ACHIEVING GREEN STEEL

Roadmap To A Net Zero Steel Sector In India

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Creating Innovative Solutions for a Sustainable Future

Energy Transitions Commission India

Authors

Will Hall, Visiting Fellow, TERI (till June 2022)

Sachin Kumar, Senior Fellow, TERI (till Dec 2021)

Sneha Kashyap, Research Associate, TERI (till Mar 2022)

Shruti Dayal, Research Associate, TERI

Reviewer

Mr Girish Sethi, Senior Director, TERI

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In 2018, ETC launched its 'Mission Possible' report, which detailed decarbonization pathways for the 'hard-to-abate' sectors. This included a sectoral focus on steel, which provided the impetus to start work on the same in India.

ETC India initiated activities in 2017-18 with a focus on the decarbonization of India's power sector. Whilst that work is still continuing, ETC India has also started to work on industry transformation, particularly in the 'harder-to-abate' sectors including iron & steel, cement, and other industry sub-sectors.

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FOREWORD

The Indian steel sector has been, and will remain an important pillar of India's economic growth and development. Steel demand is estimated to increase more than by twofold 2030-31, spurred by increased spending on infrastructure, automobiles and affordable housing. This increase in demand will provide both challenges and opportunities, including the impact of the sector on the environment. There is a need to ensure that future pathways for growing steel demand are green with minimal environmental impacts.

The Energy and Resources Institute (TERI), as part of the Energy Transitions Commission India work program, is examining various economic and technological developments across sectors to further our understanding of possible routes for decarbonizing India's energy system and key industry sectors. It has included detailed modelling of the Indian power system, technology pathways for the heavy industry sectors such as iron and steel and an assessment of the sector-wise potential for hydrogen in India.

In 2020, we published a consultation document on the iron and steel sector - Towards a Low Carbon Steel Sector - an in-depth study outlining various options for reducing emissions from the steel sector. Our analysis clearly highlighted that significant emission reductions can be achieved through technology and measures that are available today, including energy efficiency and resource efficiency. Beyond these measures, India will also need to start deploying deep decarbonisation alternatives including electrification, hydrogen and carbon, capture and storage. Achieving Green Steel: Roadmap to a Net Zero Steel Sector in India builds on this work. In the formulation of this Roadmap, TERI has carried out extensive consultations with various stakeholders in the steel sector – producers, buyers, technology providers, financiers, government bodies and the research community.

This comprehensive Roadmap provides an overview of the current state of the steel sector and details a range of possible emissions mitigation strategies. In the near term, implementation of strategies such as maximizing energy efficiency, increasing utilization of scrap, introducing green product standards, creating demand for green steel, setting up pilot demonstration plants based on low carbon technologies, and initiatives to develop a domestic carbon market may be necessary to ensure that the Indian steel sector is in a better position to move towards rapid decarbonization post-2030. International support in terms of technology and finance will be crucial for this sector. These measures could incentivize a large-scale switch that will put the entire sector on a net-zero trajectory.

We hope that the Roadmap will be a valuable source of information for the Indian Steel industry - providing insights into the possible options for meeting future steel demand growth sustainably. We at TERI look forward to working hand-in-hand with partners to accelerate this transition to green steel.

Vibha Dhawan.

Dr Vibha Dhawan
Director General, TERI

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GLOSSARY

AI – Artificial Intelligence

BEE – Bureau of Energy Efficiency

BF-BOF – Blast Furnace – Basic Oxygen Furnace

BIS –Bureau of Indian Standards

CAGR – Compounded Annual Growth Rate

CBAM – Carbon Border Adjustment Mechanism

CCUS – Carbon Capture, Use and Storage

CO_2 – Carbon Dioxide DR – Direct Reduction

EAF – Electric Arc Furnace

EBITDA – Earnings before Interest, Taxes, Depreciation, and Amortization

EIF – Electric Induction Furnace

ETS – Emissions Trading Scheme

FDI – Foreign Direct Investment

FTA – Free Trade Agreements

GDP – Gross Domestic Product

GHG – Greenhouse Gases

GoI – Government of India

IEA – International Energy Agency

H_2 – Hydrogen

IoT – Internet of Things

ML – Machine Learning

MoS – Ministry of Steel

Mt – Millions of tonnes

Mtoe – Million Tonnes of Oil Equivalent

Mtpa – Millions of tonnes per annum

NCAER – National Council of Applied Economic Research

NG – Natural Gas

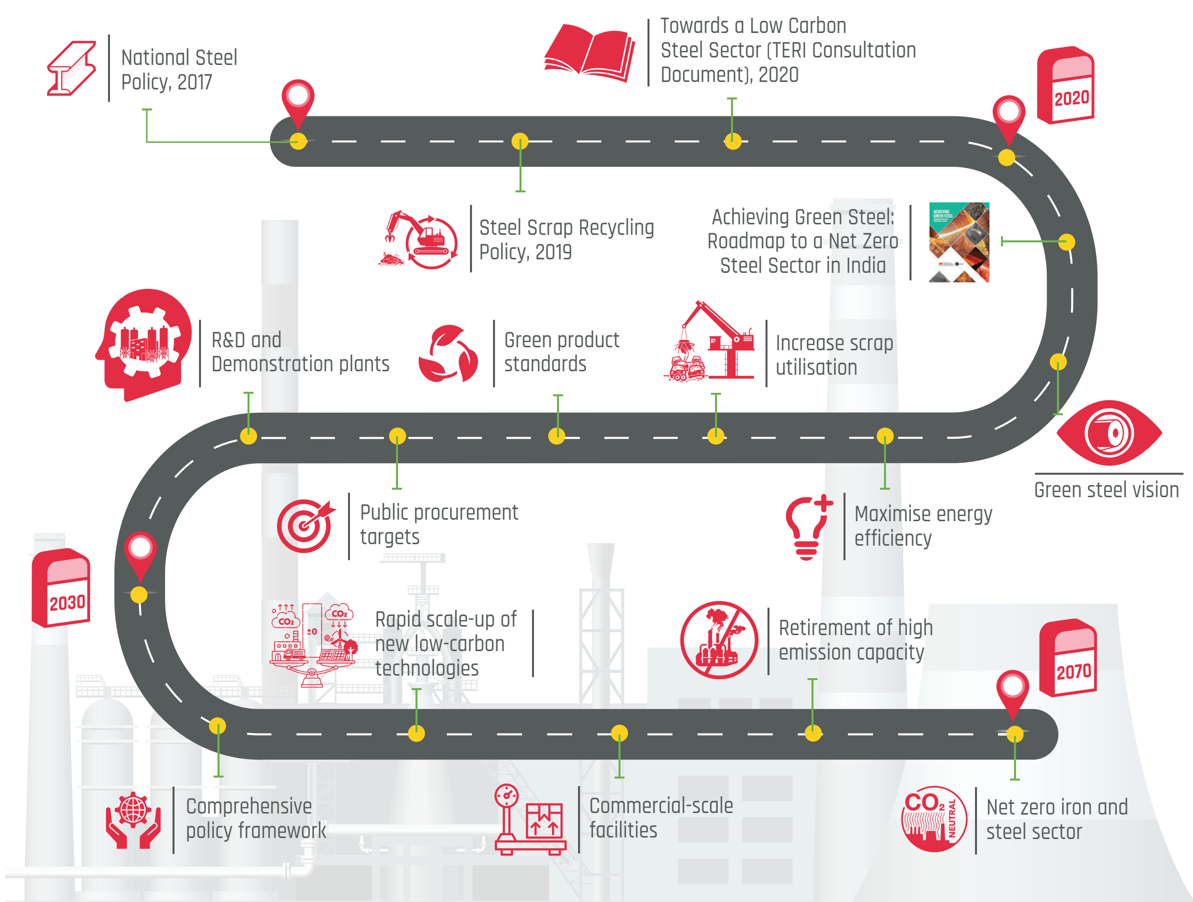
NSP – National Steel Policy

PAT – Perform, Achieve and Trade

TRL – Technology Readiness Level

WSA – World Steel Association

Achieving Green Steel: Roadmap to a net zero steel sector in India



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EXECUTIVE SUMMARY

- The global steel sector is shifting rapidly. More than 30% of steel companies (by production) have net zero targets - up from zero less than 3 years ago - and more than 90% of countries (by GDP) have national level net zero targets.
- Governments are moving fast to create 'level playing fields' to protect domestic steel sectors during transition, including carbon border adjustment proposals, commitments to joint standardization and climate clubs.
- The financial sector is shifting funds away from fossil investments, with a significant additional push from COP26 under the Glasgow Financial Alliance for Net Zero (GFANZ), as well as more steel-focused efforts from the Centre for Climate-Aligned Finance (RMI).
- Steel buyers in the construction, automotive and metal products sectors, both public and private, are signaling a commitment to buy green steel. This includes the First Movers Coalition (FMC), Steel Zero and CEM Industrial Deep Decarbonisation initiatives.
- The Indian steel sector is at a crossroad. To continue to compete globally, increase exports to a range of markets, champion domestic technology development, and drastically cut emissions the sector will need to accelerate the deployment of low emission technologies in line with net zero by the mid-century.
- Cutting emissions on a slower trajectory out to 2070, as may be possible with other sectors which are less exposed to international trade, risks limiting Indian steel exports and the ability to lead on low emission steelmaking technology development and deployment.
- This will not be easy, with the scaling of sufficient renewable energy, for both direct use and for green hydrogen production, being the primary hurdle to meeting net zero.
- In order to meet this challenge, the sector will need to make bold decisions on new technologies, rapidly build out enabling infrastructure, supported by domestic policy and international finance. The result will be a globally competitive steel sector, supporting India's ambitions of a self-reliant, net zero major economy.

INTRODUCTION

The steel sector plays an important role in the Indian economy and has been a core pillar of India's industrial development. As a critical input for various sectors, steel will play a major role in helping India support the infrastructure that facilitates growth, the housing that drives urbanisation, and the machinery and tools that power industrialisation. The sector is expected to experience significant growth in the coming decades to satisfy these demands.

However, if India is to continue to show leadership on climate change and future-proof its steel industry for a net zero world, then an ambitious strategy for emissions reduction is required. In doing so, India can pioneer a model of "industrialisation without carbonisation", setting an example for emerging economies around the world.

This report sets out such a strategy, by detailing the short-term (2020-2030) and the long-term (2030 onwards) actions required to achieve net-zero emissions for the sector by 2070. This includes measures to maximise energy efficiency, increase scrap utilisation, set green product standards, develop public and private procurement targets and build commercial-scale demonstration plants in the nearer-term. Over the longer-term, this activity should inform a more comprehensive policy framework that will assist a mass-market switch to green steel production and use, supported by phase-out policies for older, polluting plants, alongside support for new, near zero emission plants.

In doing so, this roadmap quantifies the scale of the challenge, setting out in clear terms what is required for India is to put itself on pathway to net-zero by 2070. This includes support for technology development and capacity building, to introduce the latest technologies into the Indian market, facilitated via existing partnerships with developed countries. Alongside this, collaboration on market creation policies, such as green product standards and procurement targets, can help ensure that the Indian steel industry is prepared to compete in the global steel market as it transitions to low emission production.

This roadmap is a follow-up to the consultation document published by TERI in 2020, "Towards a Low Carbon Steel Sector: An overview of the changing market, technology and policy context for Indian steel". The updated consultation document is available at our website as Tech Annex . The roadmap builds on this preceding work, along with other TERI and ETC publications on steel and hydrogen[1], incorporating in the detailed comments and feedback from discussions with international experts, steel sector representatives, and government officials.

[1] The Potential Role of Hydrogen in India (Hall et. al, 2020); Green steel through hydrogen direct reduction (Hall et. al, 2021); Making the Hydrogen Economy Possible (ETC, 2021); Net-Zero Steel: Sector Transition Strategy (MPP, 2021)

1

BACKGROUND

Background

1.1 Indian steel industry

India is currently the world's second-largest steel producer, and second-largest steel consumer (WSA, 2020a). The steel industry in India is relatively heterogeneous compared to other countries, with a wide range of different sized facilities in the primary and secondary steelmaking sectors. There are also several different technologies currently being used, including the Blast Furnace – Basic Oxygen Furnace (BF-BOF), coal-based Direct Reduction (DR), gas-based DR, Electric Induction Furnace (EIF) and Electric Arc Furnace (EAF). BOF technology dominates a growing share of steel production, being the preferred technology for most new capacity, with EAF and EIF taking an almost equal share of the remainder of the market (see Figure 1).

Use of coal-based direct reduction processes is unique to the Indian steel sector. This process is mainly used in smaller facilities to meet local steel demands, as opposed to exports. India's reliance on this technology is driven by availability of cheap domestic coal reserves, lack of sufficient domestic natural gas supplies as well as domestic coking coal of sufficient quality. The use of induction furnaces along with coal-based direct reduction often results in lower quality steel, as a result of the residual phosphorous which is not removed, unlike with EAFs. Improving the quality of the steel from this route would require either an additional refining step or the use of higher shares of good quality scrap. This is one of the reasons we are likely to see the market share of this route continue to decline, with most new steel capacity focused on the BF-BOF and EAF technologies.

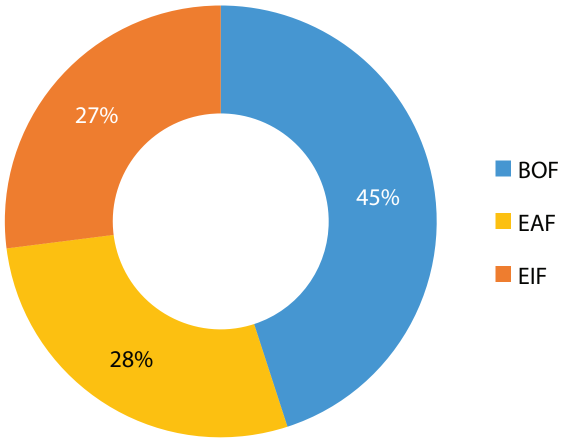


Figure 1: Route-wise crude steel production share, 2020-21

Source: (MoS, 2021a)

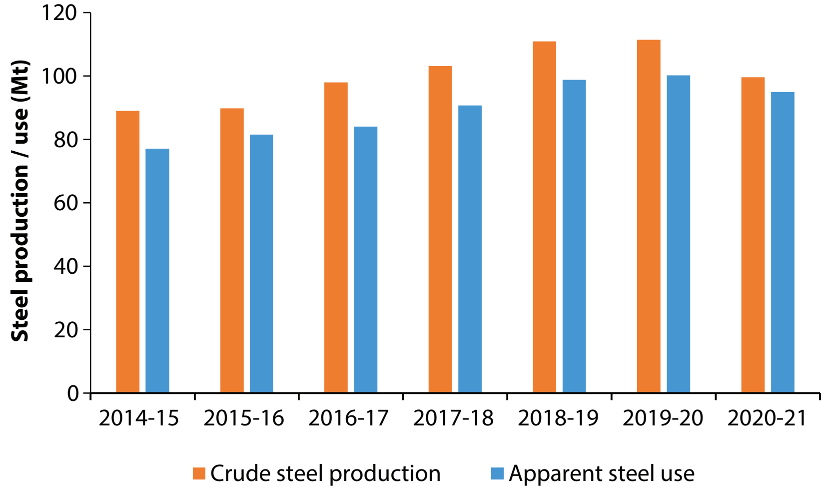


Figure 2: Historical steel production and use

Source: (MoS, 2021a; 2021b)

As with any industrializing economy, the steel sector is of vital importance to India, contributing around 2% to the country's GDP and employing around 2.5 million people in the steel and related sectors (MoS, 2020a). Crude steel production in India grew from 89 Mt in 2014-15 to 111 Mt in 2019-20. It fell to just below 100 Mt in 2020-21[2] following the Covid-19 pandemic. However, the cumulative production of crude and finished steel increased by 25% in 2021-22. The sector also experienced significant changes in the import/export pattern from before the pandemic. Imports reduced by 39.4% and exports increased by 69.5% from 2018-19, reaching 4.8 Mt and 10.8 Mt, respectively. The import and export of steel in India fluctuates significantly year to year, on the basis of domestic and global macroeconomic conditions, and the demand and supply scenario in the global steel market.

