that of developed economies such as the US (0.21) and Japan (0.20), and at par with the global average, indicating that the country has been taking the right steps to keep emissions under check.

1.4 Assessment of India's Net Zero target

Major economies such as the US, the EU and Japan have been setting aggressive targets and taking steps to achieve Net Zero emissions. India, too, has been making strides, though relatively slow. However, Government of India announced its intention to achieve Net Zero emission by 2070[7] at COP26. Further, the prime minister announced several medium-term measures to achieve the target.

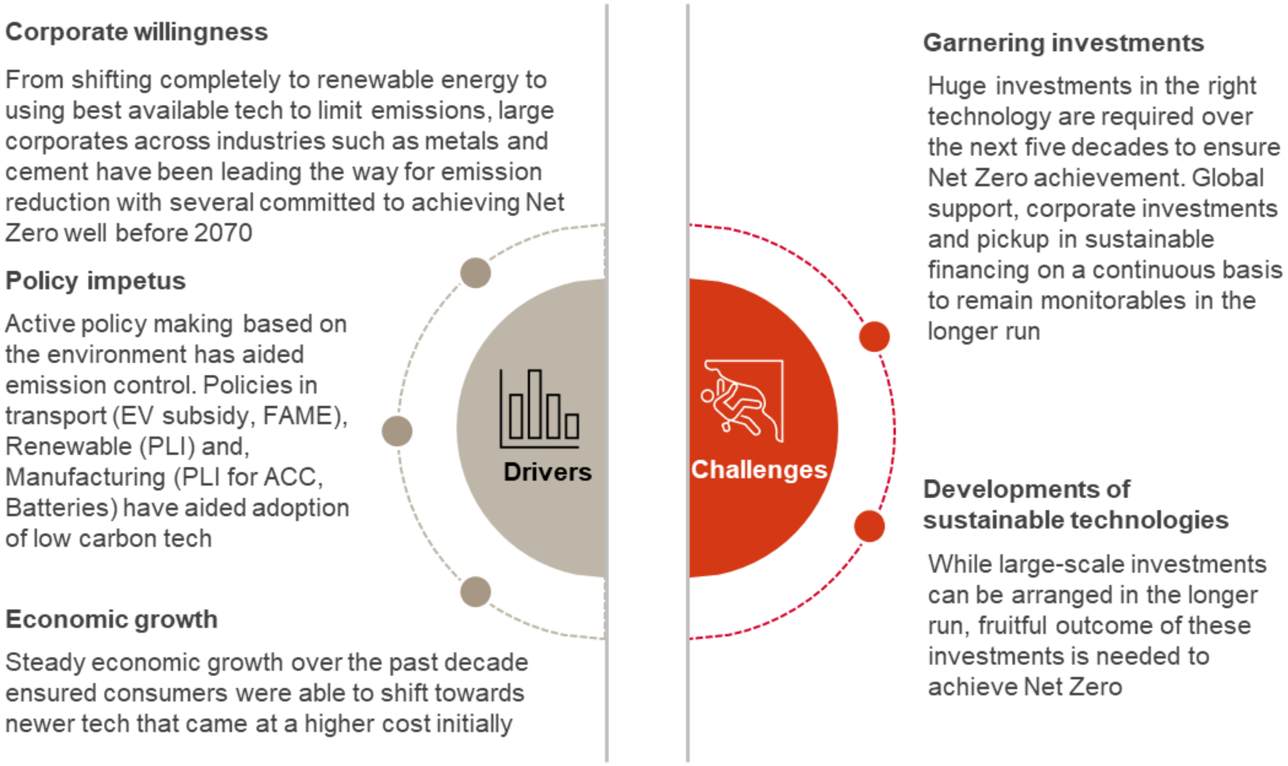
India's announcement of its Net Zero goal is a major step, given the country's per capita emission remains considerably lower than developed economies – India accounted for just ~7% of global emission despite comprising ~18% of global population.

The government announced five steps to address climate change, collectively called 'Panchamrit'. These include:

- **Achieving 500 GW of non-fossil renewable capacity by 2030:** As of March 2022, India had an installed non-fossil capacity of **163 GW**. Hence, a sharp uptick in new capacity installation is required beyond 2027 to achieve the target, given that only 125-130 GW of renewable capacity is expected to be installed over the next five fiscals. Although steep, the target is achievable with the momentum picking up post 2027, which will take the total non-fossil installed base to 460-470 GW, factoring in sharp focus on renewables (solar, wind and hybrid systems) and storage capabilities of battery and pumped storage. Private-sector participation would be the key differentiator in driving the clean energy segment and captive power consumption in industries.

- **Meeting 50% of India's energy requirements from renewable energy by 2030** – If India successfully meets its target of installing 500 GW of non-fossil renewable capacity, the second target of meeting 50% energy requirement from renewable energy will follow suit.
- **Reducing total projected carbon emissions by 1 billion tonne by 2030** – More clarity on the target is expected to emerge at COP27 conference in November 2022.
- **Reducing the economy's carbon intensity by 45% by 2030 over 2005 levels –** India must reduce its carbon intensity by 45% from 2005 levels. While a lot has been already achieved across most industrial sectors as well as transport through corporate initiatives as well as policy changes, a lot remains to be achieved over the next eight years to meet the goal.
- **Achieving the target of Net Zero emission by 2070** – The most important target of the five is achieving Net Zero emission. Not only would this require investments in the few trillion dollars, but the key challenges would also be technological evolution and scalability. Although India has 20 years more than the Net Zero targets of developed economies, such as the US and the EU, it cannot wait until 2050 to act. The country must start curbing carbon emissions immediately, which is already seen in the steps taken by the government as well as corporates.

Drivers and challenges to India's Net Zero target



Source: CRISIL Research

2 Low Carbon Emission steel pathway

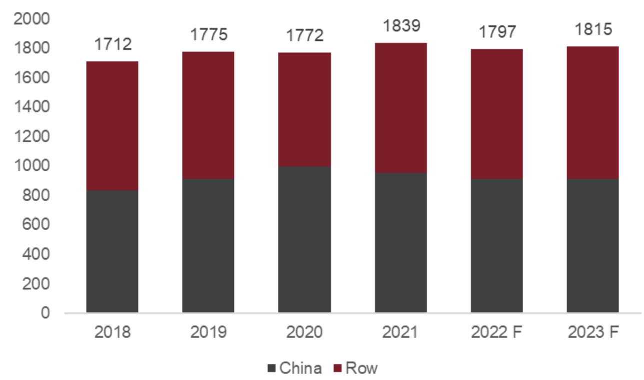
2.1 Current dynamics in the global steel industry

The global steel industry has seen some major changes since the peak of the pandemic. China, the largest producer and consumer of steel, has capped its capacity and started focusing on moving towards a service-based economy from focusing on quantitative output. Paired with this, there is increased interest and push towards lowering the carbon footprint of the industry. Further, rising geopolitical risks and implications of moving to Net Zero have increased new concerns regarding raw material security.

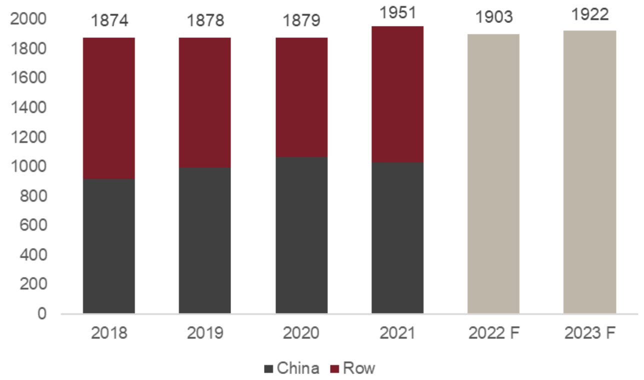
After an impressive 9% growth in steel demand in 2019 as per WSA, demand in China fell ~5% in 2021 as it cut its manufacturing volume significantly to curb emissions during the Winter Olympics. Slowdown in the property segment and decline in automobile production due to chip shortage have been the key reasons for continued weak demand in China. We foresee further decline in China's steel demand in 2022 by 3-5%, given that the first half has already been weak due to winter production cuts, surge in Covid-19 cases and associated localised lockdowns under its zero-Covid-19 policy, and a struggling housing and real-estate sector.

Excluding China, global steel consumption fell 10% on-year in 2020 during the outbreak of the pandemic, which is estimated to have grown 5% on-year in 2021. However, after a sharp recovery in 2021 global demand is expected to fall 2-4% in 2022. China was the first to see a sharp demand slowdown because of weakness in the real estate market along with intermittent lockdowns, which slowed construction activities in the infra space. Similarly, other major economies are also showing signs of weakness, with the Russia-Ukraine conflict impacting their cost structures, and persistent inflation affecting demand. India, though, remains the only major consumer with healthy growth of 6-8% expected in 2022.

Global steel demand (million tonne)



Global crude steel production (million tonne)



Source: Worldsteel Association, CRISIL Research estimates

On the capacity addition front, ~30 MT is expected to be commissioned by 2023 as per CRISIL Research estimates, with major uptick expected in India and the Middle East. However, the world's heavyweight, China, will see a fall in installed capacity on account of its capacity swap programme and the economy's focus shifting away from quantitative output.

With impact of Covid-19 waning and decarbonisation taking centre stage in the steel industry globally, the focus on production technologies used in the manufacturing process has increased. Currently, there are two main routes of production: oxygen and electric routes.

1. **Oxygen route –** It refers to the BF-BOF route of production. Here, iron ore is fed into a blast furnace, along with coke (made from coking

coal), to produce molten iron (hot metal). Hot metal then flows into a BOF where alloying agents are reduced using oxygen blown from the bottom, producing crude steel. This route accounts for ~71% of global production[12]

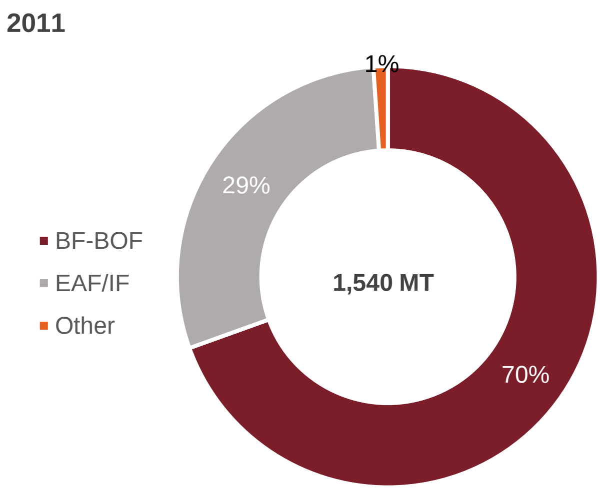
2. **Electric route –** It refers to an EAF and induction furnace (IF) route of production. In an EAF setup, sponge iron (also known as direct reduced iron – DRI), pig iron and scrap are fed into the furnace and melted using electricity. IF has a similar setup with scrap, ferro alloys, fluxes, DRI is melted using electric current. This route accounts for ~29% of global output[12]

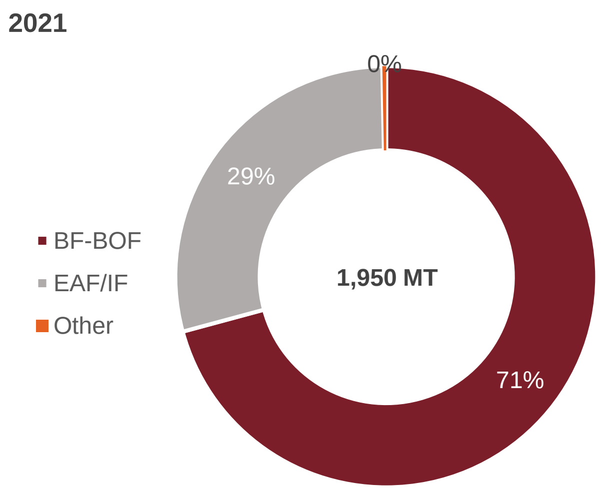
There are other routes as well within this classification that have some modifications to the standard set-up:

1. SR-BOF (COREX): This route is similar to BF-BoF and uses gas to reduce iron ore into 95% DRI, which then flows into BOF to produce crude steel
2. Scrap-EAF: It is a standard EAF set-up with the feed almost entirely comprising ferrous melting scrap

While production technologies such as MIDREX and Coal-DRI-EAF are seeing good adoption, other emerging technologies for low carbon emission steel production such as H_2-DRI and iron electrolysis (MOE) are in the early adoption phase, and will need significant cost rationalisation, policy support and end-use demand in order to be adopted widely.

Share of various processes in global crude steel production





Source: World Steel Association, CRISIL Research

The production process has a bearing on overall emissions. As reflected in the numbers reported by the World Steel Association, CO_2 intensity per tonne of crude steel increased steadily from 1.81 tonne in 2018 to 1.89 in 2020[16], owing to higher production share of developing countries which predominantly use BF-BOF route.