In terms of production capacity, India reached 144 Mt as of mid-2021 (PIB, 2021). The private sector contributes the majority of this (82%) with 118 Mt currently under operation. There is also significant new capacity in the pipeline, such as the new 24 Mt Arcelor Mittal / Nippon Steel facility slated for Odisha, which would be the largest plant in the world. Over 2020-21, utilisation rate for this capacity stood at around 70%. Even considering the impact of Covid-19, this large utilisation gap places pressure on steelmakers profits. This is something that will require close attention, including re-considering in commissioning dates of plants in the current pipeline, so as not to exacerbate domestic and international overcapacity issues.

In 2017, the Ministry of Steel (MoS) launched the National Steel Policy (NSP), which included an aim to increase India's steelmaking capacity to 300 Mt by 2030. This policy also encompasses targets to reduce energy consumption per tonne of steel, through adopting the latest energy efficiency measures. To support the adoption of energy efficiency measures across a number of sectors, the GoI has developed the Perform, Achieve and Trade (PAT) scheme, delivered through the Bureau of Energy Efficiency (BEE). The steel sector has been covered under the PAT scheme since its inception in 2012. Until PAT cycle-III, a total energy saving of just over 5.68 Mtoe has been achieved by 81 identified facilities within the steel sector (BEE,

[2] April-December 2020 for crude steel production in 2020-21

2020). Alongside energy efficiency, the Government has begun efforts to increase material circularity, with the MoS launch their Steel Scrap Recycling Policy in 2019, aimed at increasing the availability and use of steel scrap throughout India.

1.2 Global steel industry

The global steel industry has continued to grow rapidly over the past few decades, with a significant portion of that growth coming from China, which still produces over half of the world's steel (WSA, 2020a). Globally, crude production of steel increased from 734 Mt in 1991-92 to 1869 Mt in 2018-19. BF-BOF and EAF are the dominant routes, currently holding a greater than 99% share for global crude steel production (see Figure 3). In 2018, India overtook Japan as the second largest producer of steel, symptomatic of a broader shift in steel production and demand to developing countries.

China is by far the largest producer and consumer of steel, producing close to 1,000 Mt in 2019, more than nine times the production of India, as the second largest producer. Japan, the USA, and Russia are the other subsequent largest producers after China and India. The top five steel consuming countries are China, India, USA, Japan, and South Korea. Figure 4 sets out a business as usual scenario for steel demand and scrap availability in different regions around the world over the coming few decades, it is expected that low-income and emerging economies in Africa, South and East Asia (including India), and Latin America will drive most new growth, as demand in other developed regions such as China, Europe, Japan and South Korea stabilises or declines. The steel demand in India will increase significantly out to 2050 making it challenging to drastically increase scrap usage as a share of overall steel production. However in countries such as China, an increase in scrap availability, combined with declining overall demand, will allow for a switch to cleaner secondary production as can already be observed.

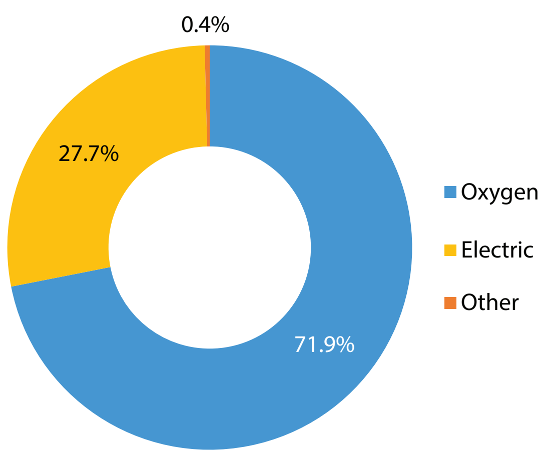


Figure 3: Global steel production route-wise breakdown, 2019

Source: (WSA, 2020a)

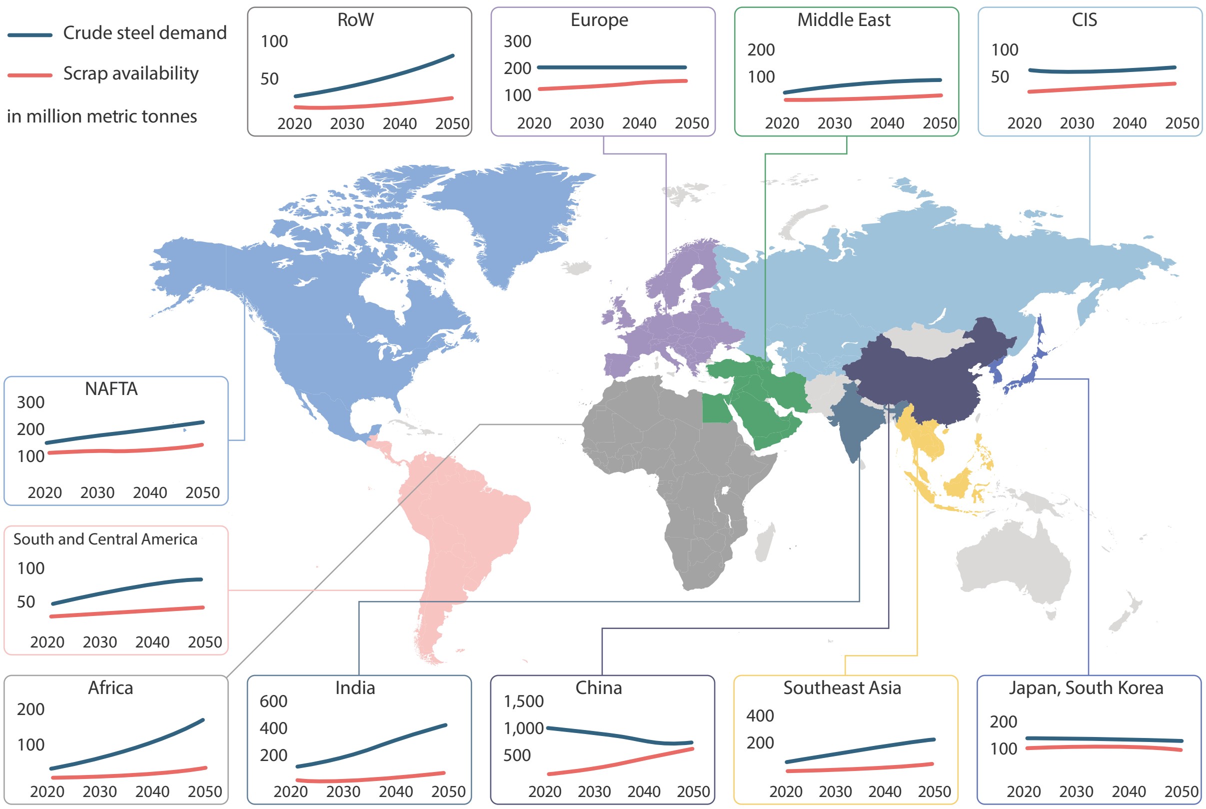


Figure 4: BAU demand for crude steel and scrap availability

Source: (MPP, 2021)

1.3 Macro-trends

In the coming decades, the iron and steel sector in India will be affected by a number of 'macro-trends', which have the potential to radically change the way steel is produced and consumed. Primarily, these are development, digitalisation, and decarbonisation. Development will drive the growth in demand for steel across a number of key sectors, digitalisation will deliver step-changes in productivity, operational efficiency and labour intensity of production, and decarbonisation will require new approaches to material efficiency and circularity and the adoption of deep decarbonisation production processes.

1.3.1 Development

Steel is a material of vital importance to countries as they develop, a key input across construction, infrastructure, and manufacturing sectors. As countries reach a certain level of economic development, steel demand starts to saturate, as most major infrastructure is built and future steel demand can largely be satisfied by recycling, or is replaced with alternative materials. As such, we are likely to see emerging economies like India become the major centres of steel demand growth in the coming decades, as demand in other major economies, such as China, stabilises.

Forecasting demand growth out to 2050, and beyond, clearly carries a lot of uncertainty. Both the rate of economic growth, as well as its key drivers, are uncertain. Will India follow a more service-based economy? Or will its rate of infrastructure investment and industrialization pick up, following a path more similar to that charted by China and other East Asian industrial powerhouses like South Korea?

In our analysis of the historical experiences of a large number of countries, we find that the most significant determinants of steel demand are income (GDP per capita), the rate of investment (GFCF) and the level industrialization in the economy (industrial GVA). Figure 5 sets out the relationship between GDP per capita and true steel use for a list of 34 countries. The detailed methodology for our steel demand forecasts can be found in Technical Annex.

The Covid-19 pandemic has sent shockwaves through global supply chains, leading to an estimated decline in global crude steel output of 5% in 2020 relative to 2019 (WSA, 2020b). India is already the world's second-largest steel-producing country and is expected to increase its annual production volumes by 2050 by an amount equivalent to twice that of the European Union's total production in 2019. Whilst the pandemic is likely to have a significant short-term impact on the steel sector, the underlying factors that will drive growth over the medium and long-term, such as population growth, industrialisation, growth in incomes, and support for major infrastructure projects such as "*Gati Shakti*", will persist.

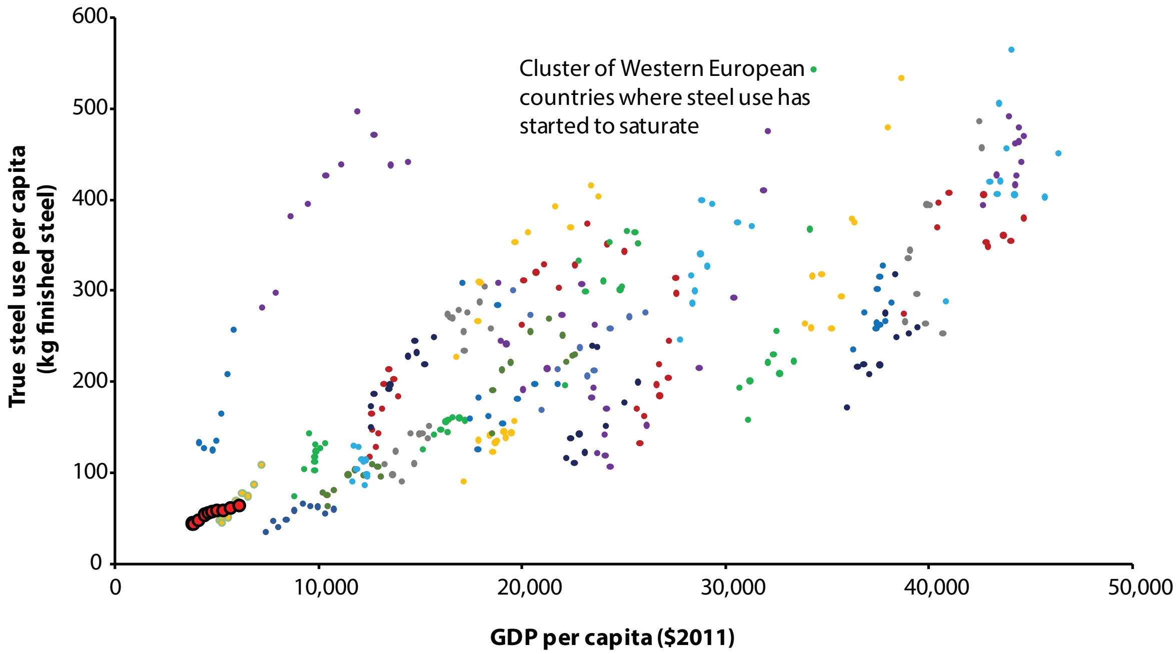


Figure 5: True steel consumption per capita versus GDP per capita

Source: TERI analysis based on data from (WSA, 2018), (World Bank, 2017)

1.3.2 Digitalisation

As with other sectors in the economy, the iron and steel sector is set to realise significant benefits from the digitalisation of production processes and supply chains. This is likely to have a step-change impact in operational efficiencies. It will be important to consider digitalisation alongside other major trends, such as decarbonisation, to better understand the net impact of such major technological shifts.

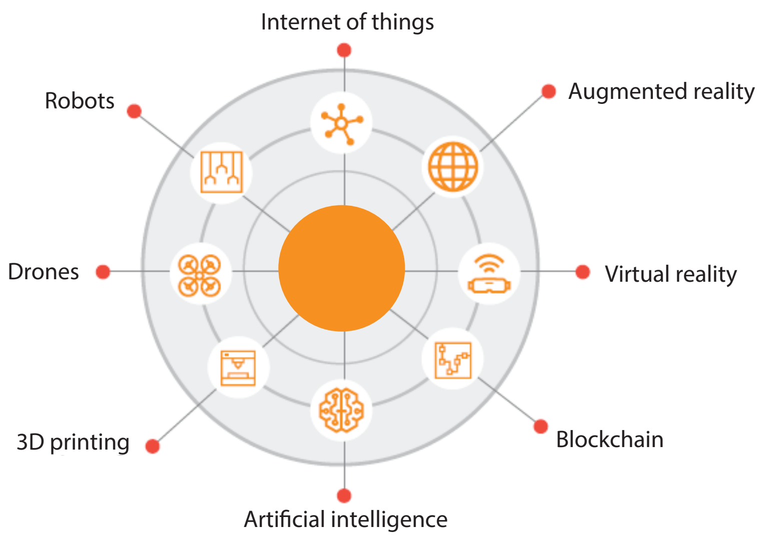


Figure 6: Digitalistion trends over the 2020s

Source: (PwC, 2019)

Digitalisation of industry is a wide-ranging area, often covered under topics such as Industry 4.0 (or 4th Industrial Revolution), Internet of Things (IoT), cloud computing, Artificial Intelligence (AI), and Machine Learning (ML). Emerging technologies that are being considered in the steel industry include augmented reality, virtual reality, blockchain, artificial intelligence, 3D printing, drones, and robots (see Figure 6). In an era of smart machines, storage systems and production facilities, the above-mentioned technologies would be capable of autonomous information exchange, triggering actions and controlling each other independently. This can result in significant cost-savings through reduction in labour costs, improvement in efficiency, and minimisation of error (PwC India, 2019).

For example, Jindal Steel and Power Ltd (JSPL) has implemented an IoT framework at its facility in Angul, Orissa, using a network of machines, advanced analytics, and highly skilled IT professionals. As a result, the health and status of machines can be monitored remotely and immediately, greatly improving the efficiency and productivity of the plant (CIO&Leader, 2017). Similarly, Tata Steel has been on a multi-year digital-enabled business transformation journey intending to be the leader in digital steel making by 2025 through the adoption of digital technologies (The Economic Times, 2021). Their Kalinganagar plant has developed an expert team of analytics specialists, including data scientists and translators.

The net impact of digitalisation on the Indian iron and steel sector is uncertain. It represents a significant opportunity for Indian steelmakers as build new capacity in the coming decades, able to take advantage of the latest technologies, unavailable to other countries when they were expanding their steel production. India has shown a proficiency for rapid adoption of new technologies in other sectors, with a relatively young and technically literate workforce better suited to taking advantage of the latest technologies.

The increasing pace of digitalisation also represents a challenge for the sector, as improved digital systems can reduce the need for labour in the steel production process. India has relatively high unemployment and an urgent need for high-skilled jobs - jobs which the iron and steel sector has historically provided. This shift needs to be factored into future conversations around a just transition for the iron and steel sector in India, as along with a loss of employment for domestic coal production, it is likely that further jobs may be lost within the steel plant. This needs to be balanced against the overall gains in employment opportunities from the renewable and green hydrogen industries, that will be required to replace fossil fuel production and import.

1.3.3 Decarbonisation

The third macro-trend, and arguably the trend driving the most significant disruption in the iron and steel sector, is the growing imperative for decarbonisation. The iron and steel sector is currently both highly energy and emissions-intensive, accounting for 8% of global final energy use and 7% of global direct energy-related CO_2 emissions (including industrial process emissions) (IEA, 2020). As progress to decarbonize the power and transport sectors accelerates, we are starting to see greater focus on the heavy industry sectors, such as iron & steel, cement and chemicals.

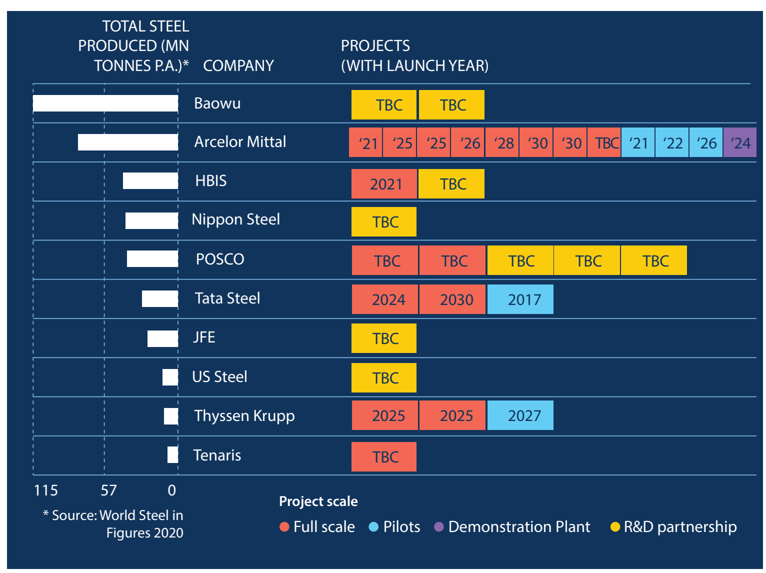


Figure 7: Green steel projects pipeline

Source: (Vogl, et al., 2021) as of June 2022

In India, total emissions from the iron and steel sector are around 250 $MtCO_2$ (about 10% of total emissions) and will increase more than threefold to approximately 800 $MtCO_2$ by 2050, if no concerted action to decarbonize is taken (Hall, Spencer & Kumar, 2020). Even with ambitious energy and material efficiency measures to reduce energy consumption and mitigate demand growth, the level of emissions in the Indian iron & steel sector will be incompatible with the ambition of limiting global warming to well below 2°C.

For further emissions reduction, the introduction of new, low carbon technologies will be required, such as the use of low carbon hydrogen or carbon, capture, utilisation and storage (CCUS). Initially, these new processes will increase the costs of steel production, and will require the introduction of supportive policies by the government to help the industry through the transition, as we have seen in other sectors, such as power and transport.

Whilst it is true that some Indian steel companies are already taking significant steps to reduce energy consumption and emissions, the pace and scale of transition taking place in other regions, most notably Europe and China, puts the domestic sector at risk of being left behind (Vogl, et al., 2021). Steel is a highly traded product, although strict emissions reduction policies and associated 'carbon leakage' measures will drastically reduce the size of the market for steel producers not investing in deep decarbonisation strategies today.

2

MACROECONOMIC IMPACTS

Macroeconomic Impacts

2.1 Overview

The steel sector contributes around 2% of India's GDP (MoS, 2020a) and is valued at well over $100bn (Niti Aayog, 2016). The indirect contribution of the sector is significantly higher, given its enabling role in several end-use sectors including construction, infrastructure, industrial machinery and consumer products. For this reason, it is estimated that the investment in the Indian steel sector has an output multiplier effect of nearly 4 times on GDP and employment multiplier factor of 6.8 times (NSP, 2017), signalling its importance for India's future growth story.

2.2 Investment and profitability

The Indian iron and steel sector is currently relatively financially fragile. Even with a recent upswing with narrow profit margins, low investment intensities, and an increasing interest burden (Hall, Spencer & Kumar, 2020). The iron and steel sector is highly cyclical, and upswings and downswings are a normal feature of this industry. However, as the impacts of the Covid-19 pandemic have lessened, the global and Indian steel sector has seen an improvement in its condition. This being said, it is clear that large and risky investments will not be possible without support from public and private players, both domestic and international.

2.3 Rapid growth

Over 80% of India's iron reserves are in India's eastern states (Odisha, Jharkhand, West Bengal, Chhattisgarh and North Andhra Pradesh) (see Figure 8). These states also have access to logistics infrastructure including ports, inland waterways and slurry pipelines (MoS, 2019b). The top states in terms of steel production include Odisha (25 Mt), Jharkhand (20 Mt), Chhattisgarh (19 Mt), Karnataka (15 Mt), Gujarat (13 Mt) and Maharashtra (12 Mt) (JPC, 2020).

The Ministry of Steel, under Mission Purvodaya, aims to support the development of an integrated steel hub in eastern India to improve the competitiveness of the steel sector and facilitate regional development and job creation. This Mission aims to facilitate investments worth $70 billion, supporting new employment (up to 2.5 million jobs) and improvement in living standards among some of India's less wealthy states (MoS, 2020b).

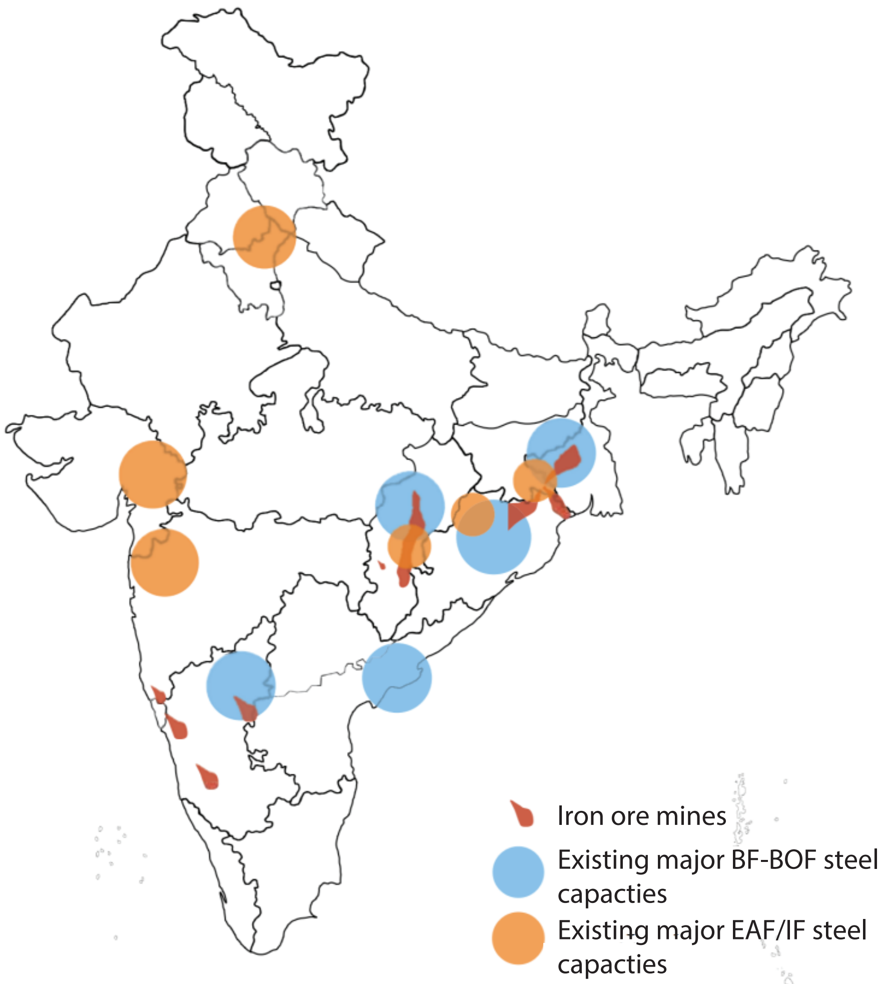


Figure 8: Plant and iron ore mine locations

Source: (NSP, 2017)

Western states, such as Gujarat, Maharashtra and Karnataka, have already benefitted significantly from good quality renewable resources (wind and solar), which will only continue as the electricity grid further decarbonizes. There is a need to better understand the future steel making competitiveness in terms of transporting iron or electrons across the mineral rich and highly endowed renewable resources regions of the country. **It will be vital for the success of the energy transition that its benefits are spread more equally across India – a competitive, green steel sector in Eastern India can be an important part of that**.

2.4 Employment

The Indian steel sector currently employs approximately 2.5 million people throughout the supply chain (MoS, 2020a). This is estimated to increase to around 3.5 million by 2030, depending on the degree of automation (NSP, 2017). The highest-skilled jobs include engineers and metallurgists, which are vital for the efficient operation of the plants and timely adoption of new technologies.

However, the sector is currently facing a significant skills shortage, which is being exacerbated by skilled graduates moving away from the manufacturing sectors to the service sectors. This is being driven by perceptions around salary, working conditions and company mission and culture. The shortage is particularly acute for metallurgists, where there could be a shortage of around 15,000 by the mid-2020s (NCAER, 2015). Whilst there are promising signs that this situation is improving, the sector will continue to face tough competition from other technical sectors.

For this reason, the steel sector needs to rapidly improve its offer to young graduates. An ambitious strategy for decarbonizing production and supporting the transition to net zero will be vital for attracting and retaining the best talent. According to a survey of 'Generation Z' students and professionals (born between 1997 and 2012), 63% state working for a company that limits their impact on the environment as a priority (Deloitte, 2021). Although attracting the young talent does not appear to be an issue for Indian steel sector at present, coming out with an ambitious strategy for decarbonising production and supporting the transition to net zero might help the steel industry in motivating best talent to work in this sector.

3

CHALLENGES

Challenges

This section covers some of the key challenges that are being faced by the Indian iron and steel sector for decarbonisation. These include cost-competitiveness of production, rapid growth of domestic demand, and the availability of the required low emission technologies.

3.1 Competitiveness

Whilst there have been significant improvements in the operational efficiencies of steel production in India in recent years, on average, Indian steel producers are still facing costs around 5-10% higher as compared to the global average. In the context of a global glut in steel supply, this places Indian steel producers in a difficult position, reducing profits for reinvestment and limiting export markets. The cost premium is driven by a number of factors (see Table 1), with the main contributors being costs of finance (approximately 12% versus 3-5% across the European Union) and the costs of logistics and infrastructure. For the latter, steel producers pay relatively high costs of raw material transport on Indian Railways, which subsidises passenger transport (Kamboj & Tongia, 2018) and requires significant investment to modernise (PwC, 2019).

This, along with other factors, places India at a comparative disadvantage relative to other major producers, such as China, Japan and South Korea, in some areas of higher technical sophistication, including stainless steel and alloy steel production. In addition, India's Free Trade Agreements (FTAs) with South Korea and Japan under the Comprehensive Economic Partnership Agreement in 2010 and 2012 respectively, have led to a steady reduction in import duties for steel. These have fallen to 0.8% for Japan and 1.25% for Korea (Niti Aayog, 2016). As a result, combined steel imports from Japan and Korea increased by 71% to 3.8 Mt in 2019-20. To help improve the relative competitiveness of domestic producers, the Government has recently approved the Production Linked Incentive Scheme for 'Speciality Steel' (PIB, 2021), although it is too early to assess the effectiveness of this programme.

Table 1: Cost premium for steel production in India

Item	Cost ($/ton)
Logistics and Infrastructure	25-30
Power	8-12
Import duty on coal	5-7
GST Compensation Cess	2-4
Taxes and duties on iron ore	8-12
Finance	30-35
Total cost disadvantage	80-100

Source: (Niti Aayog, 2016)

The impact of this, along with the global glut of steel supply, has contributed towards a steady decline in the EBITDA[3] margin for the steel sector. Figure 9 shows this decline for the five largest producers in India, including Tata Steel, JSW, SAIL, JSPL, and Jindal Stainless Steel Ltd up until 2018. However, there has been a significant upswing in more recent years, with several Indian steel producers posting record high EBITDA margins (Tata Steel at 43% for FY2021), which suggests that these pressures are lessening.

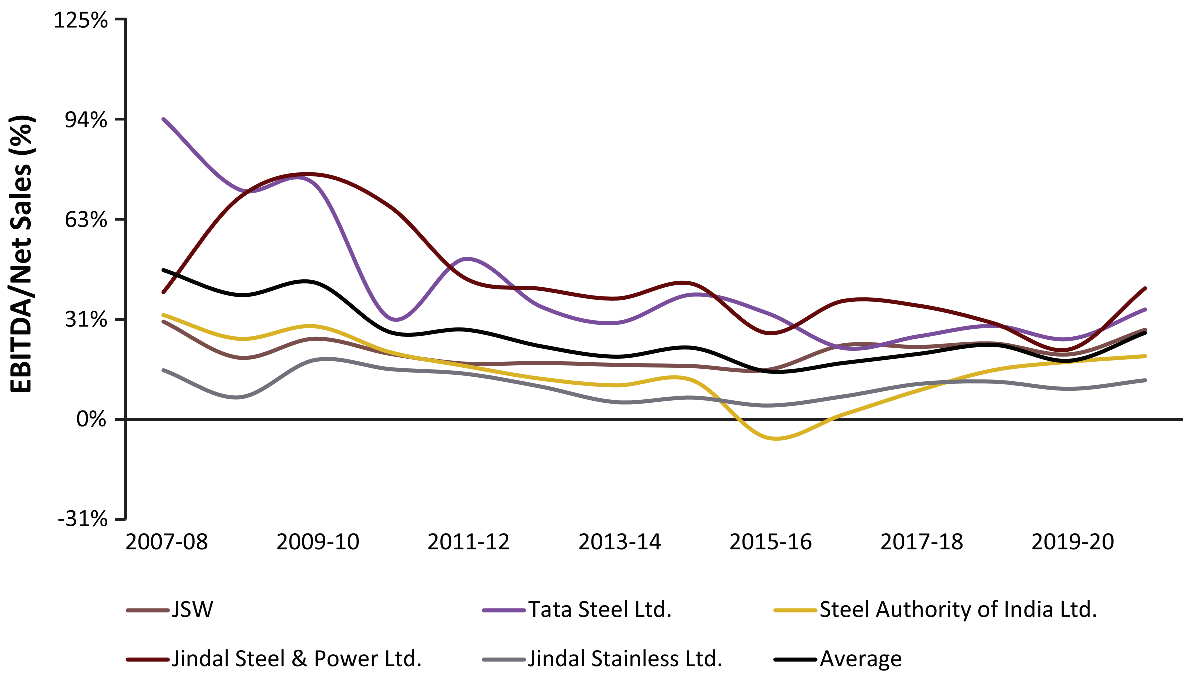


Figure 9: EBITDA for the top five iron and steel producers

Source: TERI analysis based on annual reports of iron and steel producers (JSW, Tata Steel, SAIL, Jindal Steel & Power Ltd., and Jindal Stainless Steel Ltd.)