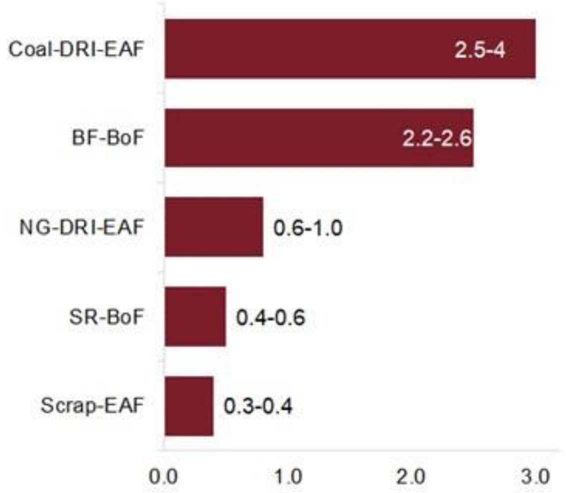
CO_2 intensity per tonne of crude steel varies across companies and regions because of difference in the share of BF-BOF and DRI-EAF techniques deployed. CO_2 intensity at each stage of crude steel making, such as material preparation, iron making, and steel making, is given below.

At about 2.4-2.6 tonne, carbon emissions are the highest in the BF-BOF route, as it uses a huge quantity of coal (coking coal or pulverised coal). Scrap-based EAF releases the least amount of carbon emissions – 0.4 tonne.

The EAF-DRI route, which is more popular in developed western countries, is less-polluting as long as natural gas is used to produce DRI. Scrap blending of 20-25% ensures overall emissions from the route remain in the range of 0.7-1 tonne. However, in India, coal is used to produce DRI owing to the unavailability of natural gas, leading to higher emissions (2.5-4 tonne) depending on the size of the plant and the grade of iron ore used.

With the share of BF-BOF in crude steel production increasing since 2018, carbon emission intensity has been on the rise because of the increased use of coking coal. China, the largest producer of steel, manufactures 90% of its steel using the BF-BOF technique. Blast furnaces use reducing agents, which have high carbon content. Implementing decarbonisation measures such as replacing high-carbon reducing agents will help the industry become a low-CO_2 producer and achieve net-zero emissions.

Process-wise CO_2 intensity (tCO_2/tcs)



Source: CRISIL Research, Industry
Note: Scope 1 and Scope 2 emissions only

2.2 Definition of low carbon emission steel

Low carbon emission steel, often loosely classified as 'green steel', can be defined as steel manufactured without the use of fossil fuels such as coal or natural gas at a broad level.

Green steel, on its part, focuses not only on reducing carbon emission, but also on all other sustainability aspects such as particulate emissions, effluent discharge, and waste management.

Thus, in the present context, green steel would largely be defined as low carbon emission steel.

Given that steel is a global commodity, its classification and definition cannot vary across economies. Even though various countries have different Net Zero targets, it is imperative to set global standards and benchmarks, including scope of emissions as well as system boundaries, to ensure investments are made uniformly across the globe to reduce carbon emissions from the steel sector.

Hence, global agencies must develop a well-defined approach in consultation with steel producers as well as governments across the globe to arrive at the definition of green steel or low carbon emission steel. In fact, IEA has published a report on achieving net zero in heavy industries for G7 countries[13]. New approach can be formed basis the report.

Today, with over 70% of global crude steel produced through the oxygen route, as per WSA, classifying only green hydrogen-based steel or scrap-recycled steel as green steel would be incorrect. A well-defined approach is needed for classification of low carbon emission steel at a global level.

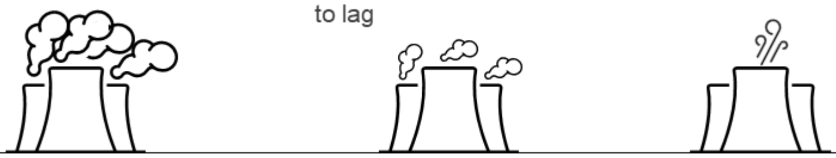
In India, too, production value chain benchmarks must be created to define "low carbon emission steel". Availability of input materials, especially natural gas and steel scrap, should be taken into consideration before setting up a benchmark for classification of low carbon emission steel.

Once scalable pathbreaking technologies are available, a roadmap can be created for classification of low carbon emission steel along with an emission benchmark.

In the interim (until 2030), until radical technologies are proven, focus should be on research and development for identifying the least-polluting and most cost-effective technology. Also, new capacity additions in path-breaking technology will take some time; until then, players should target to reduce emission intensity of up to 20% by 2030 through other available measures such as higher scrap blending.

Low carbon emission steel roadmap

	Development stage	Transition stage	Comprehensive decarbonisation stage
	2022-2030	**2030-2040**	**Beyond 2040**
Stages	Pilot projects, R&D of future tech, efficiency measures, implementation of BATs	New tech introduction, phasing out of old plants, DRI-EAF to drive new additions	Progress towards near zero emissions; adoption of radical technology by emerging economies
Overall emission reduction	**Low:** Per tonne emission reduction to remain low (<20%)	**Medium:** Per tonne emission to gradually scale up to 40%; emerging economies to lag	**High:** Emissions to trend near zero; India-China to follow US and Europe



Source: CRISIL Research

2.3 Global roadmap towards Low Carbon Emission Steel

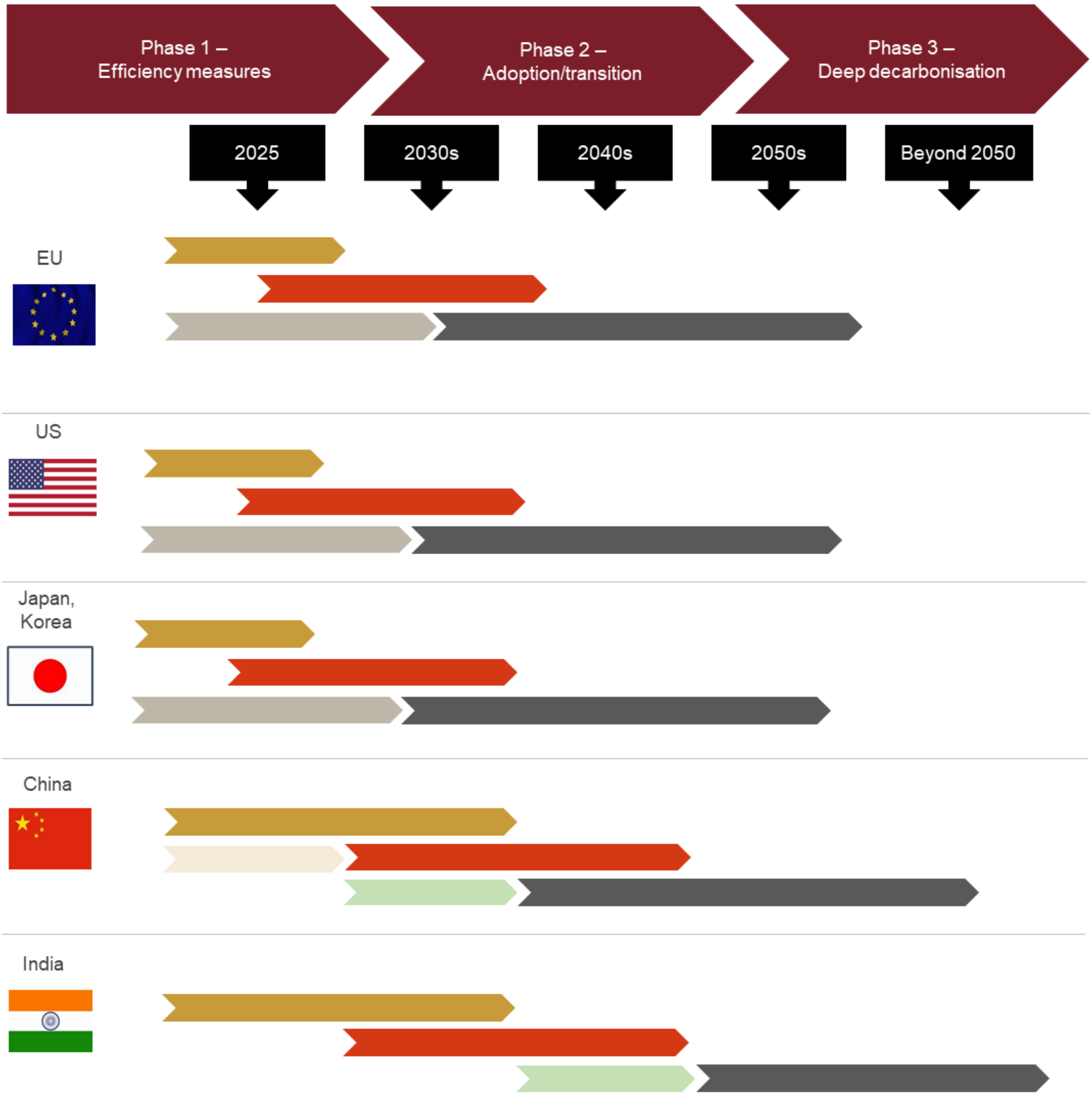
Decarbonisation of the manufacturing process, and subsequently the value chain of the iron and steel industry, is central to curbing overall emissions from the industrial sector. However, sectors such as steel are said to be hard to abate. The manufacturing processes that are widely used and economically viable are carbon- and energy-intensive. Moving away from these processes to clean production technology would lead to two key challenges:

1. **Production cost:** To see widespread adoption, emerging technologies that promise radically lower emissions (such as HYBRIT, i.e., green hydrogen-based steel production in a DRI-EAF set-up) will need significant policy impetus, cost reductions, and end-user acceptance of green premiums.
2. **Timing**: Setting up a steel plant requires significant capex and time. Further, the lifecycle of a steel plant spans over decades. Hence, to reach a net-zero target of (say) 2050, the world would need low carbon emission steel plants to come up by the next decade. This, in turn, would require decarbonisation costs to fall sharply in the medium term.

Different countries and regions are applying varying levels of efforts in mitigating climate change and reducing emissions. Europe, for instance, is leading the pack with carbon tax in place and a Net Zero target of 2050, while developing juggernauts such as China and India have delayed Net Zero targets of 2060 and 2070, respectively. In fact, China in its updated Nationally Determined Contribution(NDC) [17] has pledged to peak its overall emissions by 2030, and to achieve carbon neutrality by 2060.

Considering the steel sector alone, the decarbonisation trajectory is expected to be split into three phases — development, transition and comprehensive decarbonisation. Countries and regions will see a different pace of progress through these phases to achieve zero-emission steel.

Expected decarbonisation trajectories across regions for steel industry



Source: IEA, industry reports, company reports, CRISIL Research

1. Development

Currently, ~70% of the world's crude steel output comes from the oxygen route, which is carbon-intensive owing to the use of coking coal in the iron-making process. However, these plants would not be immediately uprooted and replaced with low-emitting technology. Hence, in the near term, we will see steel mills implementing efficiency measures to reduce their carbon intensity, such as increasing pulverised coal injection (PCI) blending in the blast furnace to reduce coke rate, increasing scrap blending, installing top gas recovery turbine (TRT), using renewable power wherever possible, recycling top gas, and managing waste efficiently.

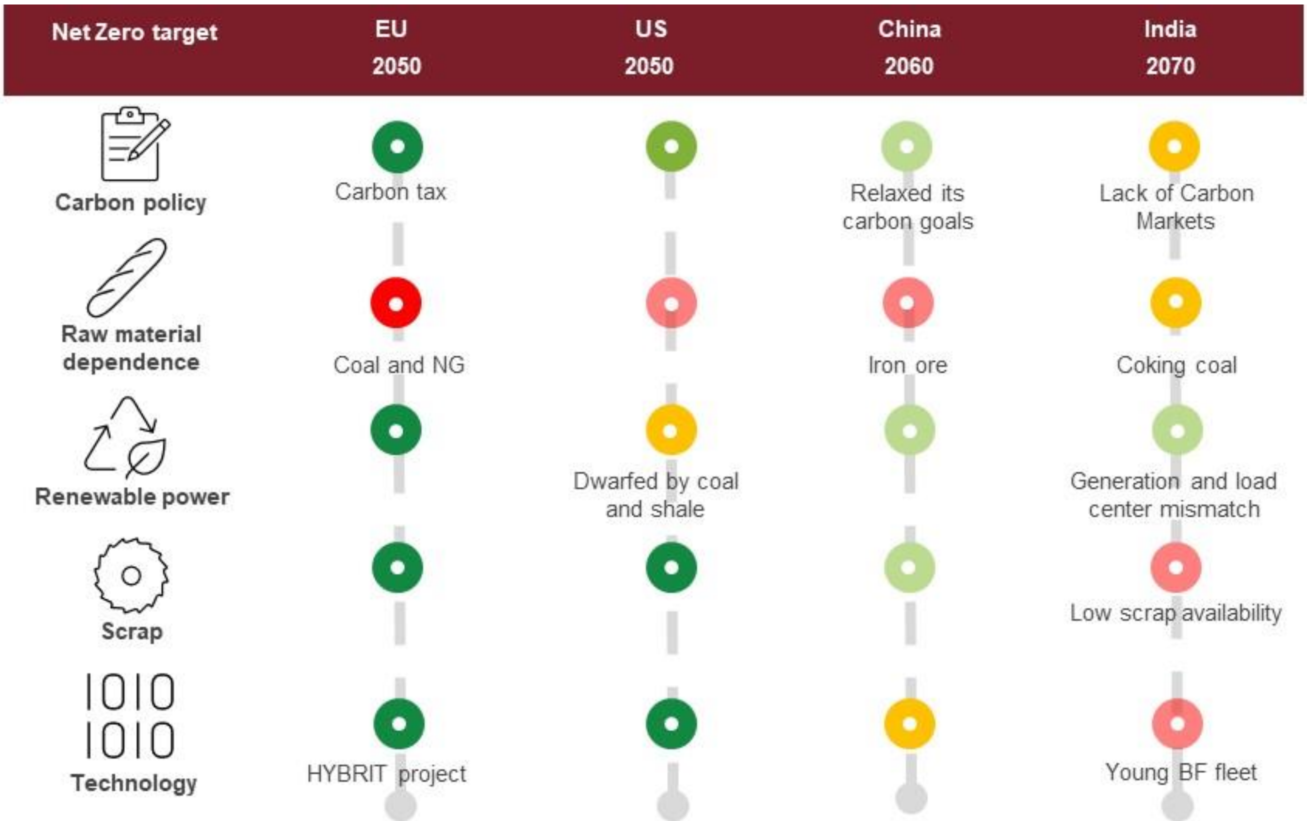
2. Transition

This phase will see adoption of technologies such as coal-based DRI-EAF and MIDREX that promise a material reduction in emissions. This would result in a 40-50% drop in emission intensity compared with traditional BF-BOF plants. However, these plants will still see emissions in the iron-making stage and during fossil fuel energy usage in the EAF. Further, adoption of these technologies would need to be supported by ensuring availability of raw materials such as scrap and natural gas.

3. Comprehensive decarbonisation

The final phase of decarbonisation would begin with zero-emission production technologies being adopted. At present, there are two production routes that could achieve this goal—green-hydrogen-based DRI-EAF (HYBRIT) and iron electrolysis. These routes require significant cost reductions, thrust on renewable energy, and willingness of end-users to pay green premiums. Support in terms of carbon taxing and plugging imports of 'dirty steel' from other regions would be imperative to ensure smooth adoption of low carbon emission steel.

Expected progress towards steel decarbonisation



Note: Color-coding has been defined based on how positively (green)/negatively (red) the region is placed pertaining to the respective factor in reducing carbon emissions
Source: CRISIL Research

These are the indicative tranches for the steel industry's decarbonisation path. Countries/regions such as the EU, the US, Japan and Korea are already at a lower carbon intensity and would move to the transition phase over 2025-30. India and China, on the other hand, will only move to the second phase in the 2030s owing to high-emitting capacities and younger BF fleet. China has a capacity swap programme in place, which will help it move to the transition phase earlier than India. Although it is a long-drawn process for China, with ~90% of its steel still being produced via the BF-BOF route, it is a right step towards achieving net zero. Accordingly, the net-zero targets of these countries are also 10 years apart. The deep decarbonisation phase is expected to set in for developed nations in the late-2030s, while developing nations will see a move towards this by the 2040s or 2050s.

This disparity in trajectories can also be substantiated by the support factors required to move to greener technologies. These factors would include carbon policy, raw material and scrap availability, renewable power generation, technological development, and support for smooth adoption.

For instance, the EU is best placed to achieve decarbonisation, with a comprehensive carbon tax in place (with tariffs on imported emissions as well), a mature scrap collection and processing industry, and accelerated investments in green steel / low carbon emission steel manufacturing (such as HYBRIT, SALCOS and H2 Green Steel projects). The only downside that the EU faces is its dependence on Russian coal and natural gas for its EAFs. In the wake of the ongoing Russia-Ukraine war and sanctions imposed, this factor is leading to a major cost escalation for steel mills.

The US is in a similar position with decent headway on carbon policy and high scrap blending ratio. However, pick-up in renewable energy could be delayed on account of cheaper fossil options (such as coal and shale) and insufficient impetus for end-users to move towards greener routes.

Meanwhile, in India and China, the biggest factor at play is the young BF fleet (with average age of 10-15 years). The existing operational BFs need to run out their useful life and be wilfully replaced with EAFs. China has a capacity-swap programme in place to accelerate this replacement. However, it will be a long-drawn process. Both China and India also have high import dependence, with China dependent on iron ore and India on coking coal. Moreover, being developing nations, their carbon goals (and hence, Net Zero targets) are relaxed compared with the developed world. These factors drive the delayed decarbonisation track of these countries, compared with the US and the EU.

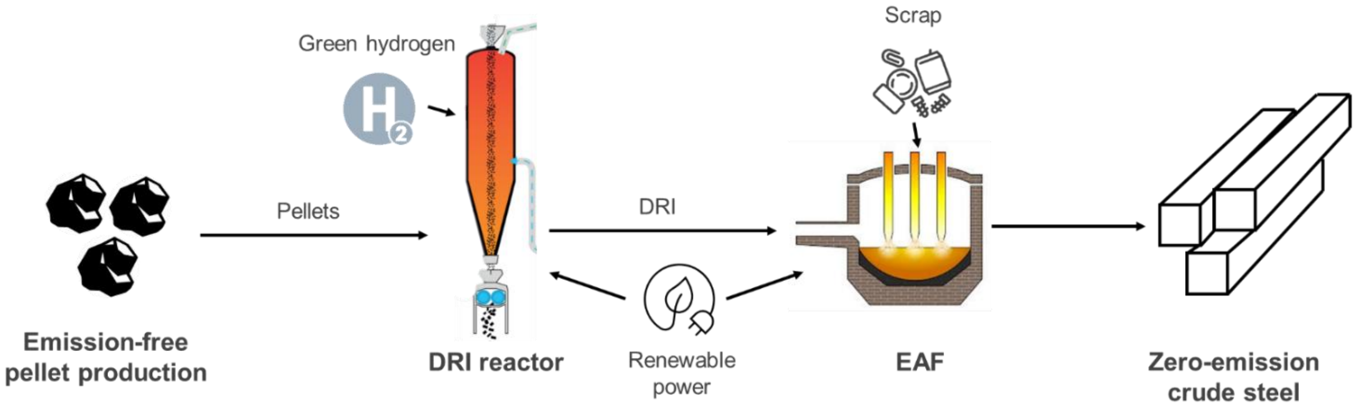
2.4 Emerging technologies

Investments and the pace of development of new low-carbon manufacturing technologies are and will remain crucial to the sector, charting its path to net-zero. In this section, we look at a few emerging technologies that show promise in producing green steel or low carbon emission steel. While MIDREX and BF-BOF with carbon capture (CCU/S) technology can yield a material reduction in emissions, currently only two technologies—Hydrogen Breakthrough Ironmaking Technology (HYBRIT) and Molten Iron Electrolysis (MOE).—show technical viability for zero-emission steel.

2.4.1.1 HYBRIT

The HYBRIT[5] project is a joint venture between three Swedish companies — steelmaker SSAB, mining company LKAB and energy provider Vattenfall. These companies partnered in 2016 to manufacture zero-emission steel. The HYBRIT route involves manufacturing DRI using green hydrogen (hydrogen produced using renewable power) instead of coal. DRI is then converted to steel in an EAF that is powered by renewable sources of energy. This would effectively mean zero Scope 1 and 2 emissions.

HYBRIT process layout



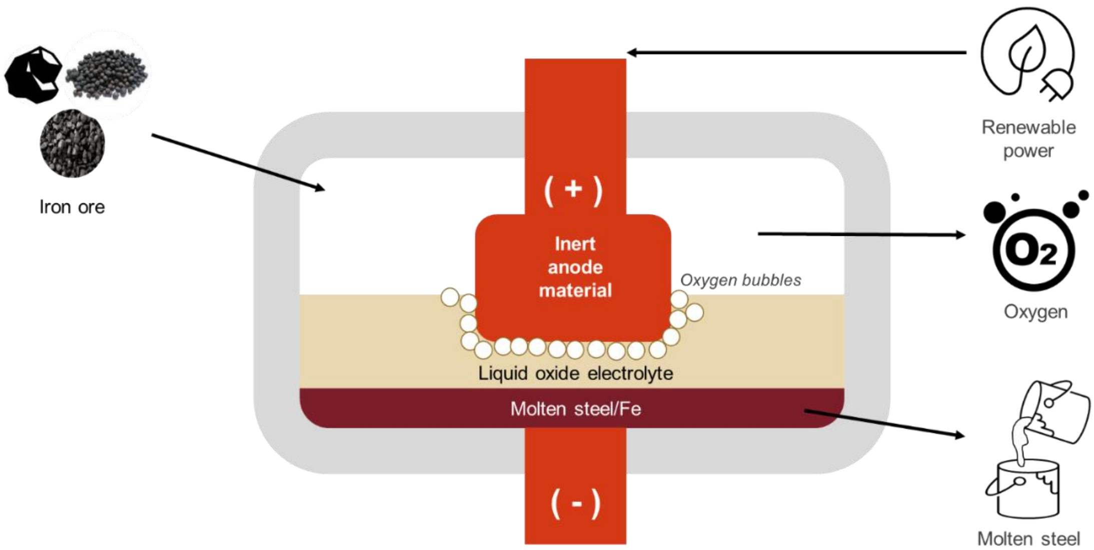
Source: HYBRIT, CRISIL Research

The project was sanctioned in 2017 to reduce emissions in Sweden's steel value chain. Its aim is to manufacture 1.35 MT of green hydrogen reduced iron, which would end up decarbonising ~25% of Sweden's annual steel production. Accordingly, the project has set up four pilot facilities that have already churned out their first consignment of zero-emission steel, which was delivered to the Volvo Group. According to Vattenfall, test results indicate green steel shows superior mechanical and ageing properties than steel produced from fossil fuels. However, these are pilot plants. Industrial-scale production and commercial rollout of green steel from HYBRIT are slated for 2026.

2.4.1.2 Molten Oxide Electrolysis (MOE)

It is an electro-chemical process of steel production developed by Boston Metal[6]. The process involves electrolysis using electric current from renewable sources to reduce iron ore into iron. This is done by inserting an inert anode (graphite for ferro alloys; titanium, iridium or chromium for iron) into an electrolyte with iron ore. The anode is then electrified and at 1,600°C-2,000°C, the bonds in iron ore are split, producing liquid metal that can be sent directly to the ladle furnace without the need for pre-heating. One major advantage of the MOE process is that it works with all grades of ore.

MOE process layout



Source: Boston Metal, CRISIL Research

The MOE process shows promise in terms of not having a threshold of ore quality, and crude steel being produced in a single step. However, one major drawback is its scalability. The process was developed in the late-2000s by material scientists from The Massachusetts Institute of Technology (MIT); however, this was under lab conditions with the reactors being the size of teacups. Scaling this up to commercial production has major hurdles, such as stability of anode material. Another key concern is the cost of production. Since a pilot plant is yet to be commissioned, the actual cost of production is still unknown. Boston Metal is aiming for commercial production of steel using the MOE process by 2026.

Hydrogen-based fine ore reduction (HYFOR)

This is a reduction technology developed by Primetals Technologies[8]. The main objective of the project is to use iron ore fines and concentrates (particle size <0.5mm) and reduce them to produce iron. All current reduction technologies require pellets and lump ore in the feedstock to be able to produce DRI. The HYFOR pilot plant is divided into three sections: the preheating-oxidation unit, gas treatment plant, and 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 direct reduced iron (HDRI) exits the reduction unit at approximately 600°C before being cooled and discharged from the HYFOR pilot plant.

The pilot plant is active in Donawitz, Austria, and is undergoing test runs for handling ~800kg iron ore. This technology can lead to a significant reduction in capex and opex required for preparation of pellet or sinter. The pilot plant is still in the testing phase to determine compatibility with different grades of ore and eventual scalability of the process. Key challenges for emerging technologies

Emerging technologies such as HYFOR hold promise in decarbonising the iron and steel value chain; however, significant challenges and bottlenecks lie ahead.

1. **Production cost** – Economic viability and competitiveness of low carbon emission steel are key concerns for steelmakers as well as end-users. Manufacturing steel via HYBRIT is almost 2x the cost of production through the traditional BF route. Significant cost reductions in the value chain (such as lower cost of hydrogen and cheap renewable energy), along with implementation of measures to penalise traditional routes for being carbon-intensive, would be necessary to spur adoption.
2. **Scalability** – The above-mentioned technologies are in pilot stages, and there are major technical (such as anode material degradation for MOE and hydrogen storage for HYBRIT) and economic issues that will need to be resolved for them to become commercially scalable.
3. **Raw material availability** – The HYBRIT process relies on DRI, which is heavily dependent on high-grade ore. The ready availability of the same is a major bottleneck, as currently accessible high-grade ore reserves globally will not be sufficient to support total transition to DRI-based steelmaking.
4. **Renewable energy** – Low carbon emission steel technologies typically rely on use of renewable power to decarbonise electricity needs (electrifying anode in MOE, electrolysis for green hydrogen production, power required for EAF) as using fossil fuel-based energy for these purposes would mean simply shifting emissions from one place to another. The growing need for reliable renewable power poses a major challenge. Moreover, renewable power is largely localised in India and would require heavy investments in transmission to ensure availability across regions.
5. **End-user demand** – While regions such as the EU are seeing a demand-pull for low carbon emission steel (with carbon taxes in place), the same might not hold true for developing nations such as China and India. The lack of demand for low carbon emission steel in such regions owing to the high-cost differential would deter steelmakers from making large capex decisions towards adopting zero-emission steelmaking.
6. **Hydrogen** – Production of green hydrogen is pivotal to adopting DRI-based carbon-free steelmaking (both HYBRIT and HYFOR). Significant reduction in electrolyser capex, ready availability of cheap renewable energy, and innovation in storage and transport of hydrogen will have to materialise for this route of production to become widely adopted.