3.2 Rapid growth required in the near term

As India's economy grows, its steel demand will grow substantially. India currently has the world's second largest population and is expected to be the largest by 2023 (OECD, 2018). By 2030, in our Baseline scenario (see Figure 10), we expect steel demand to more than double versus today, increasing the steel use per capita to 150 kg. Under the Resource efficiency[4] scenario, steel use per capita is similar over this time frame, given the time taken for resource efficiency measures to have a substantial impact.

By 2050, in the Baseline scenario, we expect steel demand per capita to nearly quadruple to 295 kg per capita. This would make it similar to middle to high income economies today, being equivalent to the average true steel use per capita across the European Union (WSA, 2020a). Whilst the growth rate implied by these projections is high (5% CAGR), we believe this is plausible, given the vast amount of steel that India still requires to develop.

[3] Earnings before interest, taxes, depreciation, and amortization.

[4] The Resource Efficiency scenario includes more optimistic assumptions around the lifetime of steel products, the recycling rate, replacement of steel with alternative materials and light weighting through intelligent design.

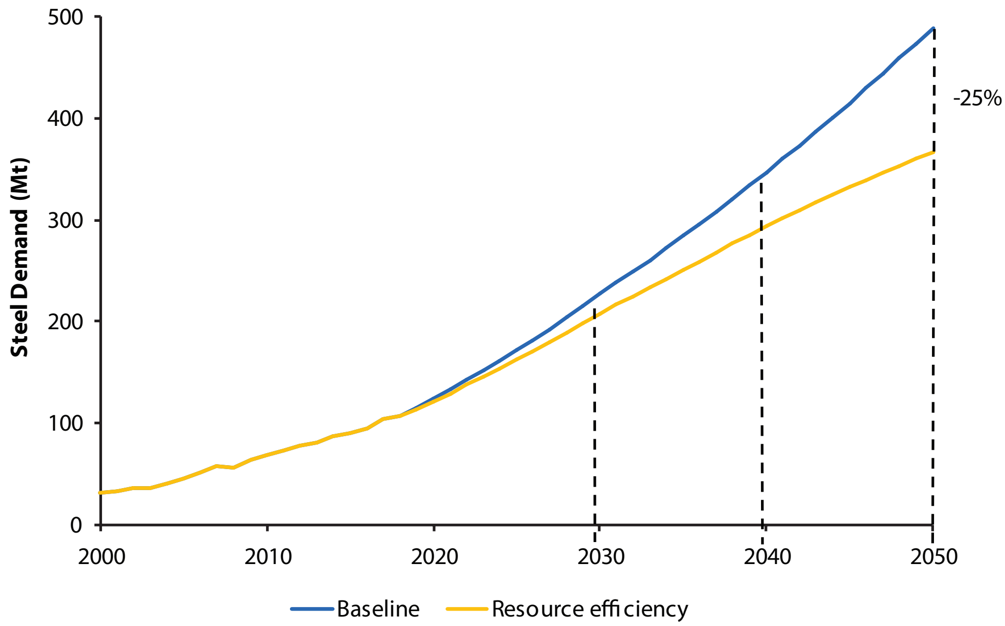


Figure 10: Steel demand scenarios including resource efficiency, 2000-50

Source: TERI analysis based on data from (MoS, 2017; Cullen, Allwood, & Bambach, 2012)

Whilst rapid growth in steel demand is positive to support India's development, the near-term requirements for new steel production place additional pressures on the sector as new green steel production technologies are still not deployed at scale even in developed countries. This puts new capacity additions at risk of being stranded in later life, as the global steel sector decarbonises and high emitting steel production becomes less competitive.

3.3 Technology availability

To achieve deep decarbonisation of the iron and steel sector, new technologies will be required – in particular for the replacement of conventional primary production processes with low emissions alternatives. There are several emerging low emissions technologies to produce steel from iron ore. They broadly fall into three categories:

- Carbon capture, utilisation, and storage (CCUS)
- The use of low carbon hydrogen to replace fossil fuels
- Direct electrification through electrolysis of iron ore

Each of these technologies differ in their suitability to the Indian context, based on their commercial availability, ability to reduce emissions, and interface with India's existing infrastructure and resource profile. An overview is provided in Table 2.

Table 2: Low emissions steelmaking technologies

Technology	TRL	Emissions reduction potential	Suitability for deep decarbonisation in India
Carbon Capture, Utilisation, and Storage			
BF-BOF with CCUS	5	Possibility to reduce CO_2 by approximately 60%. Although higher capture rates are possible, costs increase substantially due to multiple CO_2 sources (IEA, 2017).	Limited cost-effective CO_2 capture will restrict the use of this technology for deep decarbonisation, although could play an important role in retrofitting existing plants.
Coal based DRI with CCUS	4	There have been no comprehensive studies on applying CCUS technology to coal-based rotary kilns for sponge iron production but similarity to natural gas DRI suggests around 90% reduction may be possible.	Coal-based DRI units tend to have smaller capacities potentially making the fixed and operating costs of CCUS excessively large. Given the early stage of development of the necessary technology, seems to be unsuitable.
Natural gas DRI with CCUS	9	Currently operating plants have shown that around 90% reduction is possible.	Limited availability of natural gas at competitive prices has already restricted the growth of natural gas-based capacity in India. Additional costs of CCUS would make these plants less competitive.
Smelting reduction with CCUS	7	Smelting reduction processes alone can reduce emissions by approximately 20% versus conventional BF-BOF. The addition of CCUS can potentially reduce emissions by 80% (Tata Steel, 2020).	Tata Steel have developed a pilot smelting reduction plant in the Netherlands (HIsarna) and considering to install a larger demonstration plant in India. The CAPEX and OPEX savings make such a technology attractive, although the potential of CCUS is uncertain.
Hydrogen			
BF with H_2 blending	7	It is expected that H_2 would only be able to replace part of the injected coal, resulting in maximum 20% emissions reduction.	The limited emissions reduction means that H_2 injection into BFs can only ever be a transition technology to deeper decarbonisation.
H_2 DRI	7	Emissions reduction potential depends on the share of H_2 and whether the H_2 is from low carbon sources. Assuming 100% green H_2, emissions reduction can be >90%, with residual emissions from carbon sources for steelmaking, graphite electrodes and limestone.	Low cost renewable electricity provides a cost-effective route for green H_2 production. Whilst a high H_2 blend plant does not currently exist, technology is well understood.
H_2 plasma reduction	4	If produced from low carbon electricity, there is the potential for >90% emissions reduction.	Technology is still at an early stage, although trials have been carried out in both Europe and in India (Institute of Minerals and Materials Technology, IMMT). Timeline for commercial scale is unknown.
Direct electrification			
Electrolysis	4	If produced from low carbon electricity, there is the potential for >90% emissions reduction.	Current research projects are still at early stages with uncertain timeline for commercial scale. (Siderwin and Boston Metal)

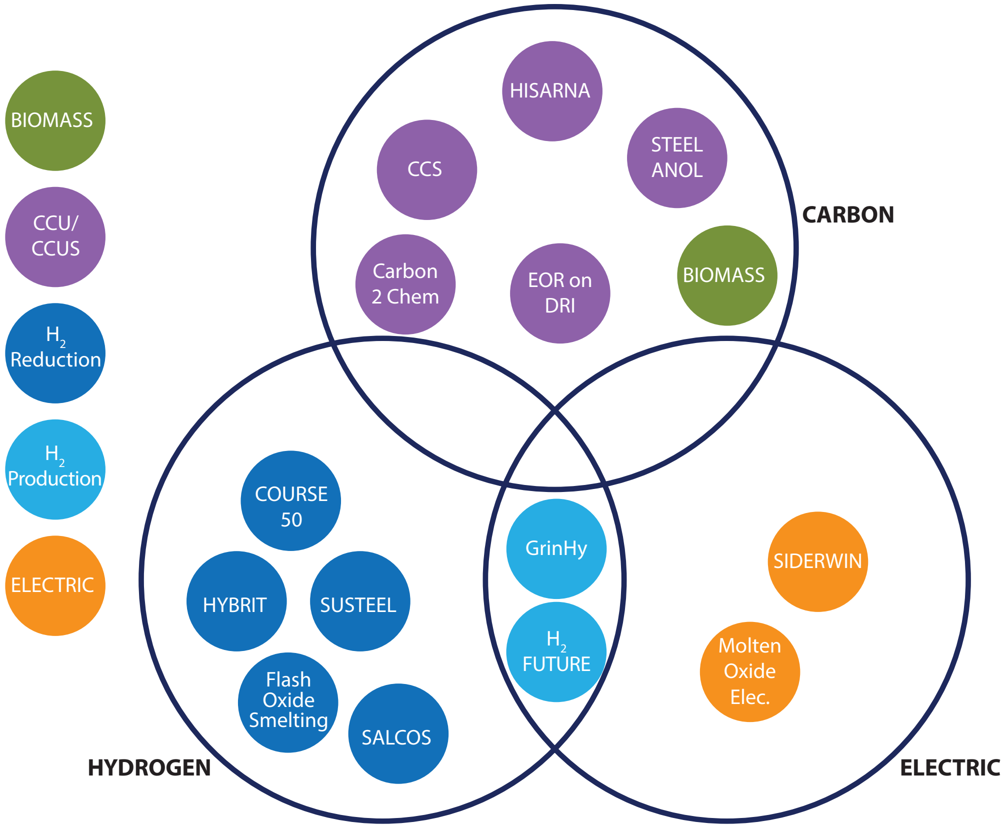


Figure 11: Overview of decarbonisation technology projects for the iron and steel sector

Source: Adapted from (WSA, 2019)

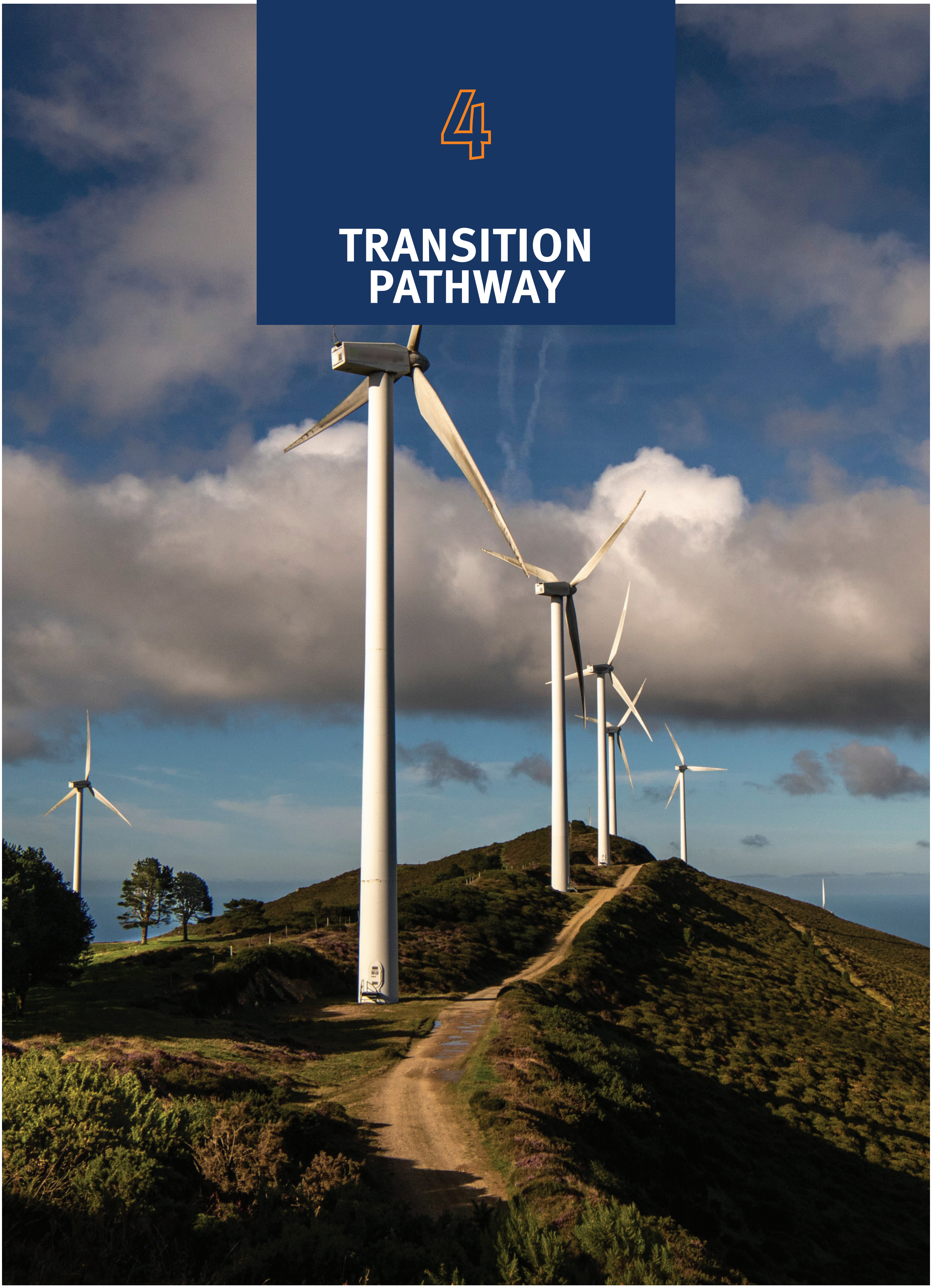
3.4 Capital requirements

The transition towards a net-zero steel sector will be highly capital-intensive, as new steel facilities will need to be built, alongside supporting infrastructure (such as electricity, hydrogen and CCUS networks). The Indian steel sector relies heavily on FDI, which was estimated to be over $14 billion between April 2000 and June 2020 (IBEF, 2021), representing 2.01% of total FDI (DIPP, 2020). This funding is increasingly looking to align itself with a net zero target, meaning only near zero emission steelmaking technologies will attract finance in future (see Glasgow Financial Alliance for Net Zero). A clear statement of intent on the future of 'green steel' in India will be needed from the Government, to provide a clear signal for foreign investment.

Beyond the quantum of finance required for new projects, efforts to lower borrowing rates will also be required, as mentioned above. Introducing blended finance options that can lower costs of borrowing, supported by public loans domestically, or from international finance via multi-lateral development banks will be vital to accelerate the deployment of new near zero emission plants.

4

TRANSITION PATHWAY



Transition Pathway

4.1 Structure of Indian steel assets

Before exploring future pathways for the Indian steel sector, it is worth outlining the structure of existing assets. Principally, we are concerned with (a) the technological make-up and (b) lifetime of the existing assets, as these two factors will be most influential in setting the future direction of the Indian steel sector.

The current make-up of India's iron and steelmaking facilities shows an accelerating trend towards larger, integrated steel plants using blast furnace, basic oxygen furnace and electric arc furnace technologies, as per global trends. There is still a relatively significant share of coal-based sponge iron units and electric induction furnaces, although we can expect these to continue to decline over the coming decades as more efficient technologies are adopted.

The preference for blast furnace technology, which is also clear in the pipeline of committed projects, represents a challenge for the future transition to low emissions steel in India. As we will come on to, CCUS technology for blast furnaces can be expensive (especially at higher capture rates) and there are questions around suitability for the Indian context due to availability of CO_2 stores.

Given this challenge for blast furnaces, it is useful to understand the age profile of these assets in India and when they might enter a stage of reinvestment. India has seen a relatively steady growth in blast furnace technology since the 1960s, with a marked acceleration in deployment since 2000 from which point two-thirds of blast furnace capacity was added.

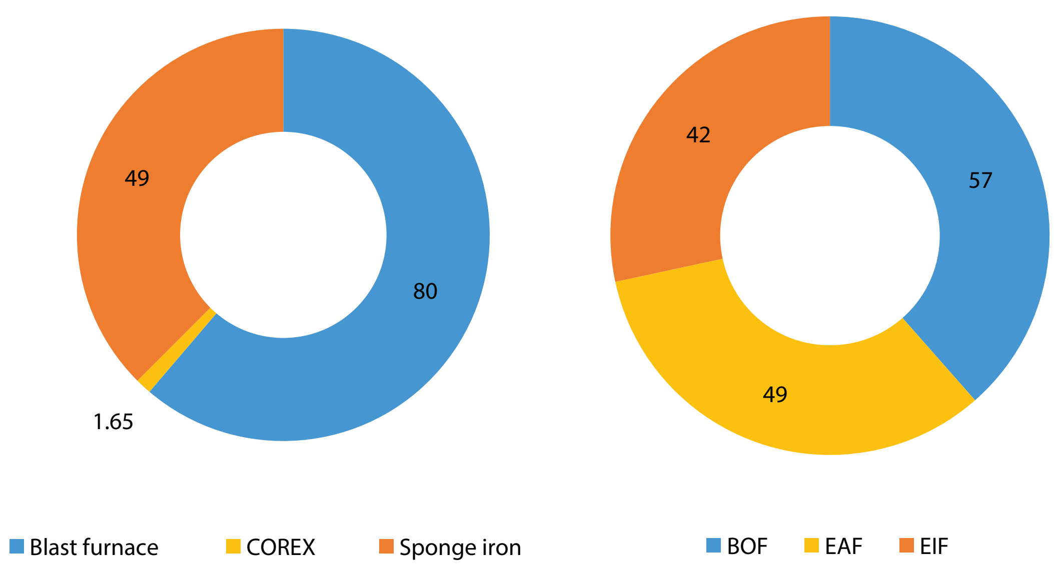


Figure 12: Ironmaking and steelmaking production routes, Mt

Source: (JPC, 2021)

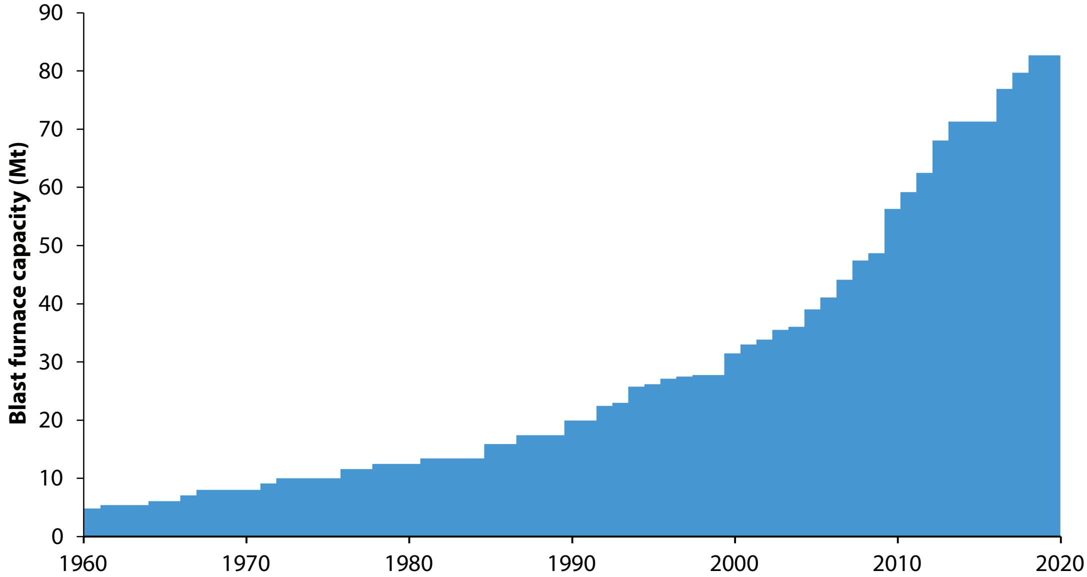


Figure 13: Blast furnace capacity in India, 1960-2020

Source: (Vogl, Olsson & Nykvist, 2021)

Based on the largest assessment of blast furnace capacity done to date (Vogl, Olsson & Nykvist, 2021), we can understand in more detail about the lifetime of this technology and timescales for reinvestment. The average blast furnace can last around 45 to 50 years, with between 2 and 3 relining campaigns occurring over that timeframe. The length of time between campaigns tends to decrease the more that take place (see Figure 14).

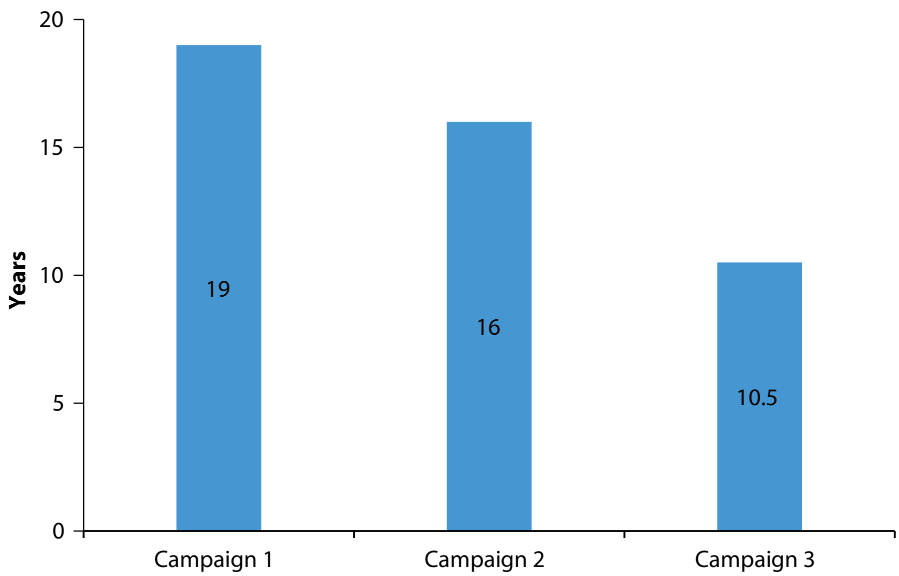


Figure 14: Global average reinvestment timeframes for blast furnace relining

Source: (Vogl, Olsson & Nykvist, 2021)

Relining the blast furnace represents the most significant investment over the lifetime of such a facility and therefore provides a point in time where the producer could choose between prolonging the life of such a plant, retrofitting with new low emissions technology, or mothballing to be replaced by a new, low emissions technology. The option of mothballing the plant will certainly be less likely after just a single campaign considering the remaining economic lifetime of other parts of the plant, such as the coke oven and sinter plant.

Based on the average reinvestment timeframes shown in Figure 14, existing blast furnace capacity in India will all reach the end of its lifetime by 2040 (see Figure 15). Much of this capacity from the 2000s will likely only be entering its second campaign, thus limiting the potential of a complete technology switch without significant policy support.

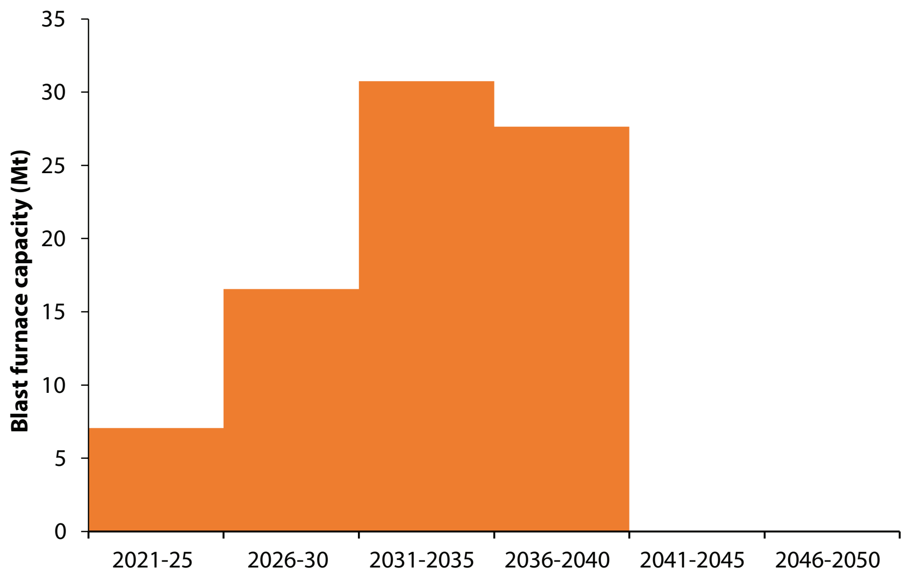


Figure 15: Reinvestment timeframe for existing blast furnace capacity in India

Source: (Agora Industry, 2021)

4.2 Technology option assessment

After understanding the existing technology make-up of the Indian steel sector, it is necessary to understand how future lower emission technologies could compete, in terms of both costs, as well as broader suitability (resource availability, import / export impacts). TERI and ETC have undertaken detailed technology assessments for the Indian and global steel sector,[5] which will inform the conclusions in this section.

Based on this assessment, we observe that the costs of steel production from the main conventional routes in India range from around $300/t of crude steel, to just below $500/t. The cheapest route in this

[5] Towards a Low Carbon Steel Sector (Hall et. al, 2020); The Potential Role of Hydrogen in India (Hall et. al, 2020); Green steel through hydrogen direct reduction (Hall et. al, 2021); Net-Zero Steel: Sector Transition Strategy (MPP, 2021)

analysis is the coal-based direct reduction using a rotary kiln. Lower capital and operational costs, as well as having access to cheaper, domestically available fuel mean that this route is one of the cheaper ways to produce steel in India today. However, many of these plants are highly polluting and the quality of steel produced is not always sufficient for certain specialist applications.

Next most competitive is the blast furnace with basic oxygen furnace (BF-BOF), which is the dominant route in India. Costs of steel production vary based on the costs of coking coal, which can fluctuate significantly over time (CRISIL, 2018). Natural gas direct reduction is costlier in India due to the higher costs of natural gas, as well as uncertainty around its continuous availability. The range illustrated assumes delivered costs of $8/mmbtu to $12/mmbtu, which represents the historical range of imported natural gas prices, although current prices have been significantly higher.

The costs of smelting reduction with CCUS assume that both capital and fixed operating costs are reduced versus the BF-BOF plant due to the removal of coke ovens, sintering plants and pellet factories. Moreover, using thermal coal over coking coal reduces the fuel costs. Without CCUS costs, the costs of steel production from a smelting reduction plant would be around 20% cheaper than the conventional BF-BOF route (Figure 43). However, with the addition of CCUS infrastructure at cost of around $20/tCO_2$ (IEA, 2020) (a range of $20-$80 is shown to reflect uncertainty), costs would be near equivalent to existing BF-BOF. There are also considerable uncertainties with regard to the availability of suitable sites for CCUS near the steel plant locations as well as the costs of CCUS infrastructure in India, which are reflected in the larger cost range for the SR-BOF CCUS route.

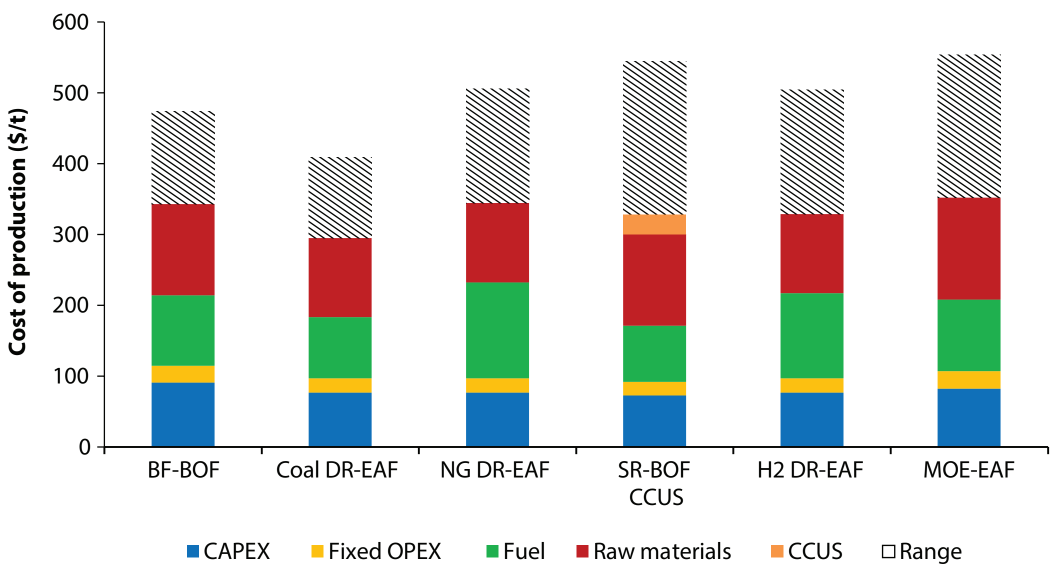


Figure 16: Costs of steel production by route[6]

Source: TERI analysis based on (IEA, 2019) and (MPP, 2021)

[6] BF-BOF = Blast Furnace – Basic Oxygen Furnace, Coal DR-EAF = Coal-based Direct Reduction – Electric Arc Furnace, NG DR-EAF = Natural gas-based Direct Reduction – Electric Arc Furnace, SR-BOF CCUS = Smelting Reduction – Basic Oxygen Furnace with Carbon Capture, Usage and or Storage, H_2 DR-EAF = Hydrogen-based Direct Reduction – Electric Arc Furnace, MOE-EAF = Molten Oxide Electrolysis – Electric Arc Furnace.