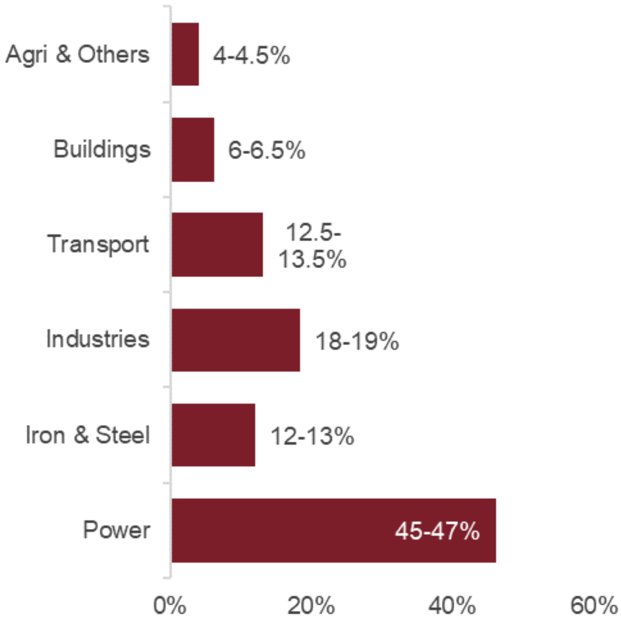
3 India's position and progress towards low-carbon steel

Although India accounts for just 7% of global CO_2 emissions[3], its emission per unit of GDP is higher than that of developed economies. The industrial sector, which accounts for almost a third of India's energy-related emissions, and the power sector are likely to drive India's transition towards a low-carbon economy.

3.1 Need for decarbonisation in the domestic market

Decarbonisation is arguably the most important factor driving major disruption in the iron and steel sector. The iron and steel sector is both energy- and emissions-intensive, accounting for 8% of global final energy use and 7% of global direct energy-related CO_2 emissions. With the power and transport sector seeing progress in decarbonisation, focus has now shifted to heavy industries such as steel and cement.

Distribution of India's energy-related CO_2 emissions



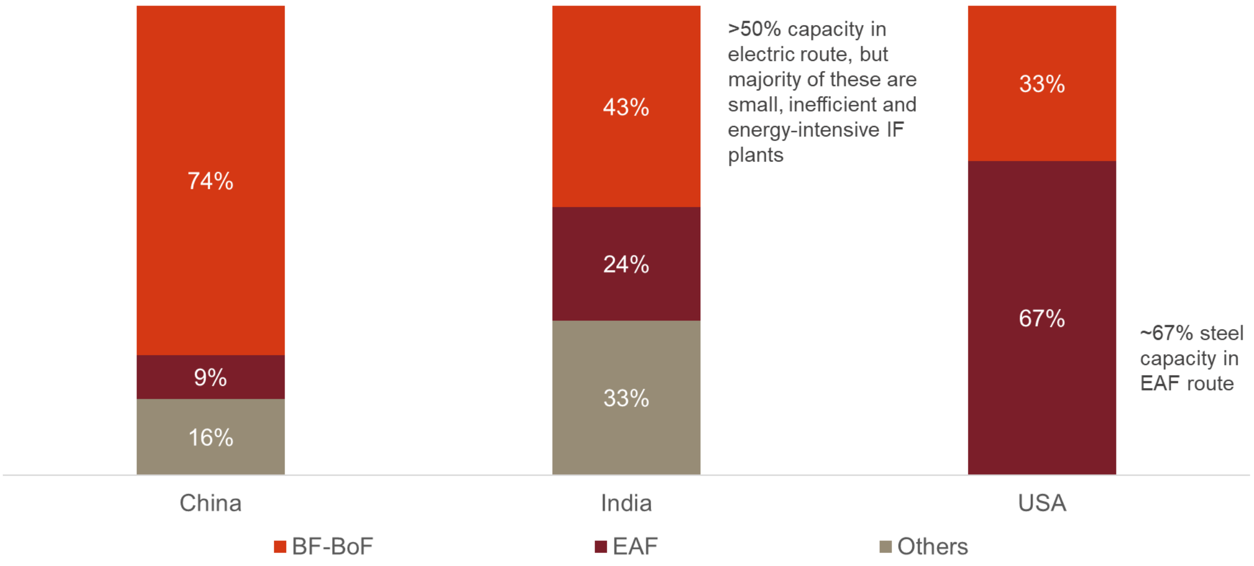
Source: IEA, IEA India Energy Outlook 2021, CRISIL Research
Note: Industries includes cement, aluminium, pharma, etc

The steel industry accounts for ~13% of India's energy-related emissions as per the IEA India Energy Outlook 2021[3] — higher than the global standard of 7-8%, and over a third of total industrial energy-related emissions. Despite improvements in recent years, average emissions at ~2.5 tonne of CO_2/tonne of crude steel as of 2021 remain well above the global benchmarks.

Being the second-largest producer of crude steel and the second-largest emitter of CO_2, India should focus on decarbonising the steel industry quickly to achieve carbon neutrality by 2070.

A large part of emissions come from the iron making value chain (iron ore to sponge iron/hot metal), as domestic steel players rely on fossil fuels such as coal, which increases the industry's carbon footprint. Over the years, abundance of iron ore and thermal coal have driven the addition of such capacities. This has led to higher emissions for India vis-à-vis the leading nations. On the other hand, economies such as the US and Japan have largely shifted to the less-energy-intensive EAF route.

Process-wise split of crude-steel capacity (2021)



Source: Industry, JPC Annual Statistics 2022
Note- Capacity split provided for India is as of March 2022

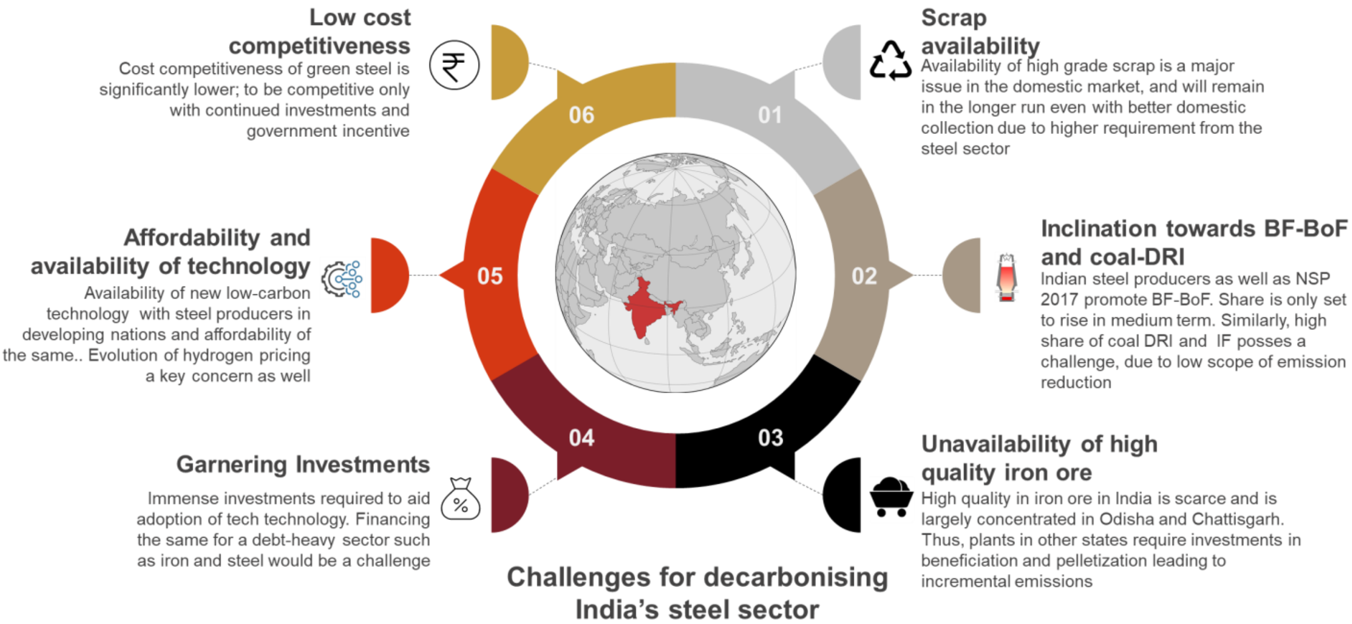
Currently, EAF-EIF is the dominant production method in the Indian steel industry, accounting for ~55% of the total crude steel capacity. However, 77% of these plants use coal-based DRI methods, resulting in higher emissions compared with global players that use natural gas-based DRI. Indian players' preference for coal is largely because of their better availability and lower cost compared with natural gas, for which India is largely dependent on imports and hence is subject to higher price volatility.

Going forward, the dominance of EAF-EIF is likely to change as the share of blast furnace in overall crude steel capacity is expected to increase to over 50% by 2025, from the current 45%. Further, we expect ~75% of total steel plant expansions over the next decade to be BF-BOF-based. Hence, preference for BF technology, which is also clearly visible in the pipeline of committed projects, represents a challenge for the future transition to low-emissions steel in India.

3.2 Decarbonisation challenges for the steel sector

Large-scale investments have been pouring in for decarbonisation of the global steel sector. While India is yet to witnesses a similar frenzy, the need for investment is not the only challenge ahead. Technology and raw material availability to decarbonise the domestic steel sector by 2047 remain major issues to be addressed, even if government incentives and a policy push can help overcome a few obstacles.

Key challenges facing the Indian iron and steel industry



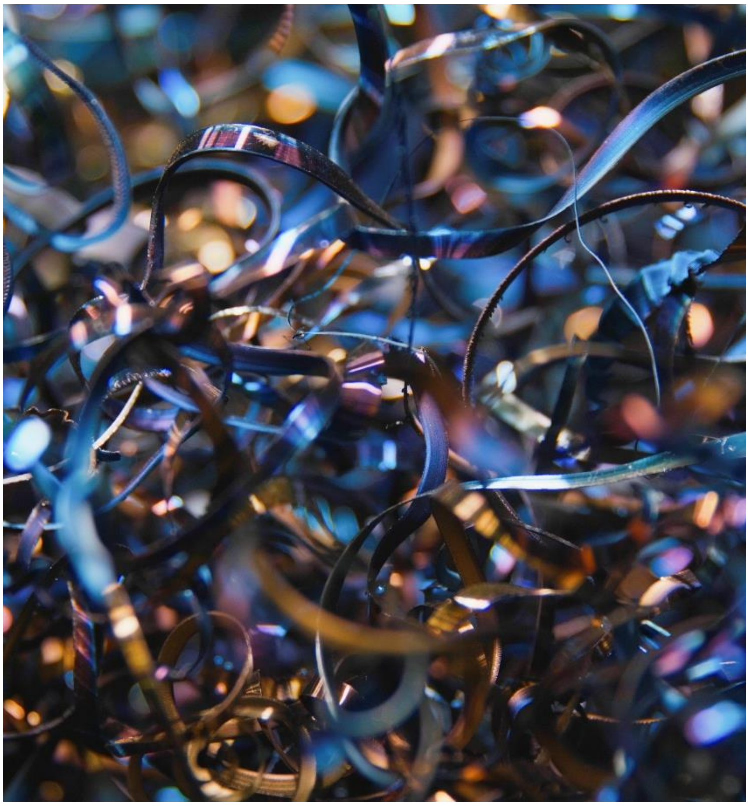
Source: CRISIL Research

3.2.1 Steel scrap availability

Steel scrap usage in the Indian steel industry has always been on the lower side due to the higher share of BF-BOF s as well as lower availability of scrap in the domestic market. The Indian steel industry consumes 17-18 MT of scrap (2021), over a third of which is imported. Even most of the domestic available scrap is largely home/mills generated scrap. End-of-life scrap, which is the largest scrap segment at the global level, remains miniscule in India despite policy support to generate more. In fact, of the total scrap generated in India, only 30-40% is old scrap as per CRISIL Research estimates.

As India aims to turn into a circular economy in the longer run, domestic scrap generation will soar. However, it will still significantly lag the demand generated from the steel industry. Given that the average life cycle of steel in India is over 30 years, steel being used now will turn into scrap 25-30 years later. For context, in fiscal 2022, against a crude steel production of ~120 MT, scrap available would be equivalent to steel usage in, say, fiscal 1992, which was a meagre ~14 MT. Given collection of the same would be even lower, especially for construction scrap, old scrap generation would only be 5-6 MT.

While large steel producers such as Tata Steel are setting up scrap collection and recycling centres, it is unlikely to eliminate dependence on scrap imports due to increasing scrap-blending norms .