Costs of production from the hydrogen direct reduction route are largely similar to those in the natural gas direct reduction route, with the main difference being the cost of hydrogen as a fuel versus natural gas. In our cost analysis, we assume that hydrogen is purchased from a separate producer by the steel plant, as opposed to having the capital costs of the electrolysers included in the capital costs of the steel plant. Today, costs of electrolytic hydrogen can be as high as $4/kg, factoring in costs of transportation and storage infrastructure, although this is falling rapidly. Assuming the hydrogen is produced on-site, we provide a range of costs between $1.5/kg and $3/kg.

Based on these ranges, it would appear that the smelting reduction route with CCUS would be cheaper than the hydrogen direct reduction route (provided there are suitable sites closer to the steel plant locations). One key sensitivity to explore in a little more detail is how the cost of hydrogen would impact their relative competitiveness and how falling costs of green hydrogen could change this over time.

In Figure 17, we present the range of costs for a smelting reduction plant with CCUS, as well as declining costs of steel produced via the hydrogen direct reduction route, based on declining costs of hydrogen. With costs in excess of $4/kg today, we can see that hydrogen direct reduction is consistently more expensive than the smelting reduction route. However, as costs of green hydrogen start to fall over time, potentially reaching $2/kg in 2030 and $1/kg in 2050 in the most suitable geographies, hydrogen direct reduction could start to compete.

It is worth noting that since the publication of our hydrogen report, which covered this in detail, there have been several key developments in this space. Firstly, the only major smelting reduction with CCUS

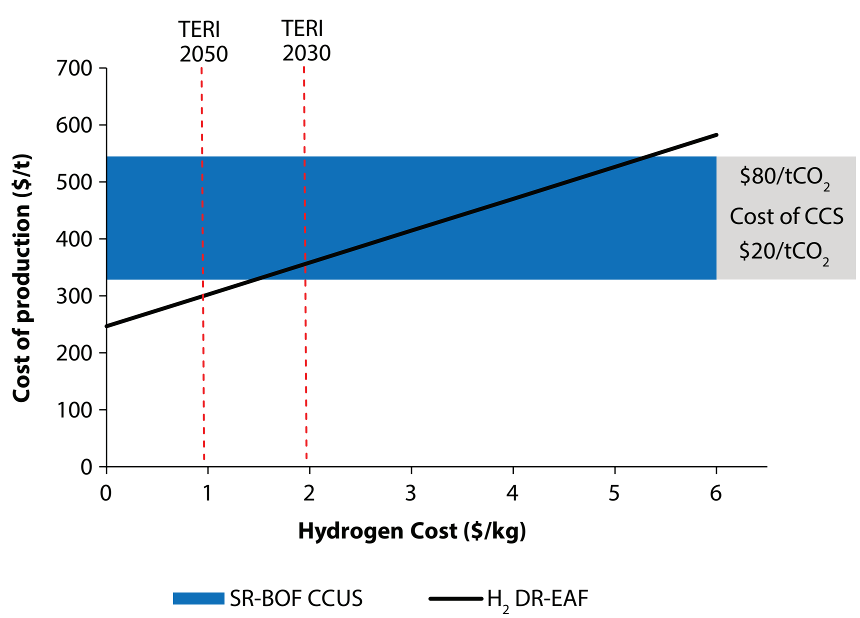


Figure 17: Costs of production - H_2-DR vs SR-BOF with CCUS

Source: TERI analysis based on (IEA, 2019; Hall, Spencer, & Kumar, 2020; BNEF, 2020)

Note: tCO_2 refers to the cost of carbon capture and storage, not to carbon price.

pilot facility, being taken forward by Tata Steel Europe in the Netherlands has now switched to developing a hydrogen direct reduction facility, signalling the industry's relative support for these technologies. Conversely, there are over 30 (and growing) hydrogen direct reduction projects.

Secondly, our estimates for the costs of producing hydrogen in India, whilst among the most ambitious when published, have been superseded by several Indian corporates own targets in this space. Most notable is Mukesh Ambani's aim to use the expertise of Reliance Industries to produce hydrogen for $1/kg by 2030. Alongside other players, such as NTPC, Ohmium and RenewPower, who are similarly taking green hydrogen production very seriously, you could well see the target of $1/kg being hit much sooner than our initial estimate of 2050, making hydrogen direct reduction competitive even earlier.

4.3 Pathways to net zero

Off the back of this understanding the existing assets and future technological trends, we can construct future pathways to help us better understand the challenges and opportunities of achieving a net zero steel sector. The main scenario illustrated here represents a pathway to net zero by 2070 **(NZ2070)**, in line with the Government's economy-wide net zero target, announced in 2021. We also explore a more ambitious scenario, which sees the steel sector reach another key government target – 'Atmanirbhar Bharat' (or self-reliance) by 2047 – which also puts it on track for net zero by 2050 **(NZ2050)**.

In the **NZ2070** scenario, we can see new low emission technologies introduced rapidly from 2030 onwards, with a number of trials and demonstrations taking place in the 2020s. As shown by our earlier analysis, the main primary route to replace the blast furnace is hydrogen direct reduction. This can be scaled rapidly from the 2030s, at which point it will start to compete directly with the less efficient conventional plants.

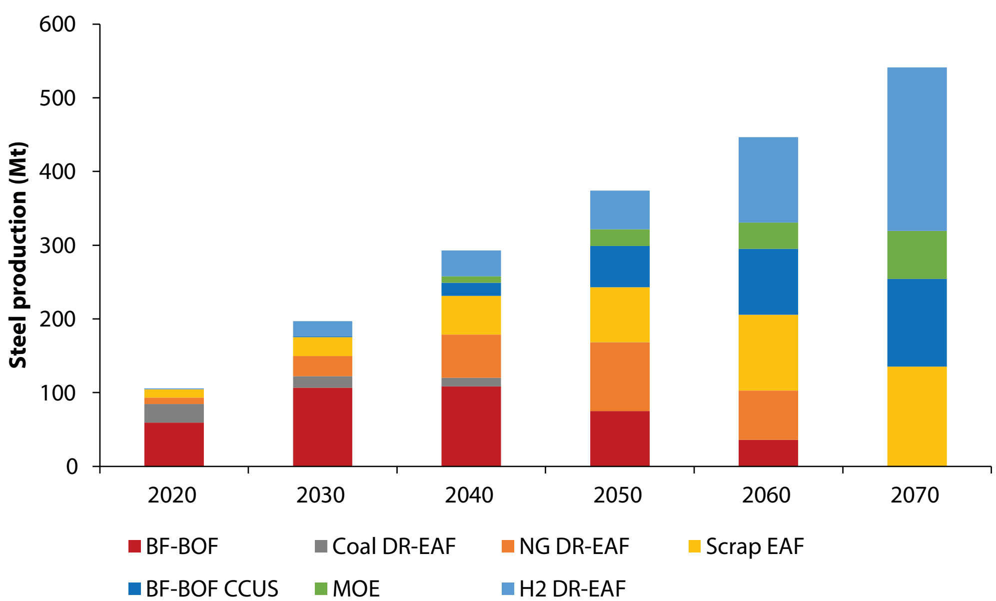


Figure 18: Net Zero by 2070 scenario

Source: TERI analysis

From 2040 onwards, we also see some early MOE plants being deployed. They are at an earlier stage of development versus the hydrogen route but could prove competitive in certain areas without access to hydrogen, as they use a similar amount of electricity. Scrap-based EAFs will see an ever-increasing role, although will be limited by the domestic availability of scrap. No import of scrap is assumed.

In terms of phasing out existing, high emission facilities, we see a relatively significant role for CCUS to help manage the large number of BF-BOF facilities. Whilst relatively expensive to fit these facilities with CCUS versus using alternative low emission routes, it may prove financially viable for those facilities located close to cost-effective CO_2 storage, who are entering their 2[nd] or 3[rd] relining campaign (see Section 4.1). Beyond 2070, we expect these will all be mothballed at the end of their economic lifetime, in favour of other low emission routes.

We expect coal-based DR facilities to be phased out much faster, given their high emissions and shorter lifetimes versus BF-BOF. In this scenario, we expect natural gas-based DR facilities to increase out to 2050, providing a readily accessible transition fuel, allowing new primary capacity to be built without resorting to the 'harder to transition' BF-BOF. As aforementioned, this could see natural gas-based facilities being built in the 20s, 30s and 40s, to steadily be replaced by green hydrogen, which can be blended in over time.

We also explore an alternative scenario, where the steel sector also meets the Government's target to be self-reliant, in line with Atmanirbhar Bharat' by 2047. In this scenario, we assume that the sector also achieves Net Zero by 2050, supported by domestic energy resources alone. This highlights the important joining together of the Net Zero vision, along with a vision of self-reliance, which can both support one another.

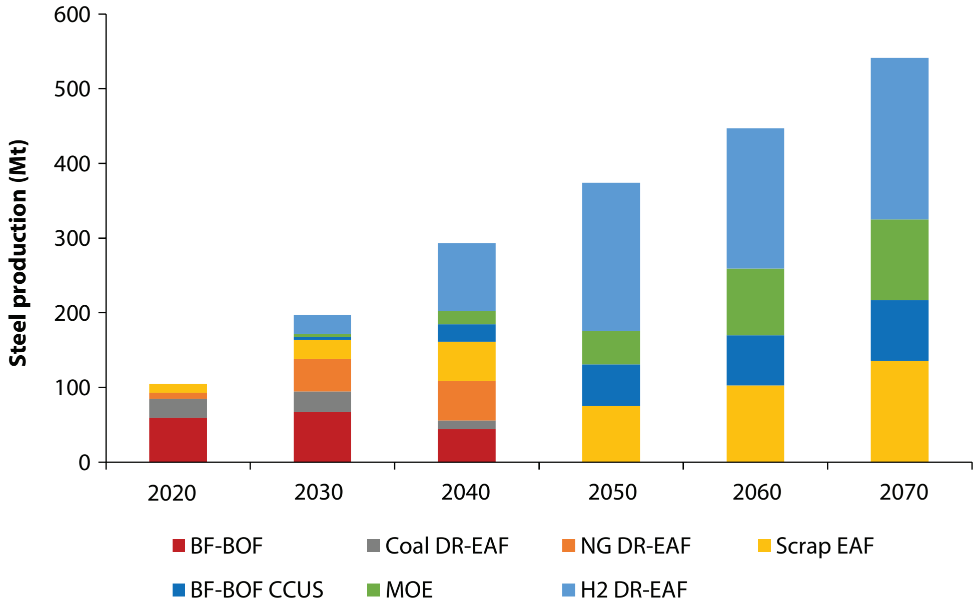


Figure 19: Net Zero by 2050 scenario

Source: TERI analysis

In the **NZ2050** scenario, low emission technologies are introduced at an even faster rate, with the most significant additions being made up by hydrogen direct reduction, followed by MOE. The greater challenge here is phasing out blast furnaces faster, potentially before the end of their useful lifetime. This is largely due to the limits on domestic coking coal of an adequate quality. Today, India imports over 80% of its coking coal, due to domestic shortages and quality issues. The National Steel Policy aims to reduce import dependence by 65% by 2030 and Coal India is taking some steps to support this, such as establishing new washeries. Based on this, we assume that domestic coking coal production reaches around 45 Mt by 2050 (see Figure 20), up from around 20 Mt today, reducing import dependence to 0%.

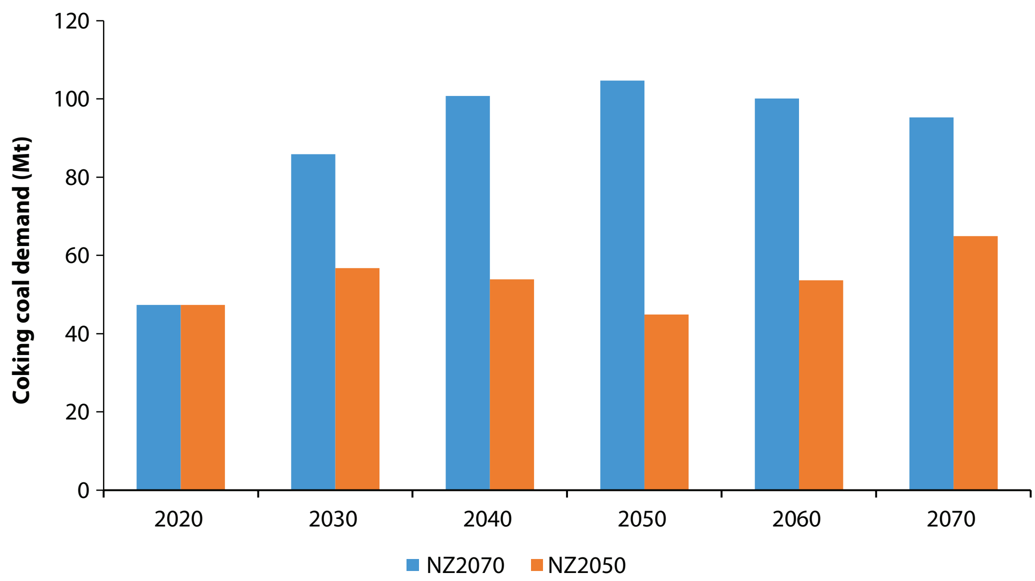


Figure 20: Coking coal demand in Net Zero scenarios

Source: TERI analysis

Natural gas-based direct reduction facilities are phased out even faster in the NZ2050 scenario versus the NZ2070 scenario, implying a more rapid transition to 100% hydrogen. This would be the result of a more rapid reduction in the costs of green hydrogen, in line with some of the more ambitious company statements we've seen from major Indian corporates. This would see natural gas completely phased out by 2050, leaving domestic gas reserves available for sectors, such as fertilisers and city gas distribution networks (see Figure 21).

One of the major challenges for achieving such a scenario is the rate at which new renewable electricity production needs to be scaled up. These estimates include electricity for scrap EAF, MOE and green hydrogen production[6]. For the NZ2070 scenario, the challenge is already extreme, with production increasing 10-fold to 70 TWh by 2030, nearly 4-fold again to 260 TWh by 2050 and then more than 3-fold again by 2070 to 900 TWh. This represents 65% of India's electricity production today, for just a single sector.