Scrap life cycle

Segment	Share in demand (FY20-22)	Average life cycle (years)
Building and construction	35-40%	40-50
Infrastructure	25-30%	20-30
Automotive	8-10%	10-15
Engineering and capital goods	20-25%	10-15

Weighted average life cycle for scrap availability
~30 years

Source: CRISIL Research

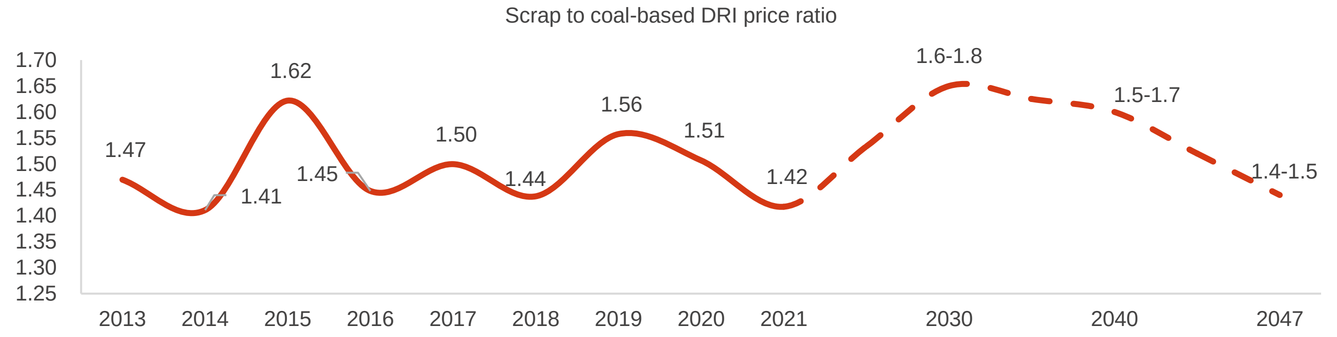
Scrap availability can be addressed through imports from developed nations and improved domestic availability on the back of the revamped vehicle scrappage policy of 2019. However, the issue of pricing differential will play a major role going ahead. Domestic scrap prices are governed by global scrap prices as well as the price of the alternative material – sponge iron.

As the world scales up capacity in the EAF route beyond 2035, and scrap usage surges, the price differential between scrap and sponge iron is only set to widen. India, which is rich in iron ore and coal, will always find it cheaper to use coal-based sponge iron instead of scrap, even with a mandatory carbon market on emissions.

Scrap usage has increased significantly over the past five years driven by China even as steel production has seen only a moderate growth on the back of higher blending of scrap to limit emissions. Against a total crude steel production of 1,631 MT in 2016, scrap usage was ~380 MT as per CRISIL Research estimates, indicating a blending of 22-24%. Since then, while crude steel production has gone up to ~1,951 MT in 2021, scrap consumption has risen to upwards of 500 MT, indicating a blending norm of 26-27%.

With the blending norm only set to rise, scrap will start trading at an incremental premium vis-à-vis its high carbon alternatives of sponge iron or pig iron, till green-hydrogen-based DRI (direct reduced iron) becomes cost effective. The average price differential between domestic scrap and coal-based DRI in India has been in the range of 40-50%, with 2022 being an aberration. In the transition phase, when steel producers would have to meet strict targets of bringing emissions lower, the price differential is set to rise to upwards of 60%, before moderating in the longer run with higher availability of scrap.

Price differential between scrap and coal-based DRI set to rise in near term



Source: CRISIL Research

India's steel capacity mix

BF-BOF plants dominate the Indian landscape, accounting for ~43% of capacity and 45% of production. The twin challenges here are to limit capacity additions in the BF-BOF and coal-DRI and ensure the gradual decommissioning of IF and coal-based DRI plants. Further, addition of CCUS for existing plants is also a challenge. The average emission of a BF-BOF as well as coal-DRI-EAF plant is almost double that of the NG-DRI-EAF route. Thus, both the routes must be discontinued in the longer run to ensure Net Zero is achieved by the steel sector. Moreover, the government of India, through the National Steel Policy 2017[14], is promoting the addition of BF-BoF capacity and would want the share of BF-BoF in overall capacity to rise from 43% as of March 2022 to 60-65% by 2030.

Another key issue is the low average capacity age in India. Over one-third of India's total capacity base has been added over the last 15 years, including a net addition of ~40 MTPA in the IF and EAF. Thus, the average age of the steel capacity in India is quite low at 17-20 years, as compared with the developed economies where capacities are quite matured. With useful life of most of these capacities extending well beyond 2050, achieving Net Zero in domestic steel industry is unlikely before 2060s.

Existing capacity mix to prevent rapid decarbonisation

Recently added capacities to continue beyond 2060
BF-BOF accounts for ~44% of the 65 million tonne added in the past decade; will last till 2060 along with investments in relining the furnaces
Coking coal availability to improve for Indian mills
Falling global demand and improved domestic supply of coking coal along with new washeries to draw more players towards the cost-effective BF-BOF route
Dealing with smaller DRI-IF capacities a challenge
Small IF and coal-DRI-EAF cannot invest in large-scale decarb measures; gradual decommissioning of the same with incentives to shift to newer tech needed

Source: CRISIL Research

Unavailability of high-quality iron ore

India currently has 33 BT (billion tonne) of iron ore reserves, 16 BT of which are accessible[10]. Even with that, the total identified reserves actively producing ore stand at only 9 BT. Moreover, iron ore grade and quality differ across states, with Chhattisgarh having the best quality ore at >65% Fe grade with lower impurities. Odisha (62-65% Fe) and Jharkhand (62-65% Fe) rank next, while Karnataka (60-62% Fe) and Goa (<58% Fe) typically have lower-grade ore. This disparity raises logistical costs for steelmakers in India having plants in the west and south region.

Moreover, capacities coming up in the west and south have to invest in beneficiation and pelletisation. This not only adds to opex and capex but also causes higher emissions as well.

While investment in research and development is being done at a global level to ensure direct usage of low-grade ores without further processing, scaling up of the same to a commercial level will be a time-consuming process.

Investments

The iron and steel industry is a highly capital-intensive sector. The decarbonisation challenge calls for incremental investments without adding to cash flows in the near term, thus burdening the already over-burdened sector. Any major downcycle as witnessed over 2009 and 2016 could lead to a surge in the sector's non-performing assets. While the sector is better placed than in previous cycles, as witnessed during the pandemic, heavy investments in decarbonisation technologies such as CCUs, hydrogen-based DRI, and renewable power will limit the ability to withstand such shocks.

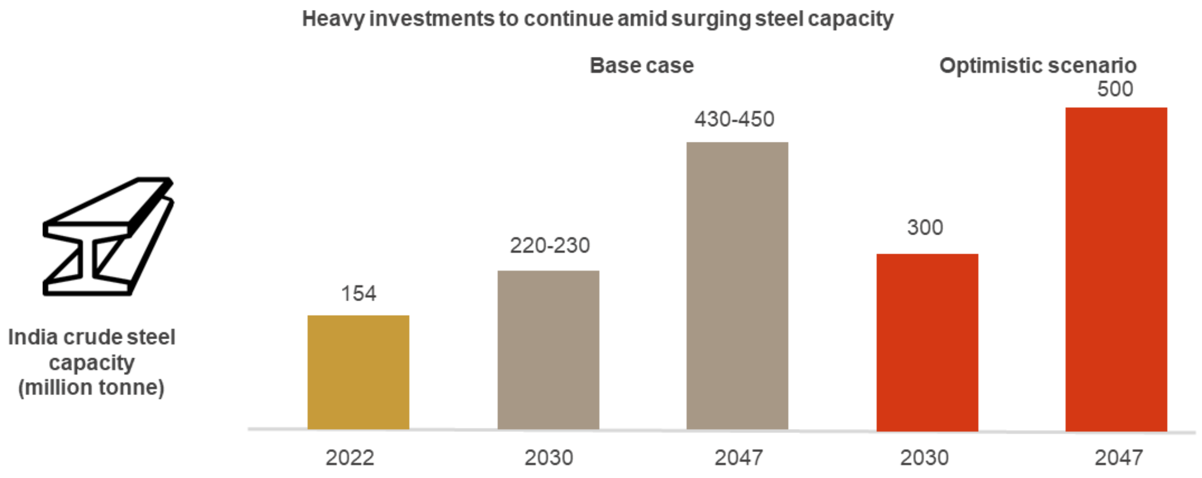
Though extremely relevant in the current situation, the decarbonisation theme is likely to take a backseat as the industry must invest to scale up to meet the surging demand. The domestic industry operates at a healthy utilisation level of 78-80% (fiscals 2021 to 2023P average) and would thus require additional capacity to meet domestic demand. Players large and small are investing heavily to ensure that any incremental demand is met through domestic producers only, in line with the National Steel Policy.

Though the Indian steel industry is likely to fall short of the '300 MTPA capacity by 2030' target set by the National Steel Policy, 2017, it would still need an additional 70-80 MTPA of capacity addition over the next eight years just to meet domestic demand.

Removal of current exports duty in the longer run would only warrant more capacity addition.

In such a scenario, iron and steel producers in India would have to invest a whopping ~Rs 5 trillion over this period to achieve enough capacity to meet surging domestic demand. Any incremental capacity requirement to meet exports would imply more capex.

Surge in capacity additions seen on the back of heavy investments



Source: National Steel Policy 2017, Ministry of Steel (Transition towards 2030 and Vision 2047), CRISIL Research

Amid such a scenario, investing heavily in decarbonisation would be limited to the large integrated players with strong balance sheets. JSW Steel and SAIL have earmarked Rs 10,000 crore and Rs 5,000 crore, respectively, to battle environmental pollution. Similarly, TATA Steel and AM/NS (Arcelor Mittal Nippon Steel) have set near-term targets to reduce emissions. However, green capex would account for less than 10% of the industry capex in near term.

That may eventually rise beyond 2035 once the technology has stabilised and production costs significantly reduce over the years. But a thrust to green capex or new technologies, requires policy incentives as well as regulations.

The Reserve Bank of India (RBI) has already taken active steps to address the issue. In its discussion paper 'Climate Risk and Sustainable Finance' dated July 2022, the RBI has highlighted the various types of risks arising because of climate change and how it threatens the entire banking system. Though the discussion paper does not mandate any norms for lending or indicate any policy stance, it presents the challenges in building a resilient financial system that will acknowledge and address climate risks for the entire economy.

One of the key highlights of the paper, discussed in this document as well, is the onus of decarbonisation that the RBI puts on individual entities. The paper highlights good practices for lending for all regulated entities that would form the backbone of future rules and regulations of lending.

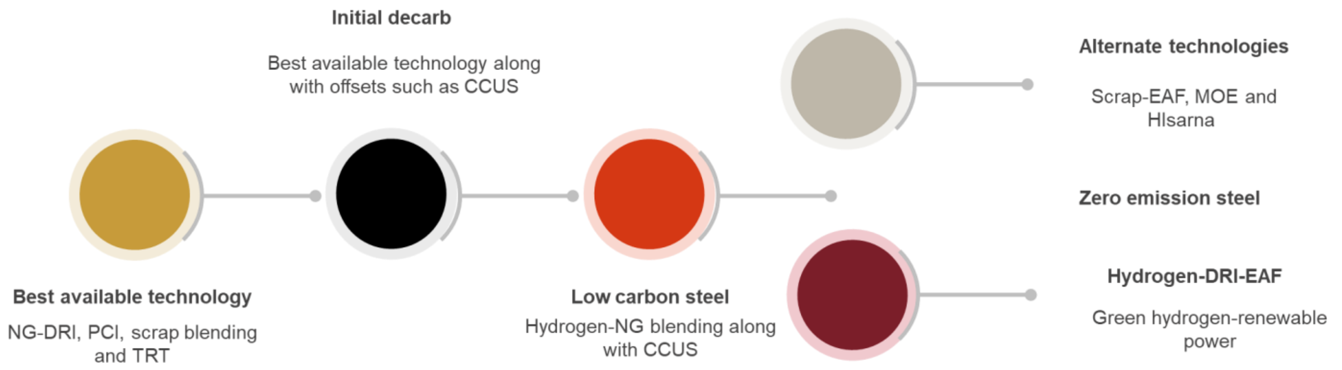
With both the central government and RBI taking cognizance of the issues of climate risk, new lending guidelines are likely to be released soon which will aid corporates looking to undertake capex in greener technologies.

Technology

Traditionally, steel has been seen as a 'hard to abate' sector when it comes to global emissions. Hence, heavy investments are being made to innovate a technology that would not only reduce but totally eliminate emissions from the sector.

The total emission in the steel-making process can be classified as: i) emissions from fuel consumption during the iron-making process (coking coal, PCI coal, coal or natural gas); and ii) power consumed in furnaces (EAF or IF). While shifting to renewable energy is relatively easy, replacing carbon-based fuel in the manufacturing process through hydrogen or any other reductant is a huge task. However, the good news is majority of the investments are towards scaling up the green hydrogen-based DRI route, though it will take a considerable amount of time until a scalable and cost-effective method of steel production is brought into the system. In the medium-term, investments are also being made in other technologies such as HIsarna, which produces hotel metal from coal directly and has the potential to reduce overall emissions in the iron-making process by 20-25%. Similarly, technologies such as scrap-EAF, molten oxide electrolysis (MOE), and rotary kiln are also being looked at.