[6] Electricity consumption assumptions = 650 kWh for EAF, 3.4 MWh for MOE and 2.9 MWh for H_2DR

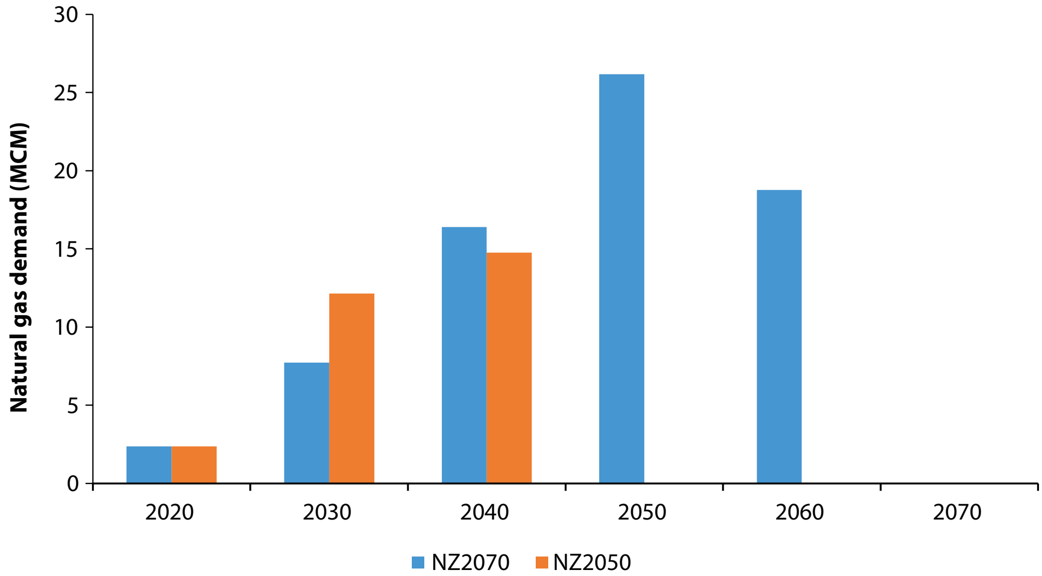


Figure 21: Natural gas demand in Net Zero scenarios

Source: TERI analysis

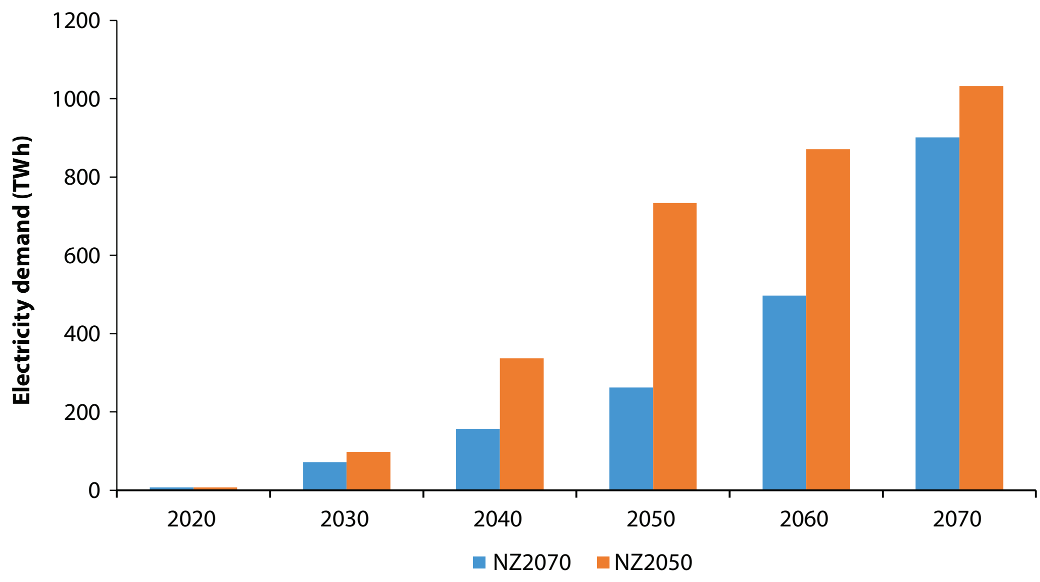


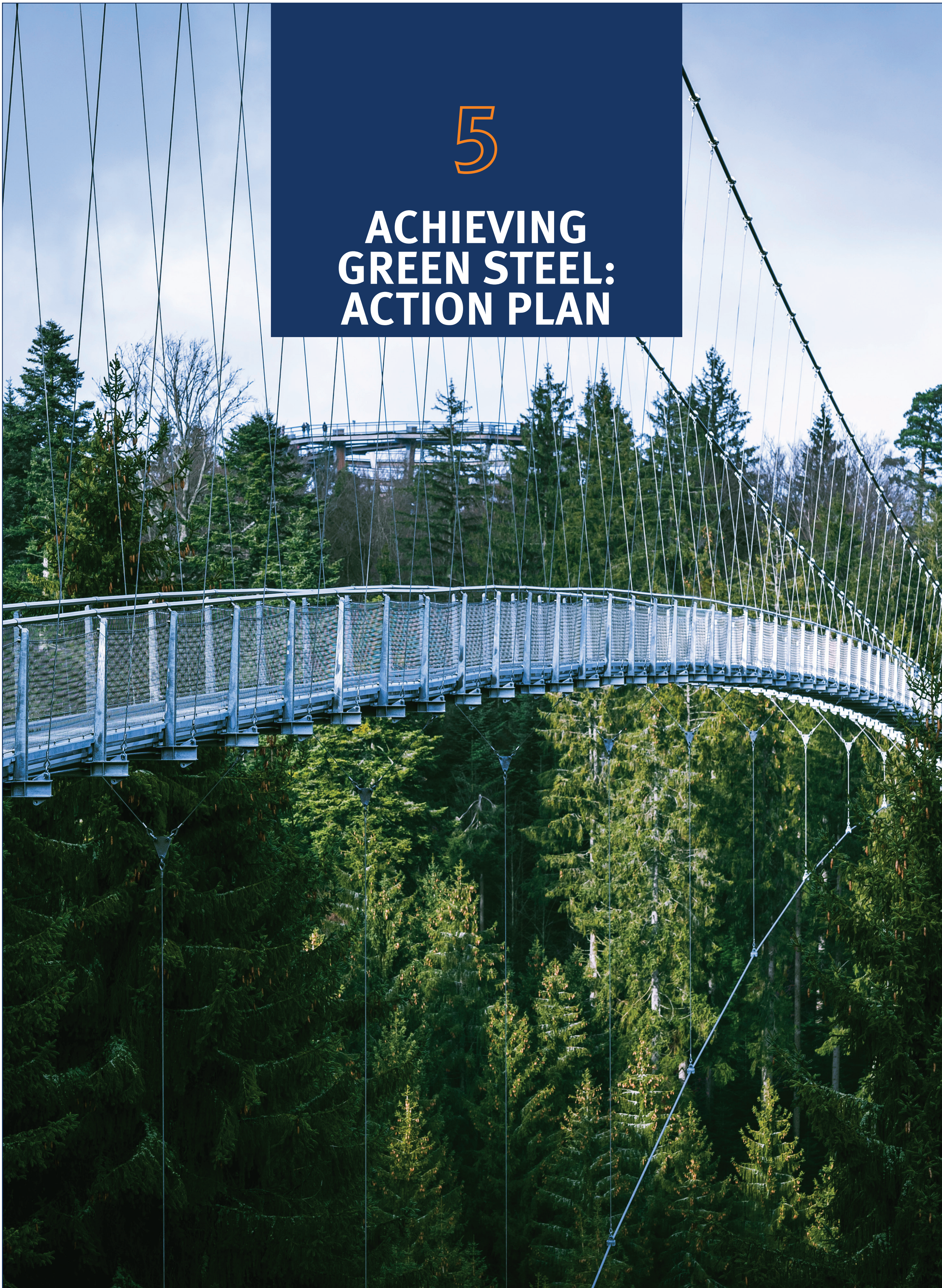
Figure 22: Electricity demand for Net Zero scenarios

Source: TERI analysis

In the NZ2050 scenario, the challenge is even more extreme with demand increasing by 100-fold between now and 2050, before reaching just over 1,000 TWh in 2070. This faster ramp-up is required in order to meet the dual targets of net zero and self-reliance. To put this in the context of India's current installations, overall renewable deployment hit 100 GW in 2021. For the steel sector alone, the NZ2050 scenario would require around 45 GW by 2030, rising to 330 GW by 2050. This, alongside the rest of the economy electrifying (transport, heating / cooling, other industry, etc.), represents one of the most significant challenges for the transition to low emission steelmaking, both in the NZ2070 and NZ2050 scenarios.

5

ACHIEVING GREEN STEEL: ACTION PLAN



Achieving Green Steel: Action Plan

In exploring illustrative scenarios for the steel sector's transition, it is clear that early action is required to ensure that the sector remains competitive as countries ramp up emissions reduction policies.

5.1 Maximize energy efficiency

The application of best available energy efficient technologies (where cost-effective) should be encouraged, particularly in recently built capacity with long lifetimes. Our analysis shows that the application of best available technologies have the potential to reduce energy and emissions by around 15% across the two primary steelmaking routes (see Technical Annex). There are a number of older plants in dire need of modernization and by applying even the already widely adopted efficiency technologies, these plants can substantially improve their energy efficiency (see Figure 23).

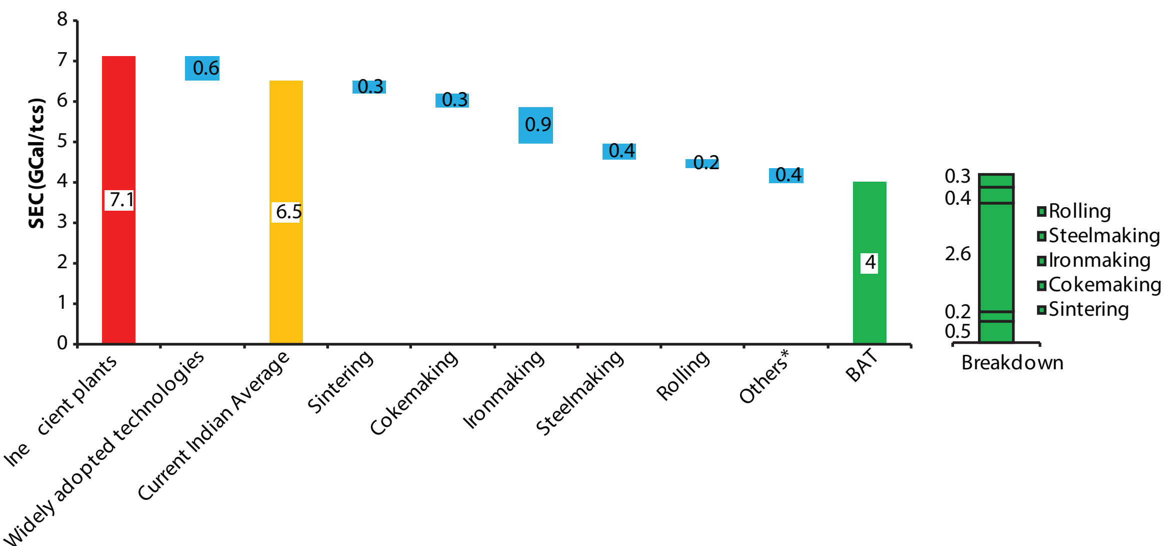


Figure 23: Energy efficiency measures for the BF-BOF route*

Source: (WSP, Parsons Brinckerhoff and DNV GL, 2015; JISF, 2014; CII, 2013; Morrow, Hasanbeigi, Sathaye, & Xu, 2014; BEE, 2018)

* The analysis is exclusive of impact of Bio-energy use or Bio-sequestration on specific energy consumption.

Investing in energy efficiency measures for electricity-based production (including electric arc furnaces and induction furnaces) represent 'low-regrets' options for further investment. Unlike coal-based production, most of which will most likely need to be retired by the mid-century, electricity-based production routes will continue to decarbonise as the electricity grid decarbonises.

5.2 Increase scrap utilisation

Improving resource efficiency and encouraging greater levels of material circularity is vital for mitigating negative environmental impacts as India continues to grow. This includes encouraging greater use of scrap, which reduces the amount of raw material required for primary steel production, resulting in positive knock-on effects for energy and emissions.

The main scrap-based production route is the electric arc furnace (EAF). If we compare the raw materials, energy and emissions from the scrap-based route with a primary steelmaking process, such as a blast furnace with a basic oxygen furnace (BF-BOF), we can clearly see the benefits of greater circularity in the steel sector (see Figure 24).

The increasing availability of scrap plays an important role in reducing the amount of energy used for steelmaking, as this can be added to EAF as well as BF-BOF routes to varying extents. We assume on the basis of our analysis, that scrap use in the BF-BOF route will increase from an average of around 10% today to 20–25% by 2050, which helps increase the efficiency of the process (See Technical Annex).

Designing steel products so that recycling is made easier, as well as building the appropriate recycling infrastructure can be done immediately and the MoS' Steel Scrap Recycling policy represents a positive first step. In doing so, scrap use in the BF-BOF route and in EAFs can be increased to reduce energy consumption and GHG emissions.

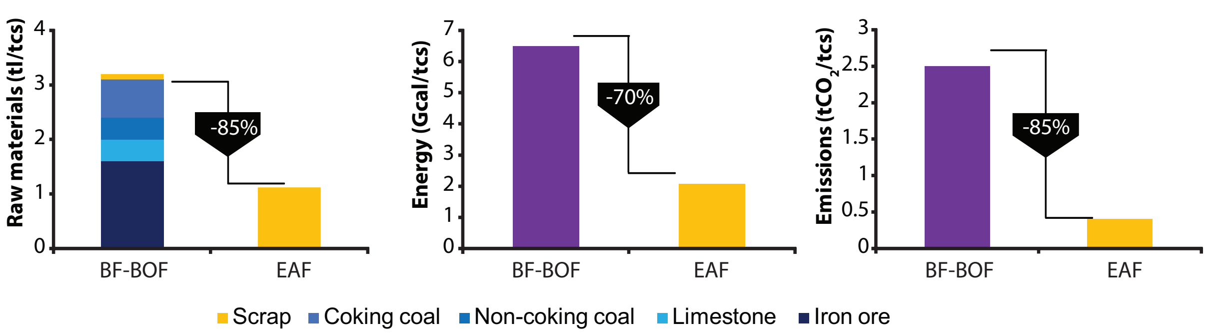


Figure 24: Material, energy and emissions benefits of scrap-based production

Source: TERI analysis based on data from BEE 2018; MoS 2017. Assuming an emissions intensity of electricity of 700gCO_2/kWh.

5.3 Create procurement alliances

To send clear demand signals to steel producers to start producing green steel, groups of corporates who use steel can band together to create clubs which achieve a critical mass of demand. Over time, such clubs could provide guaranteed markets for green steel, helping to de-risk investments for producers. SteelZero is an example of such an initiative in the private sector. Discussions are at an early stage in India.

Alongside private sector activity, to help drive initial large-scale demand for green products, governments and public bodies should also commit to procuring environmentally sustainable products, such as 'green' steel. Infrastructure accounts for around 27% of steel demand in India, most of which is used in public projects such as roads, bridges, railways, metros. Public Works Departments could help drive this initial demand, providing a guaranteed market for domestic green steel producers.

In 2021, the Government of India announced its co-leadership of a new Industrial Deep Decarbonisation Initiative under the Clean Energy Ministerial, which seeks to create markets for industrial products through procurement initiatives. This is supported through other major economies that are also looking to use public procurement as a tool to create lead markets for green steel, such as Canada and the USA.

5.4 Introduce green product standards

To help grow the market for green steel as a premium product, public and private sector players will need to develop and implement green product standards and related product labelling. This will help consumers decide between more or less sustainable products, as they seek to decarbonize their supply chains.