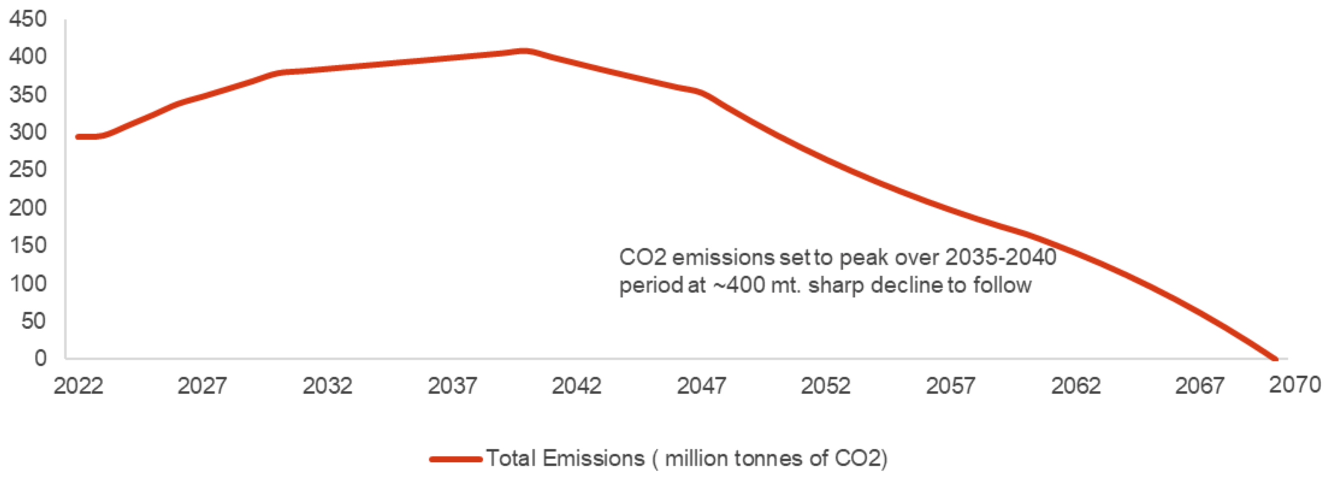
Evolution of green technology for the sector will be a long-drawn process



While steel players adopt newer technologies gradually, overall emissions from India's iron and steel sector are set to rise in line with rising production. Even as emission intensity might see a sharp decline in the transition phase, overall emissions are estimated to rise upwards of 400 MT of CO2. However, adoption of newer technologies for steel production along with policy-driven capex is expected to limit emissions and drive them lower post 2040.

If policies are implemented on time and players undertake the necessary investment to cut emissions supported by , total emissions from the industry could peak between 2035-2040 in the base case scenario (total capacity reaching 430-450 MT by 2047). To be sure, there are upside risks to this estimate arising from technological uncertainty, while successful scaling up could drive down overall emissions for the sector at a significantly faster pace.

Overall carbon emissions from the steel sector set to peak in late 2030s (base case)



Source: CRISIL Research estimates

Cost-competitiveness

The major challenge in producing low carbon emission steel is its lower cost competitiveness vis-à-vis producing steel through other routes. Without a mandatory carbon market or incentive in place, the cost of production of traditional routes such as BF-BOF as against the hydrogen-DRI-EAF route will be significantly lower, even in 2047.

The challenges do not end there. Indian steel mills have been under the weather for a major part of the past decade due to intense global competition. It was only after the finance ministry implemented an anti-dumping duty in 2016 that the industry got a much-needed breather. Large steel players backed by the new duty lapped up assets available at significant haircuts, such as Essar Steel, Bhushan Steel, Bhushan Steel and Power, Uttam Galva, and Usha Martin to name a few. While consolidation of industry has helped improve cost structures, the industry is still not out of the woods.

Elevated global supply, stiff competition in exports market, high borrowing costs, and import dependence for key inputs such as coking coal, natural gas and scrap are still major causes of concern. Low return on capital employed and uncertainty on technological evolution will only deter large-scale investments in the near term.

On the plus side, other industries have started investing heavily in green hydrogen and are likely to witness easing cost of production in the long run. How cost-effective the hydrogen-DRI-EAF route becomes vis-à-vis the BF-BOF route will not only depend on the global evolution of the electrolyser technology but the source of energy in India as well.

Global research and development in the green hydrogen space is likely to bring down the cost of production of hydrogen, which is the only route known to increase the competitiveness of low carbon emission steel. While the production cost of steel through the hydrogen route will decline sharply in the longer run as electrolyser and renewable power costs come down, correction is expected in other routes as well. A shift away from BF-BOF at a global level will reduce the demand for coking coal; however, prices are unlikely to see sharp decline as supply is set to see a drastic decline as well.

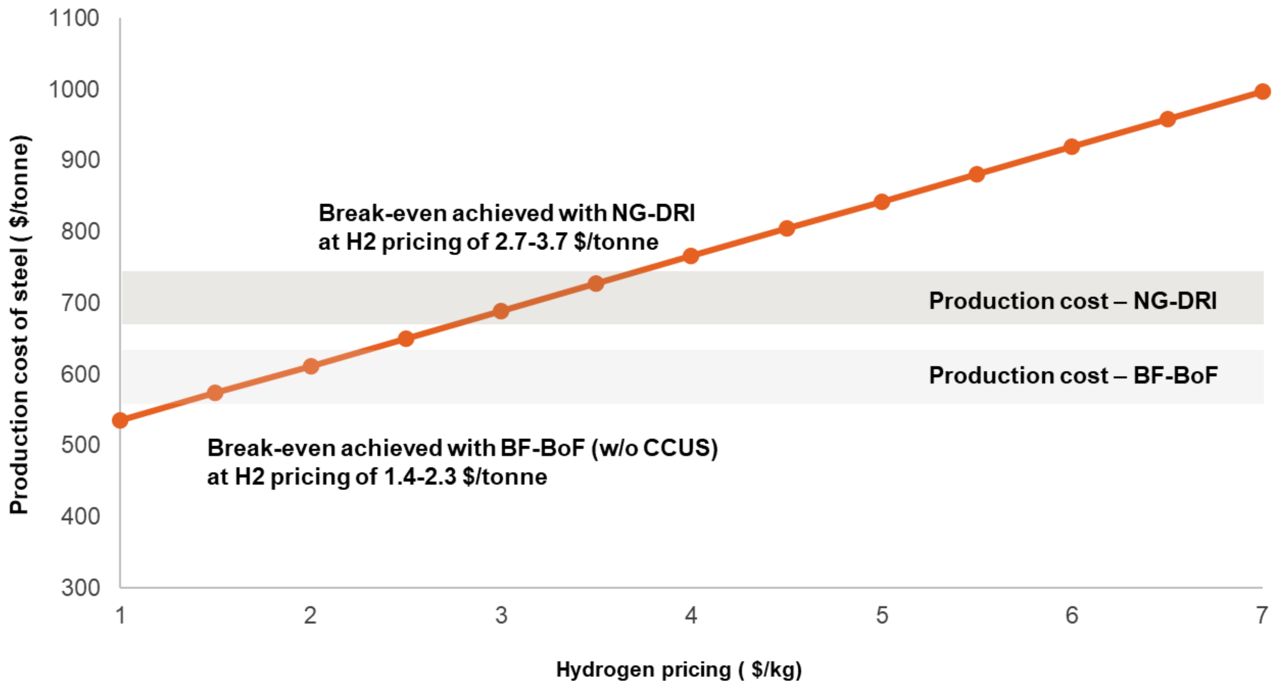
On the other hand, if India is able to scale up domestic production of steel-grade coking coal (ash content <18%), the requirement for expensive imported coking coal will reduce further. While the scalability of the same is in question given the poor availability of steel-grade coking coal in India, recent events point towards investments in washeries as well as focus on increased mining of coking coal in Jharkhand.

Currently, domestic coking coal meets only 7-8% of the total coking coal requirement. However, given that it is at over 70% discount to the landed cost of imports (average for fiscal 2022), any uptick in its availability will drive down production cost for BF-BOF significantly. With 35 billion tonne of coking coal reserves in the country and unlikely to be used beyond 2060, we expect a pickup in supply of steel grade coking coal in the domestic market.

Despite these measures, India will be largely reliant on Australian coking coal which accounts for over 70% of India's coking coal imports. While the dependence has reduced over the years and is set to reduce further; it will remain a key supplier of coking coal for Indian steel mills. Slowdown in global coking coal demand and low coking coal prices in 2020 as well as fall in exports to China has led to fall in mining investments in Australia keeping coking coal prices elevated.

The situation is unlikely to change in the longer run, with Australia's other export destinations Japan and South Korea, accounting for ~35% of Australia's total exports in 2021, likely to shift away from coking coal well ahead of India. Thus, coking coal prices are unlikely to see a sharp correction in the medium term and likely to average $200-250 per tonne over 2030-2047 (transition phase and early deep decarbonisation phase).

Hydrogen-DRI EAF to remain uncompetitive vis-à-vis BF-BOF route, policy support needed to bridge gap



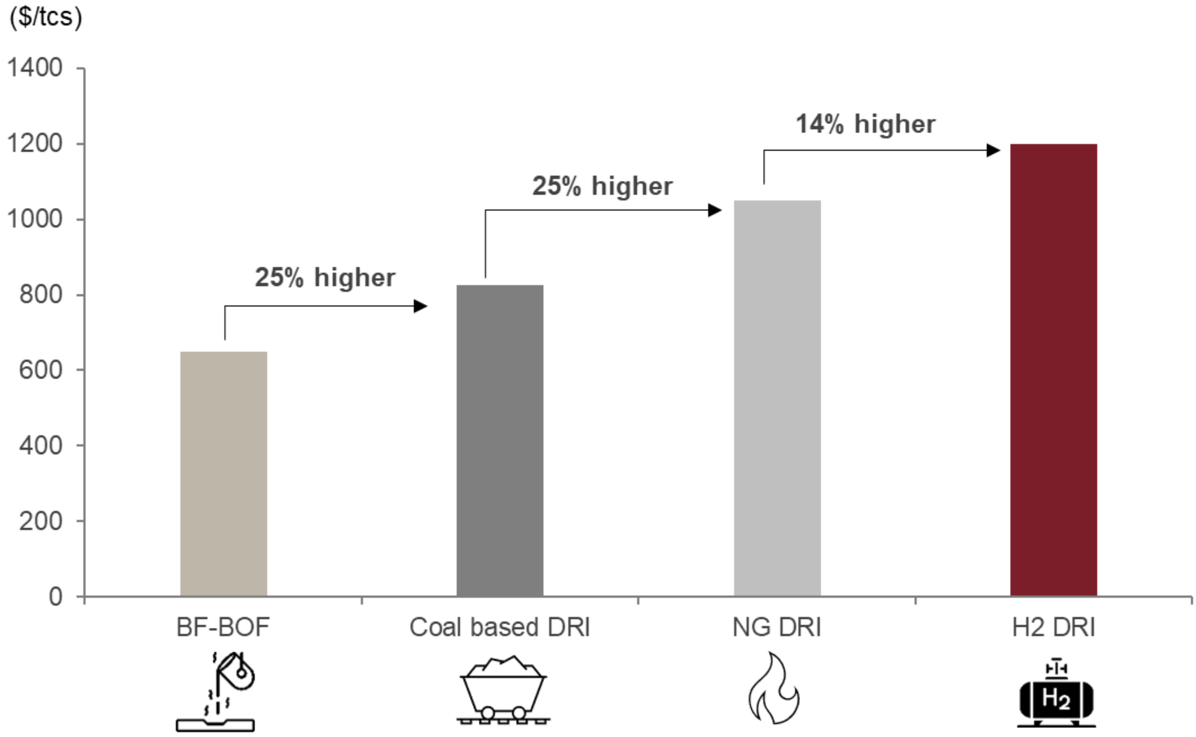
Source: CRISIL Research Estimates

3.3 Challenges in generation of demand for Low Carbon Emission steel

Key challenges in generation of demand for Low Carbon Emission Steel

- **Price differential with other methods**: Currently, the hydrogen-based DRI method is considered entirely emission-free, at least in theory. However, the cost of production per tonne of crude steel (COP) is $1100-1200, which is nearly two times than the BF-BOF method. In fact, NG-DRI and coal-DRI are nearly 50% and 20%, respectively, more expensive than BF-BOF . Hence, Indian players prefer coal-based production methods to remain competitive in global markets given that nearly 15% of the production is exported
- **Lack of incentives to use Low Carbon Emission Steel:** Introduction of new carbon reduction processes, along with heavy investments, will lead to a rise in steel prices, which steel producers must pass on to end users to ensure long-term sustainability. Moreover, low carbon emission steel prices will remain uncompetitive vis-à-vis steel produced through traditional routes without any tax support from the government. Hence, consumers of steel must be willing to pay a higher price for steel in the medium term to support the decarbonisation goals of steel producers as well the economy. But this is still a far-fetched idea since there is currently no incentive for end-consumers to opt for higher-priced low carbon emission steel

Hydrogen-based DRI is ~2x more expensive than BF-BOF-based steel (2021)



Note: Units are $ per tonne of crude steel ($/tcs)
Source: Industry, Crisil research estimates

Given these challenges, the Indian steel industry is taking a cautious approach towards low carbon emission steel. In the near term, steel producers will invest in best available technologies (BAT) to reduce emissions with an eye on the cost of production. In the longer run, investments towards decarbonisation will rise based on the offtake of low carbon emission steel.

Demand offtake for low-carbon-emission steel will need an external governmental push until cost parity is achieved with conventional steel. The pace of transition to low-carbon steel will vary from player to player, which will result in an advantage for steel players opting to delay the transition process. Policy support here would ensure proactive steel players willing to invest in low-carbon emission-steel production are not penalised.

Institutional customers in the automotive, capital goods or construction space have their own ESG targets and can potentially drive low carbon emission steel demand in India. Some other institutional customers can be coaxed through taxes or incentives to increase their offtake of low carbon emission steel. However, steel producers will find it difficult to make inroads among retail customers, especially in the building and construction segment. Without policy intervention, this market will remain largely out of reach for low carbon emission steel producers until the production costs even out.

Also, from the industry side, companies can explore low carbon emission steel adoption on a pilot basis in the form of collaborations on the lines of global counterparts. One such venture is the collaboration between Sweden-based steel producer SSAB and automotive giant Volvo.

Case study: Volvo group-SSAB collaborate on the world's first fossil-free steel

Volvo Group and SSAB signed a collaboration agreement on research, development, serial production, and commercialisation of the world's first vehicles to be made of fossil-free steel. In line with this, in August 2021, SSAB supplied automotive group Volvo with what is claimed as the world's first fossil-free steel, produced from iron reduced using

100% hydrogen instead of coal and coke in the process.

This steel was used in the production of arguably the first vehicle made of low carbon emission steel, a load carrier used in mining and quarrying.

This sort of collaboration with end-users will ensure certainty in demand for steel players, incentivising them to further invest, research and develop low carbon emission steel products. In turn, this would lower the cost of production as players gain expertise in new production processes

Emission reduction capex/initiatives by industry players

JSW Steel	Plans to spend ~$1.3billion on cutting emissions by 2030
adani posco	**$5 billion** green steel investment in Gujarat
JINDAL STEEL & POWER	Announced two more coal gasification units to produce syngas
AM/NS INDIA	**$6-7 billion** renewable energy investment
TATA STEEL	Achieving CO2 emission intensity of < 1.8 tCO_2 /tcs 2030 for Tata Steel India
सेल SAIL	Target intensity of 2.3 tCO_2 /tcs from current 2.55 tCO_2 /tcs

Source: Company filings , Crisil Research

4 Policy support

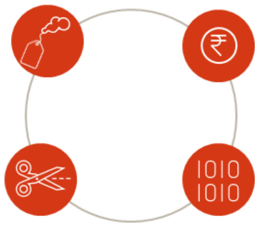
While the shift towards low carbon emission steel is largely being driven by the private sector across the globe, the transition cannot be achieved without government support, especially in the case of emerging economies such as India. In the medium term, to facilitate investments in low carbon emission steel capacities, the Indian government needs to introduce the following policies:

Introducing carbon markets

While green steel will eventually become competitive to ensure faster transition and to disincentivise new capacities in BF-BoF or Coal-DRI route, mandatory carbon markets must be set up to bridge the gap further

Tax breaks for green steel producers

Mandatory carbon markets can help bring parity between green steel and traditional steel producers. But in the early stage, when the cost differential is higher, tax breaks in the form of lower corporate tax and lower GST rate will aid green steel producers. This can be done away with in the longer run.



Facilitating financing of green projects

A shift to green steel will not be easy and will require substantial capital. However, the domestic iron and steel industry remains highly leveraged despite severe deleveraging over 2020-22. Thus, adhering to Net Zero targets and shifting to green steel will need easier availability of capital at a lower cost – else it will be a major deterrent for green transition

Enhancing technological prowess

Policy support will be needed to make the domestic sector future ready in terms of technology. Setting up of an agency under the Ministry of Steel to understand and explore new technologies can help faster adoption. Collaboration with developed economies for technology transfer under UNFCCC mechanism will also be needed

1. Introduction of mandatory carbon markets

The key deterrent in low carbon emission steel production is the low cost competitiveness of the product. Despite heavy investments in green hydrogen, its production cost is unlikely to fall steeply in the near term, necessitating a mandatory carbon market.

The cost of production of low carbon emission steel and steel through the BF-BOF route varies from $200-400 per tonne in the early stages, depending on the price of green hydrogen and coking coal, with most other factors remaining stable. Fall in demand of coking coal globally, along with a pickup in domestic supply, will expand the cost differential.

The Government of India can support low carbon emission steel producers with a mandatory carbon market that will be regulated by the government. Industries can buy or sell units of carbon from the market.

Carbon purchase and sell price can be set based on the nature and emission intensity of the industry. While the price of carbon would largely depend on the availability of breakthrough technology at a competitive capex as well as opex, steel players can invest in the best available technology till then to ensure that overall emissions continue to decline.

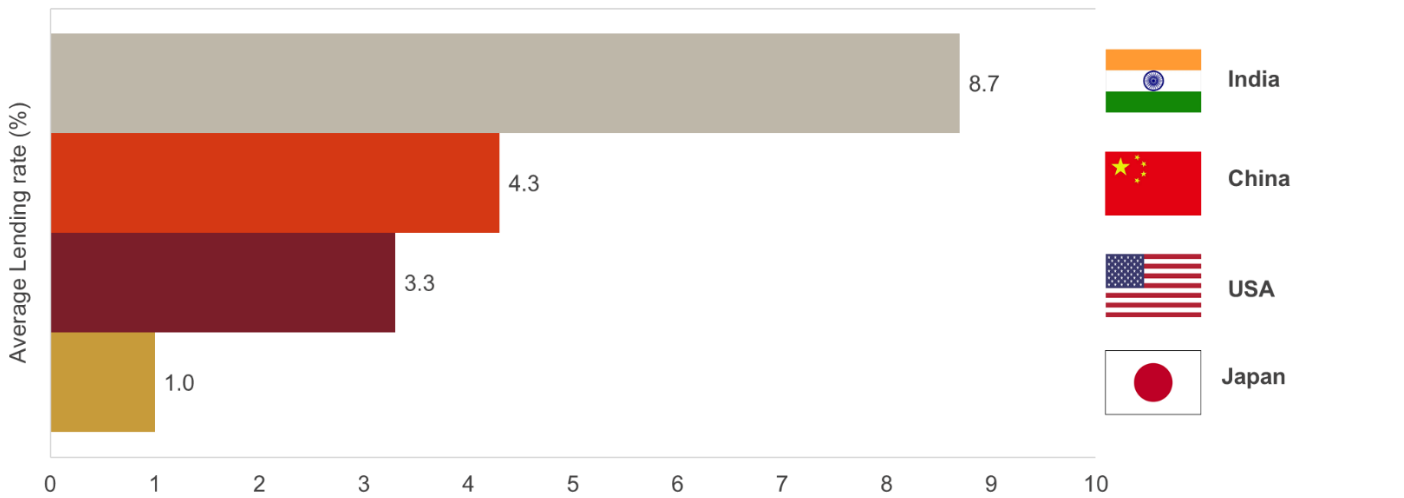
2. Facilitate financing of green projects

The iron and steel sector is one of the most capital-intensive sectors in the country and has seen investments upwards of Rs 3 trillion over the past five years. Investments are only set to rise, given the rising demand and elevated utilisation levels in the sector. While a majority of capex would be towards augmenting capacity in the near term given healthy demand expectations, green capex of Rs 200-250 billion is also expected over the next 5-7 years. Although low carbon emission steel capacity is unlikely to substantially add to the sector's operating profitability, it is necessary for the industry's long-term sustenance.

The sector has seen a significant fall in outstanding debt levels over the past few years due to haircuts taken for assets under the National Company Law Tribunal (NCLT), along with deleveraging over fiscals 2021 and 2022 amid a surge in profitability. However, the trend is unlikely to continue. A sharp fall in profitability amid higher input costs and steady capacity additions will lead to debt levels staying elevated for the industry. Thus, investments in low carbon emission steel would require external debt at a cost the players can sustain.

India's overall borrowing cost was 400-700 basis points (bps) higher on average vis-à-vis other developed economies. If India wants to continue its fight against emissions, the borrowing rate for green capex must decline. The Reserve Bank of India has a policy on primary sector lending (PSL) to ensure fund availability for needy sectors such as agriculture and microfinance. A similar policy push is required to ensure green capex across sectors is supported through low-cost debt. A CRISIL Research analysis of 40 large corporates that announced green capex, showcases that these companies are likely to spend Rs 1.4 trillion on green capex over the next six years (fiscals 2023-28) against a total of Rs 1.6 trillion over the past five (fiscals 2017-21), highlighting the rise in green capex.

Average lending rates (2021)



Source: World Bank, CRISIL Research

3. Tax benefits for low carbon emission steel producers

The Indian government has made provisions for providing tax breaks to corporates to increase domestic manufacturing capability, such as providing tax cuts to exports-based units, offering tax benefits to new production facilities and providing incentives under various schemes such as the production-linked incentive (PLI) scheme and the Merchandise Exports from India scheme (MEIS).

To facilitate low carbon emission steel production, the government needs to provide some tax breaks to steel producers as well. While carbon markets would bring parity between the cost of low carbon emission steel and traditional steel, tax breaks would ensure sustainable profitability for the sector, driving more investments and an earlier break-even for producers investing in low carbon emission steel.

As seen in the case of the hydrogen policy, the Indian government wants the country to be an export powerhouse of green products in the future. The National Steel Policy 2017 (NSP 2017) aims at achieving steel exports of ~25 million tonne by 2030. With Europe and North America – India's key export destinations – most likely to introduce some sort of carbon border tax to curb imports of high-carbon products, Indian steel producers must gradually shift to greener steel to ensure continued exports to these geographies. Hence, better taxation norms for exports of low carbon emission steel will help Indian steel producers achieve the goal set out in NSP 2017.

4. Push for developing technological prowess

Though the aforementioned polices would ensure that green or low carbon steel production picks up in India and becomes cost competitive, more government support is needed for the domestic steel industry to be future ready. Domestic technological prowess to produce low carbon emission steel can be achieved through two government-backed initiatives.

First, research and development in breakthrough technologies in steelmaking should be furthered. Forming of agencies under the Ministry of Steel in collaboration with steel manufacturers as well as global technology producers would ensure early adoption of breakthrough technologies.

Second, the Government of India must push for technology transfer under the United Nations Framework Convention on Climate Change (UNFCCC) mechanism for all hard-to-abate sectors, especially steel and cement. The government should begin dialogues with developed countries that are leading the decarbonisation race to ensure domestic producers have access to the relevant technologies, which can be transferred under Article 4 of UNFCCC. Indian steel mills will benefit from early access to breakthrough technologies, and domestic steel producers will be able to gradually adopt emerging technologies on lower capex.

5 India's pathway towards low carbon emission steel

The progress towards low carbon emission steel will be staggered in the near term before rapid development is witnessed. Indian steel players, unlike its global counterparts, cannot invest heavily in newer technology before the same is established given the price sensitive nature of Indian consumers as well as high cost of borrowing, which will put immense pressure on producers during the downcycle.

The steel producers in consultation with the Ministry of Steel as well as the Ministry of Environment, Forest and Climate Change should set realistic goals. The domestic steel producers as well as the government are aware of the challenges in the near term, and overall emissions from the sector are expected to go up significantly before they come down.

Keeping that in mind, short-term, medium-term and long-term goals must be set by the policy makers in association with steel producers. Indian steel producers are already on the backfoot due to unavailability of natural gas in the domestic market for steel production, leading to capacity addition in the more polluting space. Hence, a sudden change will bring down steel supply as well as competitiveness of domestic steel producers. Hence, gradual progress in line with the 2070 Net Zero target has to be made without any deviation.

Pathway

Development stage 2022-2030

Focus on recycling and adoption of best available technology

While the world emerges from the Covid-19 pandemic amid an inflation-led slowdown post the Russia-Ukraine war, steel producers across the globe face headwinds from falling demand amid elevated production costs. Meanwhile, Indian producers also face challenges due to diminishing exports led by imposition of export duty. The recovery that the steel industry witnessed following the pandemic, both in terms of volumes and realisation, was wiped out within a quarter of the starting of the war. Hence, huge investment commitments in yet to be proven technology are unlikely amid demand uncertainty. However, steel producers and the government alike cannot wait for less polluting technology to evolve as evident from the recently released "Vision Document 2047" for the Indian steel industry, where emphasis was placed on reducing emission intensity by more than 30% from current levels by 2030.

Government support: The first step towards achieving low carbon/ green steel is by setting standards and benchmarks that steel producers would look to achieve. In the development phase, the objective would be to reduce average emission from the industry by up to 20% from current levels.

Initially, the government policy can ensure that players achieve its near-term objective. The easiest way to reduce emissions would be to increase scrap blending which reduces iron production, the highest carbon emitting stage. Since India is a net importer of scrap, the focus should be on improving domestic availability.

As highlighted earlier, the average life of scrap is over 30 years; however, the scrap generated from auto and consumer appliances and durables industry is less. Better implementation of vehicle scrappage laws would be the key focus. Removing old vehicles off the road would not only ensure higher scrap availability but also reduce emission intensity from the transport segment. The government must facilitate strict adherence of its vehicle scrappage policy, especially in smaller towns and villages, where older vehicles continue to ply.

While the scrappage policy and benchmarks for low carbon steel will indirectly nudge steel producers towards reducing emissions, the players need financial incentives to set up new green steel / low carbon steel capacities. Incentives can be provided under the PLI scheme for new low carbon steel facilities. The gestation period for a steel plant is 3-5 years, and such an incentive would be applicable for facilities coming up only at the end of the decade, but that would set the tone for the next phase.

Further, the government should provide policy support for promoting research and development in breakthrough technologies in steelmaking. Forming of agencies under the Ministry of Steel in collaboration with steel manufacturers as well as global technology producers would ensure early adoption of breakthrough technologies.

Steel producers: Indian steel producers are already on the right track to meet their near-term targets. Most players have set near-term targets to reduce emissions and are undertaking investments to achieve them. Increasing the share of scrap blending is not only the easiest way to reduce carbon emissions, but also the most cost-effective way as well. Further, one of the major benefits of higher scrap blending is reduced material handling; hence, logistic costs and Scope 3 emissions would decline as well.