The Confederation of Indian Industry (CII) is working in partnership with producers such as Tata Steel to apply its GreenPro framework to products such as steel rebar. At the global level, an alliance of steel producers and users are developing 'ResponsibleSteel' standards, where a reduction in GHG emissions is one requirement for responsible production.

In March 2021, ArcelorMittal also announced the launch of its first three XCarb™ initiatives, as part of its 2050 net zero commitment. These initiatives include green steel certificates, recycled and renewably produced products and an innovation fund to help introduce new low emission technologies (ArcelorMittal, 2021).

To implement, the Ministry of Steel could work through the Bureau of Indian Standards (BIS) to develop green product standards, similar to the existing process with steel quality controls. For example, in March 2020, MoS introduced a Quality Control Order that prohibits the import, sale and distribution of substandard steel and steel products to help improve the availability of quality steel for the construction, infrastructure, and automotive sectors. A similar approach could be taken with green steel standards, to gradually decrease the GHG intensity of steel.

5.5 Promote technical research & development and set-up demonstration plants

Technological research and development (R&D) plays a crucial role in determining a steel producer's sustained success in global markets. Whilst the Indian steel sector has invested some resources into R&D for cleaner production, this is often limited to early-stage laboratory and pilot scale efforts. To do this at the pace and scale required will require joint efforts from the government and industry. The Government of India, through the "Promotion of R&D in Iron & Steel Sector" scheme has been providing financial support to R&D projects identified for funding by the Ministry of Steel. Major projects covered under this scheme include R&D initiatives to upgrade Indian low grade iron and Indian coking/non-coking coal.

Going forward, these funds need to increase in size to support medium to large-scale demonstration plants focused on new 'breakthrough' clean production technologies. This will help familiarize the sector with new technology, bring forward the date at which technology can scale-up, and signal a serious intention for deep decarbonisation.

Given the high risk associated with demonstrating new, more expensive technologies in the steel sector, it will be necessary to establish public-private partnerships between GoI, Indian steel companies, technology providers, academia, and international finance.

5.6 Future-proof new capacity

An important consideration for low carbon steelmaking routes in India is the lifetime of the plants and the possibility of retrofit in the coming decades. Steel plants have long lifetimes (30 years plus), resulting in significant potential for emissions lock-in for plants being built in the coming years, when low carbon options might not be commercially available.

Figure 25 illustrates two potential transition pathways for the leading technologies discussed earlier. For the hydrogen route, gas-based capacity could be built in the 2020s, using natural gas or coal-based syngas, which is more readily available. This could then be switched to low carbon hydrogen over time, reducing emissions without a significant change in the infrastructure. Alternatively, steel producers could establish smelting reduction facilities, such as HIsarna, over the coming decades, which could then be retrofit with CCUS technology to reduce emissions. CCUS technology is relatively underdeveloped in India, with only a few, small-scale projects currently underway in the oil and gas and fertilizer sectors.

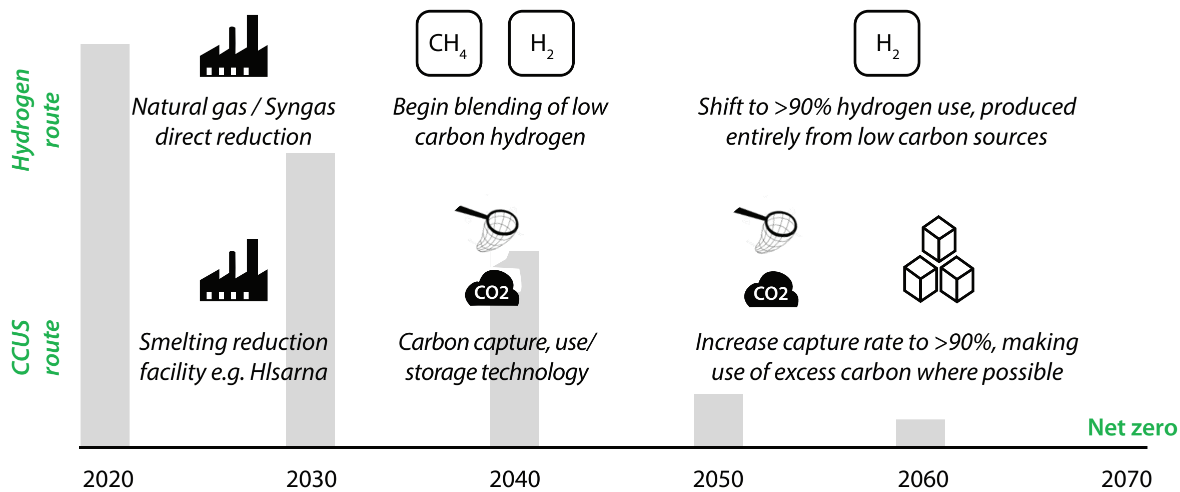


Figure 25: Pathways for low carbon primary steelmaking

Source: TERI Analysis

5.7 Lay the groundwork for a domestic carbon trading market

An important tool to help accelerate the switch to low carbon technologies is development of domestic carbon trading market. India has already achieved much success with the implementation of the Perform, Achieve and Trade (PAT) scheme, which trades energy efficiency certificates between Designated Consumers (DCs), including the iron and steel sector. As the need for emission reduction grows, one possibility would be to amend this existing policy to measure and control carbon emissions, as opposed to energy consumption. This would operate similar to the EU Emissions Trading Scheme (ETS).

Taking the steps over the 2020s will put the Indian steel sector in a strong position to then start to rapidly decarbonize its production post-2030. This will require more significant, coordinated policies and measures to incentivize a mass-market switch that will put the entire sector on a net zero trajectory, not just the most progressive companies.

5.8 Support for commercial-scale plants

As a series of demonstration projects in the 2020s help clarify the preferred technology options for low emission steel production in India, by the 2030s, public and private sector should have proven joint financing models to facilitate the construction of commercial-scale green steel plants. This will require considerable support, assuming some cost difference between green steel and 'dirty' steel persists. Whilst the difference in production costs will be mitigated somewhat if green product standards, procurement initiatives, and an emissions penalty are introduced, it may still be necessary to support the first few commercial-scale plants.

This could include direct financial support from the GoI, via existing bodies such as the Ministry of Steel (for example through Carbon Contracts for Difference, which are being explored in Germany), although this is likely to be insufficient given limited domestic resources. As renewable electricity projects become 'self-financing' in India, thanks in large part to a dramatic reduction in technology costs, as well as a growing familiarity with such projects among private sector lenders, greater focus should be given to the heavy industry sectors, such as steel. Organisations such as the World Bank, the Asian Development Bank and the Climate Investment Funds should increasingly look to support these heavy industry projects, either through support to reduce costs of capital, or through direct grants.

Alongside direct financial support from multilateral development banks, it will be important to help facilitate active technology partnerships. This can include partnerships between companies, as well as partnerships between India and other governments (for example, the U.S. - India Climate and Clean Energy Agenda 2030 Partnership).

5.9 Implement a carbon border tariff

Steel, a carbon intensive product which is also heavily traded globally, has found a lot of attention in recent years in the trade environment policy discourses. For example, the EU green deal mentions imposition of Carbon Border Adjustment Mechanism (CBAM), to prevent carbon leakage while creating level playing field in the EU where steel is one of the few sectors that will come under this measure. It may be worth exploring similar import restrictions on steel imports to India originating from countries having

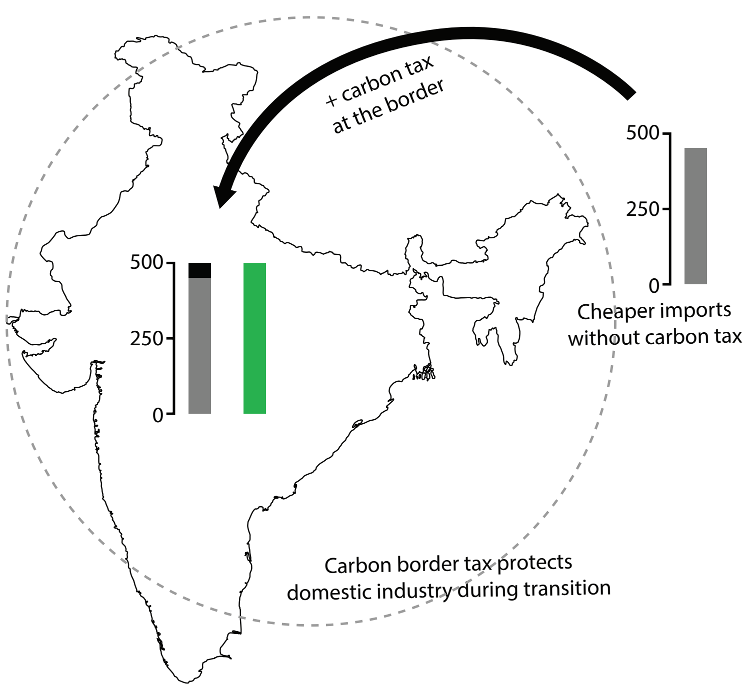


Figure 26: Carbon border adjustment

Source: TERI

higher steel carbon intensity. This may dissuade Indian steel importers from importing and will help in switching to domestic. Additional revenue, that may be collected as import duty, based on carbon content of imported steel, can be considered for supporting India's greening of steel. This may enhance export competitiveness of India's steel sector particularly when it comes to our export to developed nations like the EU. However such strategies will require better understanding of the extent of CBAM and its ability to shift demand for steel from within India and the adequacy of import duty revenue, thus generated from CBAM, in subsidizing the greening of India's steel industry.

5.10 Retire older, polluting facilities

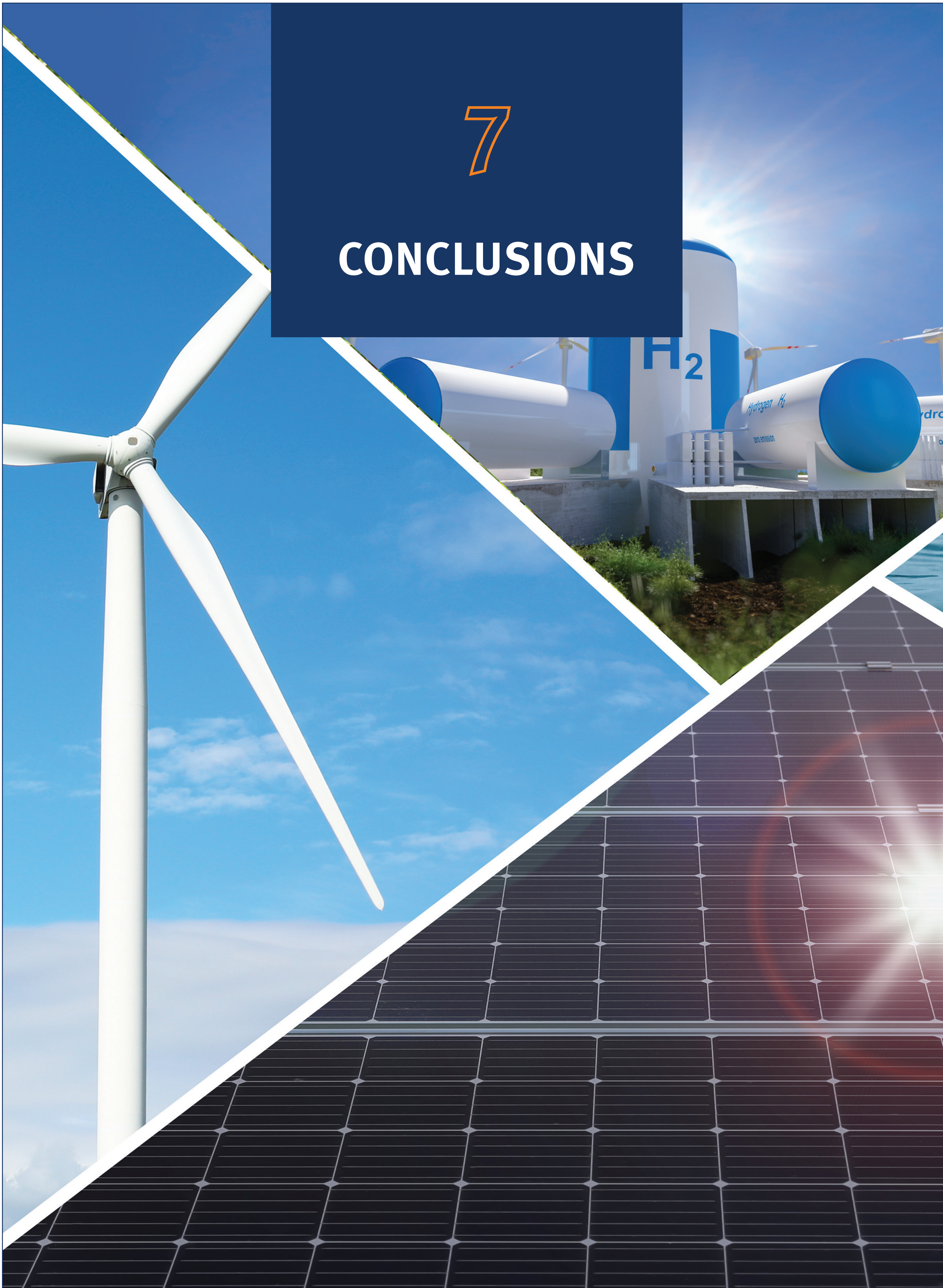
As the industry decarbonises and new, low emission capacity comes online, it may be necessary to retire older, polluting facilities that are close to the end of their lifetimes. Whilst all efforts should be made to 'future-proof' new capacities, high emission steel plants built in the 2010s and early 2020s could still be operating in 2070 without concerted efforts to retire these facilities.

For a net zero by 2070 scenario, it is assumed that largely gas based direct reduction plants are installed during the 2020s, primarily using natural gas. When low-cost hydrogen is available, these plants can switch over to hydrogen. From 2030 onwards, it is assumed that further direct reduction plants using high shares of green hydrogen from the beginning will be constructed.

The existing blast furnaces would need to be steadily decommissioned as they reach the end of their economic life. This might require consideration for some form of fiscal/ financial packages to facilitate this process. By 2070, a limited number of blast furnaces would remain, and those that do would be fitted with carbon capture technology. Coal-based direct reduction units have a shorter lifetime and higher emissions versus blast furnaces and so these units would need to be phased out before 2050, with natural gas and hydrogen based direct reduction units being deployed in their place.

7

CONCLUSIONS



Conclusions

The Indian steel sector is on the cusp of a significant transformation. As explored in this report, India is well positioned to reap many of the benefits associated with a competitive, digital, and decarbonised sector, making use of domestic resources and skills.

Nonetheless, there are significant risks of not rising to this challenge. The global steel sector is shifting rapidly, with governments, the finance sector, and steel buyers all moving fast to clean up their act. India currently operates one of the highest polluting steel sectors and so has further to go than many others, whilst growing production at the same time.

Whilst challenging, this report sets out that such a pathway is possible and desirable. Through rapidly scaling-up renewable electricity and green hydrogen production, in particular, the steel sector can shift away from imported fossil fuels, putting the sector on a path to a net zero, self-reliant future.

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