Larger players such as Tata Steel and JSW Steel have already announced measures to increase scrap usage. In fact, Tata Steel have set up a large scale scrap collection and processing centre in Rohtak, Haryana. Group company Tata Motors has set up a vehicle scrapping plant in Pune and also signed an MoU to set up a similar plant in Ahmedabad, Gujarat. Similarly, JSW Steel has set up a joint venture with National Steel Holdings Limited (NSHL) of New Zealand to set up scrap shredding facilities in India.

Further, players have to start investing in other best available technologies such as SR-BOF , CCUS, etc. to ensure incremental emissions from newer facilities are way lower than the benchmark. Continued investments in research and development are also needed to ensure that newer technologies are scaled up faster.

Transition phase

Setting up plants with newer tech; lower competitiveness of low carbon emission steel to be countered through government policies

The transition phase would be the key period for the Indian steel industry to achieve Net Zero. While steel players would wait for evolution and scaling up of newer technologies such as Hybrit in the development phase, players must start investing in the newer low carbon tech over the transition phase.

Government support would also be required in this phase in the form of mandatory carbon market as well as easing of financing regulations.

Government support: The government should ease funding norms as investments required for decarbonisation will be way higher than regular capex of the steel industry. Further, low carbon emission steel as well as green hydrogen could be brought under “primary sector lending”.

Moreover, to ensure investments in newer technologies remain competitive against traditional BF-BOF and coal-DRI-EAF routes, carbon markets must be implemented as well. Also, to limit new additions in the IF or coal-DRI-EAF space, capacity swap programmes must be introduced where new capacity via the aforementioned routes can be added by discontinuing capacities operating under emission-intensive routes. This will limit the extent of emissions from all new capacities.

Steel producers: The journey to reduce emissions further can be achieved by ensuring all new capacities are in the low-carbon technology and limiting emissions from already installed capacity. For the existing capacity base, players must invest in CCUS wherever possible, although the potential of CCUS in India remains low. Further, all power requirements should be met through renewable sources only. Since the rolling and casting stage accounts for 20-40% of the total carbon emissions for steel producers, shifting to 100% renewable energy would help bring down the emissions.

As hydrogen-based DRI becomes scalable and cost competitive, most new additions would be in that space, however, for existing plants in NG-DRI routes, hydrogen blending must also be incorporated to bring down overall emissions.

As these initiatives by both the government as well as steel producers would increase production costs, the interests of end users should be factored in as well. Tie-ups with large corporates, especially in the B2B segment such as auto, capital goods and consumer durables and appliances to ensure offtake for low carbon emission steel would support a gradual shift to newer technologies.

Comprehensive decarbonisation phase

Accelerating the shift towards low carbon emission steel through capacity closures, green energy, and new tech adoption

Beyond 2040, the pathway towards low carbon emission steel would be relatively easier with most technologies already being scaled up across the globe. Also, demand growth moderation in the domestic market, along with higher availability of steel scrap, would reduce the need for huge capital investments, even as investments will be made to replace old and more polluting capacities.

Government support: It will also be needed in the comprehensive decarbonisation phase as India marches towards the 100th year of independence. Renewable energy would be scaled up significantly by then and its usage should be mandated across all industries, including steel.

The shift to newer low carbon tech would lead to a higher cost of production, making India prone to imports from markets such as China. Hence, an import duty or an anti-dumping duty must be in place to restrict imports of low carbon emission steel, along with a total ban on imports of non-green steel. Further, to ensure higher cost competitiveness of domestic steel producers, tax incentives (lower GST rates and corporate taxes) should also be provided.

These steps would induce offtake of low carbon emission steel by making it more cost competitive. However, the government must mandate the closure of old facilities where emissions are way above the benchmark to meet net-zero targets through radical decarbonisation. Incentives must be provided to ensure that smaller players currently operating old facilities do not go under and there is no sudden shortage of capacity.

Steel producers: The shift to newer technologies in the transition phase will be scaled up in the comprehensive decarbonisation phase. The government's policy mandate can ensure new capacities will be in low carbon emission steel only. Existing hydrogen-DRI plants will have to completely shift to green hydrogen as well.

However, the overhang of old capacities will continue, and these capacities have to be gradually discarded. Relining must be fitted with CCUS to ensure zero emissions in blast furnaces added over 2010-2030 to enable them to continue to operate beyond 2050. While the government's initial incentive programme to retire old tech plants will support closure of smaller EAF-IF plants, large-scale BF-BOF plants have to be gradually decommissioned as done in the past.

Further, any other technologies such as MOE or HYFOR should be adopted as well if they are cost effective and clean. The investments done in research and development over the transition phase would support faster transfer to other technologies as well. By 2060s, all capacities added till 2035 in older technologies would be discontinued and newer greener technologies must be adopted by steel producers irrespective of their size and location.

	Development stage	Transition stage	Comprehensive decarbonisation stage	
	2022-2030	2030-2040	2040-2047	2047-2070
Policy support	• Improved scrappage policy • Set standards and benchmarks for green/ low carbon steel • Green steel to be included in PLI	• Mandatory carbon markets • Easier financing norms • Capacity swap programme	• Mandating green energy usage • Restrict imports of steel • Tax incentives	• Incentive for closure of old plants
Manufacturers	• Adoption of BAT – TRT • Increase scrap collection and usage • Higher R&D spend	• Gradual implementation of CCUS • H2-NG blending for DRI • 100% green power usage • Tie-up with end-users	• New capacities only in green technologies • Complete shift to Green H2 • Adoption of	• Retire old tech (BF-BoF, NG-DRI) plants

Source: Crisil Research Estimates

6 Conclusion

Being the second-largest producer of crude steel and the second-largest emitter of CO_2, India needs to focus on decarbonising the steel sector quickly to achieve carbon neutrality by 2070.

However, the decarbonisation path is strewn with hurdles in the form of the current capacity mix and low investments. At present, BF-BOF plants dominate the Indian landscape. The twin challenges here are to limit capacity additions in the BF-BOF and coal-DRI beyond 2035, and ensure the gradual decommissioning of IF and coal-based DRI plants. The average emission of a BF-BOF as well as coal-DRI-EAF plant is more than double that of the NG-DRI-EAF route. Thus, both the routes must be discontinued in the longer run to ensure Net Zero is achieved by the steel sector.

As most technologies are at a very nascent stage, investing in unproven technologies will be difficult for a highly leveraged sector such as this. Investments will automatically flow in once technology scale-up is evident and it becomes economically viable from a capex and opex perspective.

Another key factor that would bear watching is how prices of green hydrogen evolve on the back of continued investments and policy support. Green hydrogen is currently 3-5 times more expensive than grey hydrogen. Our preliminary calculations indicate that cost of production is 1,200-1,300 $/tcs, nearly two times more expensive than the BF-BOF method. More than the decarbonisation target, the cost of production would drive the transition in India. Thus, reduction of hydrogen price is essential for the decarbonisation journey.

However, government incentives and policy push could help overcome a few obstacles.

We expect decarbonisation of India's steel sector to take place in three stages/ phases: (a) the development stage (2022-2030), (b) the transition stage (2030-2040), and (c) the comprehensive decarbonisation stage (2040-2070).

In the **development stage**, the focus would be on adoption of the best available technology and recycling. The government must form an agency under the Ministry of Steel in collaboration with producers, academicians and global technology players for the same. The agency should ensure that technology transfer happens from developed nations to developing nations such as India under the UNFCCC charter, which will encourage investments in the sector.

The government must also ensure strict adherence of its vehicle scrappage policy. While the scrappage policy and benchmarks for low carbon steel will indirectly nudge steel producers towards reducing emissions, the players need financial incentives to set up new green steel / low carbon steel capacities. Incentives can be provided under the PLI scheme for new low carbon steel facilities.

In the **transition stage**, the focus would be on setting up plants with newer technology, and lower competitiveness of low carbon emission steel to be countered through government policies. This phase would be the key period for the Indian steel industry to achieve Net Zero. While steel players would wait for evolution and scaling up of newer technologies such as Hybrit in the development phase, players would need to start investing in the newer low carbon tech over the transition phase. Government support would be required in the form of mandatory carbon market as well as easing of financing regulations.

The **comprehensive decarbonisation stage** would stress on accelerating the shift towards low carbon emission steel through capacity closures, green energy, and new technology adoption. Beyond 2040, the pathway towards low carbon emission steel would be relatively easier with most technologies already being scaled up across the globe. Also, demand growth moderation in the domestic market, along with higher availability of steel scrap, would reduce the need for huge capital investments, even as investments will be made to replace old and more polluting capacities.

These three phases do promise a definite effort towards taking carbon out of steel by 2070.

7 References

1. CO2 emission intensity of GDP (https://www.iea.org/data-and-statistics/charts/co2-emissions-intensity-of-gdp-1990-2021)
2. Global energy review: CO2 Emissions in 2021 (https://www.iea.org/reports/global-energy-review-co2-emissions-in-2021-2)
3. India Energy outlook 2021 (https://www.iea.org/reports/india-energy-outlook-2021)
4. Hybrit Fossil free Steel (https://www.hybritdevelopment.se/en/)
5. Hybrit (https://www.ssab.com/en/fossil-free-steel/hybrit-a-new-revolutionary-steelmaking-technology)
6. Molten oxide electrolysis (https://www.bostonmetal.com/transforming-metal-production/)
7. Panchamrit (https://pib.gov.in/PressReleasePage.aspx?PRID=1768712)
8. HYFOR (https://www.primetals.com/press-media/news/hyfor-pilot-plant-under-operation-the-next-step-for-carbon-free-hydrogen-based-direct-reduction-is-done)
9. Monthly Summary for the Cabinet for the month of May, 2022, Ministry of Steel, Ref Document - No. S-24013/1/2020-EA-RFD
10. IBM Minerals yearbook 2018
11. JPC Annual Statistics 2022
12. World Steel in figures 2022 (https://worldsteel.org/steel-topics/statistics/world-steel-in-figures-2022/)
13. Achieving Net Zero Heavy Industry Sectors in G7 Members (https://iea.blob.core.windows.net/assets/c4d96342-f626-4aea-8dac-df1d1e567135/AchievingNetZeroHeavyIndustrySectorsinG7Members.pdf)
14. National Steel Policy 2017 (https://steel.gov.in/sites/default/files/draft-national-steel-policy-2017.pdf)
15. Transition towards 2030 & Vision 2047 (https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1853991)
16. World Steel Association Sustainability indicators (https://worldsteel.org/steel-topics/sustainability/sustainability-indicators/)
17. China's Climate Policy Documents (https://www.undp.org/china/publications/issue-brief-chinas-climate-policy-documents-1n-and-updated-ndc)

About CRISIL Limited

CRISIL is a leading, agile and innovative global analytics company driven by its mission of making markets function better.

It is India's foremost provider of ratings, data, research, analytics and solutions, with a strong track record of growth, culture of innovation and global footprint.

It has delivered independent opinions, actionable insights, and efficient solutions to over 100,000 customers.

It is majority owned by S&P Global Inc, a leading provider of transparent and independent ratings, benchmarks, analytics and data to the capital and commodity markets worldwide.

CRISIL Privacy

CRISIL respects your privacy. We may use your contact information, such as your name, address, and email id to fulfil your request and service your account and to provide you with additional information from CRISIL. For further information on CRISIL's privacy policy please visit www.crisil.com.

About Indian Steel Association

The Indian Steel Association (ISA) is the voice of India's robust and growing steel industry. ISA came to life to create a conducive environment for steel production in the country and has since worked towards representing the interests of the Indian steel ecosystem both nationally and at international forums. As a not-for-profit society, ISA proudly shoulders the responsibility of communicating the views of its constituents to all stakeholders in the steel production supply chain. It remains at the forefront of all policy deliberations and contributes to decision-making in public and regulatory policy, raw material sourcing, global trade, technology, environmental concerns, and the entire gamut of issues related to steel making, steel consumption and steel usage.

Disclaimer

This document does not constitute professional advice. Neither CRISIL nor Indian Steel Association (ISA) has any financial or commercial engagement for the making of this document. The views expressed in this document are those of the authors and do not necessarily reflect the views and policies of ISA or the reviewers. The information in this document has been obtained or derived from sources believed to be reliable but does not represent that this information is accurate or complete. Readers are advised to seek their own professional advice before taking any course of action or decision, for which they are entirely responsible, based on the contents of this document. ISA neither accepts nor assumes any responsibility or liability to any reader of this document in respect of the information it contains or for any decision readers may take or decide not to or fail to take.

Indian Steel Association: Upper Ground Floor No-4, Kanchenjunga Building, 18 Barakhamba Road, New Delhi - 110 001, India
Phone: + 91 11 4266 8800 | Fax: + 91 11 4266 8805 | www.indiansteel.org
company/indian-steel-association @steel_indian @Indiansteelassociation c/IndianSteelAssociation indian_steel

IndianSteel ASSOCIATION

Argentina | Australia | China | Hong Kong | India | Japan | Poland | Singapore | Switzerland | UAE | UK | USA
CRISIL Limited: CRISIL House, Central Avenue, Hiranandani Business Park, Powai, Mumbai – 400076. India
Phone: + 91 22 3342 3000 | Fax: + 91 22 3342 3001 | www.crisil.com
/company/crisil @CRISILLimited /CRISILLimited /user/CRISILLimited /lifeatcrisil

CRISIL An S&P Global Company